Journal of Sports Research and Innovation

Volume 1, No 1 2024



ISSN 2956-980X





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2 of 57

CONTENT

Kickboxing K1 Competition	
o <i>r</i>	
Katarzyna Golenia, Agata Rzeszutko-Bełzowska	
The impact assessment of the pandemic on the quality and lifestyle of students	11
Mateusz Kaczor , Henryk Duda, Mateusz Korcala	
Selected elements of general fitness and effectiveness in 1x1 test games among 12-year-ol	d foot-
ball players	
Henryk Duda, Mateusz Kaczor, Grzegorz Jakubiszyn, Andrzej Szwarc	
The Praxeological Characterization of the Goalkeener Model in Defensive-Offensive Activ	ons as a
Determinant of Rational Training	



Original Research Articles

Analysis of Cortisol Concentration Changes Induced by Stress in Kickboxing K1 Competition

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Abstract

Background: Kickboxing is a sport that imposes significant physical and psychological stress on athletes, often pushing them to the limits of their physical endurance and mental resilience. This study focuses on analyzing changes in cortisol concentration, a key stress hormone synthesized in response to stress caused by physical and mental effort during kickboxing competitions in the K1 format. **Methods:** The study was conducted on 20 kickboxing athletes following K1 rules, in accordance with the Helsinki Declaration and the approval of the ethical committee. Cortisol concentration levels were measured before and after fights, and statistical analyses were performed using PQ Stat software to compare pre- and post-fight levels. **Results:** The results indicate a significant increase in cortisol concentration levels after the fight, suggesting a strong impact of kickboxing training on cortisol levels. This may indicate the body's natural response to intense physical effort, highlighting the role of cortisol in energy mobilization and adaptation to increased training demands. **Conclusions:** Monitoring of steroid hormones - cortisol seems to be essential in coaching practice, and understanding these responses allows athletes to optimize their preparations for competitions.

Keywords: Kickboxing, Cortisol, Stress Response, Physical Stress, Psychological Stress

Introduction

Kickboxing fights generate high physical and psychological stress, often pushing the boundaries of physical fitness and mental endurance (1,2). Kickboxing is not merely a sport, but also a profound study of the dynamics of human stress and resilience (3). A key element of this research is cortisol, a steroid hormone crucial in the body's response to stress, which also plays significant roles in various bodily functions, including the regulation of blood sugar levels, metabolism, inflammation, and memory formation (4–6). In a broad research perspective, various studies are conducted during kickboxing fights in the field of hormonal changes and physiological analyses, and more recently, neurophysiological analyses (7–11). Cortisol measurements have often been performed in combat sports, with such practices taking place in judo (6,12,13), boxing (14), and various kickboxing competition formats (3).

Kickboxing in the K1 format, characterized by rigorous physical requirements and acute fight stress, presents an ideal scenario for studying the role of cortisol in the body's

Received: 26.10.2023 Reviewed: 22.12.2023 Published: 02.01.2024

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response to acute stress and physical effort. Stress during a fight is a complex phenomenon, involving both physical and psychological aspects. The fight poses unique challenges to the fighter, activating the body's defense mechanisms, putting it into a state of heightened readiness for action (15–18).

Previous studies have emphasized the impact of various forms of exercise on cortisol levels (6,19–22), yet there remains a gap in understanding how combat sports like kickboxing in the K1 format specifically affect these dynamics. This article aims to fill this gap by investigating changes in cortisol concentration among kickboxing athletes during fights under K1 rules, thus providing insight into the acute stress response induced by this demanding sport.

This study not only contributes to the development of sports sciences but also offers valuable implications for stress management, sports training, and our understanding of the body's resilience mechanisms.

Material and Methods

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Regional Medical Board in Kraków (approval No. 287/KBL/OIL/2020).

Study Design

The detailed study design is presented in Figure 1.



Figure 1. Experimental Desing



Participants

The study was conducted on a group of 20 kickboxing athletes specializing in K1 rules fights. The sample size was calculated using G*Power software, assuming a significance level of 5%, statistical power at 80%, and aiming for 95% confidence intervals. The participants had an average age of 25.55 ± 3.46 years, body mass of 78.6 ± 7.68 kg, and body height of 176.89 ± 4.43 cm. Selection of athletes for the study was based on specific inclusion and exclusion criteria (Table 1).

Table 1. Inclusion and Exclusion Criteria for Participation in the Study

Inclusion Criteria	Exclusion Criteria
Minimum of 5 years of training expe- rience	Presence of chronic diseases affect- ing training capacity
Good health condition	Use of doping substances
Positive recommendation from a	Lack of consent to participate in
coach	the study
	Presence of injuries preventing par-
Minimum of 4 competition starts per	ticipation in training and competi-
year	tions
	Less than 5 years of training expe-
Consent to participate in the study	rience

K1 Fight

The kickboxing fight under K1 rules took place in a ring with internal dimensions of 6x6 meters, lasting 3 rounds of 2 minutes each, with 1-minute breaks between rounds. Competitors competed according to the rules of the World Association of Kickboxing Organizations (WAKO) (1), equipped with 10 Oz gloves, protective helmets, and shin and foot guards. The entire match was supervised by a ring referee.

Cortisol Measurement

Cortisol concentration was measured by a qualified diagnostician. Blood was drawn from the antecubital vein. The drawing procedure took place under controlled conditions in the morning to minimize the impact of natural fluctuations in cortisol levels throughout the day. The first blood sample was taken before the kickboxing fight to establish a baseline level of cortisol. The second sample was taken immediately after the fight. Serum cortisol levels were determined using the enzyme-linked immunosorbent assay (ELISA) technique.

Statistical Analysis Methods

Statistical analysis of the collected data was performed using PQ Stat software version 1.8.4. Basic descriptive statistics were calculated: arithmetic mean, standard deviation, minimum value, maximum value. A one-way analysis of variance (ANOVA) for dependent groups was used to compare cortisol levels before and after the fight. Before choosing the test, the conformity of variable distributions was checked using the Shapiro-Wilk test, and the homogeneity of variances was confirmed with the Levene's test. The effect size was represented by the Eta2 value. A p-value of <0.05 was considered statistically significant.



6 of 57

Results

Before the kickboxing fight, the average cortisol level in the study group was 11.95 ug/dl, with a standard deviation of 2.64 ug/dl. The range of cortisol values (min-max) before the fight varied from 5.3 ug/dl to 17.5 ug/dl. After the K1 fight, the average cortisol level increased to 17.8 ug/dl, with a standard deviation of 2.79 ug/dl. The range of cortisol values after the fight also increased, reaching from 8.8 ug/dl to 21.8 ug/dl. These results indicate a significant increase in cortisol levels after the kickboxing fight, as confirmed by an F statistic value of 207.10 and a p-value of <0.001, indicating a statistically significant difference. The effect size (ES) was 0.91, suggesting a strong effect of the kickboxing fight on cortisol concentration levels (Table 2, Figure 2).

Table 2. Cortisol Measurement Results Before and After the K1 Kickboxing Fight

Cortisol (ug/dl)	x	SD	Min	Max	F	р	ES
Before	11.95	2.64	5.3	17.5	207 10	<0.001	0.01
After	17.8	2.79	8.8	21.8	207.10	<0.001	0.91

X- Mean, SD- Standard Deviation, Min-minimum, Max-maximum, p- p-value, ES- Effect Size



Figure 2. Cortisol Concentration Before and After the Kickboxing Fight

Discussion

Cortisol levels are conditioned by the circadian rhythm, which is under the control of the central nervous system, with its highest concentration in the blood noted in the morning hours and the lowest during nighttime. Cortisol affects the metabolism of carbohydrates, proteins, and fats in the body (13). During physical exertion, it plays a crucial role in regulating exercise metabolism. Alongside hormones such as insulin, glucagon, adrenaline, and growth hormone, cortisol participates in metabolic processes and can also affect protein metabolism, hence it is attributed a catabolic action. It is a stressogenic hormone, whose concentration can increase as a result of physical effort, physical training, pre-competition states, or an increase in internal temperature. Physical effort at an intensity of about 80%VO2max causes an increase in cortisol concentration, and an intensity of about 60% VO2max is considered the threshold intensity for its stimulation (24).



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7 of 57

However, it should be emphasized that short-term or pulsatile efforts modify the increase in cortisol concentration to a lesser extent than aerobic work, but the adrenal response to anaerobic effort is much more pronounced than in the case of aerobic exercises. The synthesis of cortisol after a single effort or series of efforts, as occurs in judo tournament fights, is a diagnostic indicator informing about the judoka's ability to tolerate endurance-oriented loads (13).

Cortisol concentration is often used as a criterion for the adrenal cortex's reaction to maximal physical efforts. It's noteworthy that post-exercise cortisol concentration can be either positive or negative. Among rowers, no changes in cortisol levels were observed after exercise on a hand ergometer, while tennis players showed minor changes, and sprinters showed an increase in cortisol concentration after physical effort. This reaction is caused by specific physical effort, in which cortisol's response to anaerobic efforts is higher than in other athletes.

The results of conducted studies provide significant evidence of an increase in cortisol concentration after intense kickboxing fights, which is consistent with expectations regarding the body's response to physical and psychological stress, confirmed in literature (25,26). Also, in other combat sports such as judo, a significant increase in cortisol concentration was observed, which aligns with the obtained results (13). Cortisol, often called the "stress hormone," plays a key role in the body's response to stress, mobilizing energy resources, which is essential in situations requiring a quick physical reaction (27). The increase in cortisol level after a K1 fight can be interpreted as an adaptive response of the body, enabling better coping with intense effort (27). However, prolonged elevated levels of cortisol can have negative health effects, including weakening the immune system, increasing the risk of cardiovascular diseases, and metabolic disorders (28). Therefore, understanding the mechanisms underlying these changes and developing stress management and recovery optimization strategies for athletes is crucial to minimize potential negative effects. The stress experienced during sports competition is a complex phenomenon that can significantly affect cortisol levels, mainly due to the combination of physical and psychological stress. The fight requires a high level of vigilance, quick decision-making, and adaptation to pain and fatigue, which increases stress levels (29). This increased stress activates the hypothalamic-pituitary-adrenal (HPA) axis, leading to increased cortisol production (30).

Competition conditions and fighting in the ring can cause a higher cortisol concentration level than training fights due to high expectations, the presence of an audience, the pressure to succeed, competition, and the official nature of the events may additionally introduce an element of psychological stress (31).

Psychological stress, combined with the physical stressor of the fight itself, intensifies the body's response, leading to increased HPA axis activation and higher cortisol production than during training, where conditions are less stressful and more controlled. Additionally, K1 rules fighting presents the most contact-intensive form of combat among all kickboxing competition formats (32). This aspect means that the exchange of strikes is intense and the sensation of receiving blows painful, which may further elevate the stress level for the fighter. However, further observations and analyses are required to more precisely verify the occurring changes.

Limitations of the Study

The main limitation of the study was the absence of a control group that would perform the fight under standard training conditions. The study does not consider the subjective perception of stress by participants, which may vary independently from objective cortisol measurements. Focusing solely on cortisol level may not fully reflect the body's stress response, omitting other stress biomarkers.



Conclusions

Intense physical and psychological stress associated with the fight causes a significant increase in cortisol levels in athletes' bodies. This increase is interpreted as a natural adaptive response to stress. However, prolonged exposure to high levels of cortisol can have negative health consequences, highlighting the need for further research on stress management and recovery in combat sports. Monitoring steroid hormones - cortisol seems to be essential in coaching practice, and understanding these responses allows athletes to optimize their preparations for competitions.

Author Contributions: Conceptualization, Ł.R.; methodology, Ł.R. and T.P.; software, Ł.R.; validation, Ł.R., I.O. and T.P.; formal analysis, Ł.R. and L.P.; investigation, Ł.R.; resources, Ł.R.; data curation, Ł.R. and I.O.; writing—original draft preparation, Ł.R. and T.P.; writing—review and editing, Ł.R., T.P. and L.P.; visualization, Ł.R.; supervision, Ł.R., T.P. and I.I.; project administration, Ł.R. and I.I.; funding acquisition, Ł.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Regional Medical Board in Kraków (approval No. 287/KBL/OIL/2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data are included in the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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Original Research Articles

The impact assessment of the pandemic on the quality and lifestyle of students

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Abstract

Background: The aim of the research was to present aspects related to the impact of the pandemic on the quality and lifestyle of students majoring in Physical Education at the University of Rzeszów. Methods: The study was conducted on a group of 217 students from the University of Rzeszów first, second, and third-year students majoring in Physical Education. In the surveyed group, there were 52.5% women and 47.5% men, aged between 19 and 25 years. The chosen method to implement the objectives outlined in this study was a survey based on a self-prepared questionnaire, developed according to standard principles of constructing such research tools. Results: In the context of the conducted research, it can be stated that the pandemic and its related restrictions have influenced a deterioration in the quality of life of the respondents. A moderate impact of gender on the quality and lifestyle of the respondents was observed both before the pandemic and during the partial lifting of restrictions. Regarding the impact of the pandemic on the quality and lifestyle of the respondents, it cannot be unequivocally stated whether it is inversely proportional to age, meaning it is higher the younger the respondents are. Conclusions: The respondents noticed changes in their body weight during the imposition of restrictions. The introduced limitations and the shift to remote learning resulted in a decrease in mood, worsened well-being, difficulties in concentration, and material assimilation for the surveyed students.

Keywords: pandemic, COVID-19, students, lifestyle

Introduction

Since March 2020, Poland and the entire world have found themselves in a completely new and unprecedented situation. On March 11, 2020, the World Health Organization declared the first pandemic of the 21st century, resulting not only in a high mortality rate but, as the perspective of the past year reveals, irreversible social and economic consequences. Due to the implementation of government restrictions, people worldwide were forced to change their previous habits, including those related to physical activity. In addition to understandable health issues directly associated with the infection, there was a justified concern about the deterioration of well-being and mental health, including an increase in depressive and anxiety symptoms. During the third wave of COVID-19, as of March 1, 2021, there were 114 million cases worldwide, 1.7 million in Poland, and the virus caused 2.53 million deaths worldwide and 43,656 in Poland. The pandemic became a shock, a stressor. According to CBOS research, 60% of respondents considered the past year as bad, while 70% perceived it as such for Poland – these were the worst results obtained in the history of CBOS research since 1984 (1).

The situation related to the spread of the SARS-CoV-2 virus abruptly changed the daily functioning of businesses and institutions worldwide. Higher education institutions

Received: 13.11.2023 Reviewed: 28.12.2023 Published: 13.01.2024

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in Poland were not exempt from this. Public entities and decision-makers introduced regulations aimed at limiting the scale of the epidemic in our country. These measures caused the academic community, like many others, to change its methods of achieving goals overnight. Direct relationships were necessarily replaced by online interactions. In the context of the topic of this work, it is crucial to present research related to the changes that occurred in the lifestyle of students after the introduction of restrictions related to the COVID-19 epidemic.

In 2020, international and multicenter research was conducted as part of the "IRG on COVID and exercise" group, led by the University of Potsdam. The project aimed to assess the impact of social isolation on the habits related to physical activity and the well-being of the surveyed individuals. The research was carried out using an original questionnaire, translated into 18 languages, and distributed online from March 29 to May 7, 2020. Among the respondents, nearly 60% were students. The participants declared engaging in various forms of physical activity even before the epidemic. The most popular physical activities were running and walking, both at 25% among respondents, strength exercises (23%), and cycling (almost 8% of respondents). The research did not show a correlation between the type of physical activity undertaken before the epidemic and well-being (p=0.87). However, during the epidemic, the most popular activities among the respondents were walking (about 22%), running (almost 19%), strength training (18%), cycling (12%), and fitness (11%) (2).

In connection with the World Health Organization's declaration of a coronavirus pandemic in March 2020, most countries worldwide introduced restrictions and limitations in the form of social isolation. In 2020, an online survey was conducted on a group of 13,696 respondents from 18 countries to study the effects of pandemic-related government restrictions and their impact on lifestyle, subjective well-being, and the frequency and forms of physical activity. The results of the conducted research unequivocally indicated a tendency to maintain physical activity among individuals who exhibited such tendencies before the introduction of restrictions, and low or minimal physical activity among those who were physically inactive before the pandemic (3).

In 2020, a study was conducted on the lifestyle and physical activity of students from California universities during the pandemic. In a group of almost 2000 surveyed students, over 81% did not follow an appropriate diet during the pandemic and remote education, and more than half of them (55.2%) significantly reduced physical activity (4).

Another interesting example of a survey examining the impact of isolation and restrictions related to COVID-19 on lifestyle was the ECLB-COVID19 survey. The study was conducted using an electronic form from April 1-6, 2020. The questionnaire included 64 questions about health, mental well-being, mood, life satisfaction, and multidimensional lifestyle-related behaviors (physical activity, diet, social participation, sleep, technology use, need for psychosocial support). All questions referred to conditions "before" and "during" isolation. The research revealed that COVID-19 home isolation had a negative impact on all levels of physical activity and extended daily sitting time by over 28% (5).

Social distancing and restrictions largely changed the lifestyle of students. In 2020, a review of research conducted by various scientific and commercial centers worldwide on the impact of the pandemic and associated restrictions on the physical activity of students was carried out. Physical activity studies during quarantine were conducted in Spain (6), Croatia, and Mexico (7). In Spain, 213 students participated in the study. The main dependent variables were physical activity and sitting time, measured using the International Physical Activity Questionnaire – short form (IPAQ-SF). The analysis of responses indicated an increase in both physical activity and relaxation time. Differences were observed depending on gender, year of study, BMI, alcohol consumption, smoking, anxiety/depression symptoms, Mediterranean diet, living situation, and stage of change.



Regarding research conducted among Polish respondents, it's worth mentioning a study from 2020 conducted by Kantar on behalf of Benefit System, examining the impact of physical activity on the personal and professional lives of Poles during the COVID-19 pandemic. The study took place in January, April, and September 2020, with a sample of 1200 adult Poles, utilizing computer-assisted telephone interviews. The study found that Poles are not only aware of the need for physical activity but also recognize numerous health benefits in this regard. The majority of respondents in this study were young people living in large cities, students, or university graduates. Before the pandemic, 65% of respondents were physically active, with those aged 15-24 accounting for 89%. During the first wave of the pandemic, the number of physically active individuals decreased by 4%, and during the second wave, it decreased by 2% compared to the pre-pandemic period and increased by 2% compared to the first wave (8).

Modern technologies, serving as the basis for communication among young people, have excluded many forms of their physical activity and led to a decrease in motivation for activities outside the home. According to CBOS research on the physical activity of Poles, 34% of respondents do not engage in any form of physical activity (6). Among physically active individuals, 40% exercised regularly, while 26% did so sporadically. In this context, Poles fare worse than the European Union average. Eurobarometer studies indicate that 25% of Europeans do not engage in any physical exercises or sports (9).

One of the groups whose lifestyle is subject to numerous studies and analyses is the student community. They believe that a healthy lifestyle is primarily associated with physical activity and healthy eating, rather than focusing on relaxation or avoiding substances (10). According to conducted research, university students tend to reduce the intensity of sports activities compared to high school. Significant changes also occur in dietary habits, and there is an increase in the proportion of people using various substances (11).

Material and Methods

The main objective of the research was to conduct an analysis of the impact of the pandemic on the health and lifestyle of students majoring in Physical Education at the University of Rzeszów, as well as to assess this impact. The study was conducted on a group of 214 students from the University of Rzeszów - first, second, and third-year students majoring in Physical Education. In the surveyed group, 52.5% were women and 47.5% were men, aged between 19 and 25 years. The majority of students had a normal BMI, constituting 49% of the respondents. Underweight was observed in 12.55% of students (27% men), while 9.45% of students were classified as obese based on BMI calculations (93% of whom were men).

The chosen method for implementing the adopted assumptions was a survey based on a self-prepared questionnaire, developed according to standard principles of constructing such research tools. The survey is one of the methods belonging to the group known as diagnostic survey methods. Other techniques included in this category are interviews and discussions. Diagnostic survey methods are considered fundamental research techniques.

The developed questionnaire was introduced into the "Google Forms" tool and then distributed among first to third-year students. The study was conducted in April 2022. The collected responses form the basic database in a spreadsheet format. Some basic data, after aggregation, were available in the form of charts directly from Google Forms.

The survey questionnaire was quite complex, consisting of numerous closed and partially open-ended questions, allowing respondents to provide answers beyond those selected by the researchers. To facilitate the analysis of research results, a response database was prepared using MS Excel, enabling basic descriptive statistics and the creation of



more detailed charts. In the conducted research, the variables were the gender and age of the students.

The following research hypotheses were formulated:

1. The pandemic and its associated restrictions have led to a deterioration in the quality of life of the respondents.

2. The impact of the pandemic on the quality and lifestyle of the respondents is gender-dependent, with a greater impact on men than women.

3. The impact of the pandemic on the quality and lifestyle of the respondents is inversely proportional to age, with a higher degree of impact at a younger age.

Results

Students mostly assess their health as good (25.8%, including 43% of men), reporting an annual illness occurrence and undergoing medical examinations 2-4 times a year. A very good health status was reported by 36.6%, including 52% of men, indicating not experiencing illnesses, regular check-ups, regular exercise, and a healthy diet following the food pyramid, while avoiding fast food (Figure 1).



Figure 1. Subjective assessment of health by students.

Questions related to physical activity and lifestyle before the pandemic began with inquiries about the use of activity tracking applications. Out of the 217 students surveyed, only 35.9% utilized such technological solutions before the pandemic. Men were more likely to use these applications (61.7%) compared to women (38.3%). It can be concluded that these applications had moderate interest among the student population (Figure 2).





Figure 2. Usage of fitness tracking apps.

After the partial lifting of restrictions, among the group of 217 students, 96.8% of respondents declared using technological solutions such as activity tracking applications. Men were more likely to use these applications, with 100%, compared to women at 83.3% (Figure 3).



Figure 3. Usage of fitness tracking apps after partial lifting of restrictions.

Before the pandemic, individuals aged 19-21 (49% of respondents) were more likely to use the applications than those aged 24-25 (8% of respondents). After the partial lifting of restrictions, 100% of individuals aged 23 reported not using the applications. It can be concluded that post-pandemic, these solutions were used much more frequently among students than before the pandemic.

Before the pandemic, students consumed either 5 meals (20.7%) or 4 meals (20.7%) a day. More than five meals were consumed by 16.1% of respondents. Only 14.7% had meals



three times a day, 17.1% twice a day, and 10.6% once a day. The majority of women attached more importance to eating a greater number of meals. Before the pandemic, in the group of people eating from 4 to above 5 meals a day, women constituted 64.7%. Men most commonly had one or three meals a day, accounting for 56.7% of respondents, respectively (Figure 4).





As evident from the above data, the number of meals consumed by female respondents has undergone changes. Before the pandemic, there was a prevalence of individuals consuming 4 meals a day, as well as those consuming 5 or more than 5 meals a day. However, after the partial lifting of restrictions, a significantly higher number of individuals declared consuming 1, 2, or 3 meals a day, while fewer reported consuming 4 or more than 5 meals.

In the group of individuals consuming four meals a day before the pandemic, those aged 22 (31%) and 20 (27%) predominated. As much as 29% of 23-year-old students declared consuming 5 meals a day. Individuals aged 19 consumed two meals a day (100%). After the partial lifting of restrictions, the number of individuals aged 25 (32% from 18%) and 24 (19% from 15%) consuming three meals a day increased (Figure 5).





Figure 5. The number of meals consumed by male students.

For the respondents, the changes in the number of meals consumed daily were not as significant. The number of individuals consuming from one to three meals a day remained at a similar level. After the partial lifting of restrictions, the number of respondents consuming 4 meals a day and more than 5 meals a day decreased by over half. However, there was an increase in the number of respondents consuming 5 meals a day (from 12% to 18%).

Before the pandemic, more than half of the students (52.1%) did not pay attention to the calorie content of meals. A significant portion (47.9%) of respondents attached importance to this, with women predominating in this group (64%).

The most frequently consumed products before the pandemic included fast food (17.5%), raw vegetables (24%), hot dogs (25.8%), rice (23%), cream (19.4%), butter (30%), oil (24%), deli products (23.5%). Rarely found in their diet were products such as nuts (4.6%), olive oil (2.8%), coconut oil (0.5%), lard (0.9%), peanut butter (1.8%), margarine (1.8%), processed cheese (3.7%), yellow cheese (7.4%), natural yogurts and kefirs (4.6%), fruit yogurts (3.7%), curd (6%), legumes (1.4%), wheat products (3.2%), oat flakes and grains (4.1%), canned goods (0.9%), red meat (6%), seafood (1.4%), fish (4.1%), cooked vegetables (7.4%), sweets (7.4%). Occasionally consumed were milk (10.1%), eggs (9.7%), potatoes (12%), cold cuts (8.3%), lean meat (11.1%), fruits (11.1%). Students preferred carbonated drinks (32.7%), 100% fruit juices (25.3%), and coffee (24.4%) in their diet. Relatively rarely chosen were mineral water (10.1%), tea (9.2%), and fruit juices (6%). The least consumed were isotonic drinks (2.3%) and energy drinks (3.2%).

After the partial lifting of restrictions, more than half of the students (51.2%) still did not pay attention to the caloric content of their meals. Only 48.8% of respondents considered it, with a majority being women (63.8%).

The most commonly consumed products before the pandemic by students included fast food (27.2%), sausages (25.8%), salty snacks (18.9%), powdered products (19.8%), wheat products (20.7%), cold cuts (25.8%), red meat (24.9%), oil (14%), convenience products (12.9%), margarine (16.6%), and oats (19.8%). These results clearly indicate changes in the types of consumed products towards those with increased caloric content.

Less frequently included in their diet were products such as nuts (5.5%), olive oil (3.2%), coconut oil (0.9%), lard (0.9%), peanut butter (1.4%), processed cheese (2.3%), yellow cheese (7.4%), natural yogurts and kefir (4.1%), fruit yogurts (4.1%), curd (6%), sour cream (3.2%), eggs (10.6%), legumes (3.2%), cereals (5.5%), canned goods (2.3%), sausages



18 of 57

(4.1%), seafood (1.8%), fish (5.1%), cooked vegetables (7.8%), raw vegetables (6%), and sweets (7.8%). In terms of beverages, students preferred carbonated drinks (14.3%) – despite a decrease compared to the pre-pandemic period – 100% fruit juices (25.3%), coffee (22.6%), and tea (25.8%) – showing an increase in tea consumption compared to the pre-pandemic period. They rarely opted for mineral water (10.1%), isotonic drinks (2.8%), and energy drinks (3.2%).

In relation to the period before the pandemic, among 19-year-old students, the consumption of processed and fast food products was negligible. The pandemic caused the largest increase in the consumption of processed and fast food products, as well as proteins. Beverage and carbohydrate consumption decreased. In the group of twenty-yearolds, changes in the structure of consumed meals were as follows: a decrease in the consumption of carbohydrates and processed and fast food products, while the consumption of proteins, fats, and beverages increased. For 21-year-old students, the most significant changes were observed in the consumption of fats and beverages, where they reported an increase in the consumption of these products after the partial lifting of restrictions. However, the consumption of proteins, processed and fast food products decreased compared to the period before the pandemic.

Students at the age of 22 stated that they consumed highly processed products and fast food much more often than before the pandemic. However, the consumption of carbohydrates and proteins decreased. Students at the age of 23 mentioned that as a result of the pandemic, they started consuming more protein-containing products and fats. Additionally, they increased their intake of beverages. They significantly reduced carbohydrates and processed products, including fast food.

For this group of respondents, changes were minimal and mainly related to an increase in beverage consumption after the partial lifting of restrictions. In the 25-year-old age group, the pandemic led to changes in the consumption of fats, carbohydrates, and processed/fast food products, with a slight increase observed. Individuals in this age group also reported an increased intake of beverages in their daily diet after the partial lifting of restrictions.

Before the pandemic, more than half of the students engaged in physical activity (60.4%), with women dominating this group (64.5%). As much as 36.6% of students did not engage in physical activity, including 54.37% of men. Physical activity was most commonly undertaken once a week (30.9%), with men being the majority in this group (91.3%), or seven times a week (26.3%—this response was chosen by 56% of women and 44% of men).

For women, the dominant forms of activity were fitness exercises (78.6%) and aerobic exercises (65.3%). Men more frequently chose strength training (72.3%) and strength-endurance exercises (95.1%) (Figure 6).







After the partial lifting of restrictions, over half of the students engaged in physical activity (59.9%), with women dominating in this group (63.5%). A significant 40.1% of students did not participate in physical activities, including 59.7% of men. There is a noticeable increase in the number of individuals declaring a lack of physical activity during this period. Prior to the pandemic, among the entire group of students, strength training was the most popular (28.6%), followed by relaxation exercises (27.2%), endurance training (19.4%), and interval training (18%) (Figure 7).



Figure 7. Types of training undertaken by respondents before the pandemic.

The prevailing exercises after the partial easing of restrictions were fitness activities (40.6%), aerobic exercises (24.4%), and strength training (32.7%). The most commonly chosen exercises before the pandemic included fitness classes (44%), dance (17%), weightlifting (17%), running (33%), team sports (68%), table tennis (27%), swimming (47%), and cycling (53%). Students engaged in these activities 2-3 times a week for 30 to 60 minutes.



The least commonly used forms of exercise, as reported by the respondents, were home workouts (39%), walking (30%), CrossFit (16%), rollerblading (44%), table tennis (10%), and badminton (19%). Most respondents allocated 30 minutes daily for these activities. The impact of physical activity in on-campus sessions before the pandemic had a motivating effect on 49.8% of respondents, with 81.3% of men being influenced to engage in physical activity outside the university setting.

Respondents most frequently engaged in physical activity five times a week (19.4%, with men constituting 71.3% in this group) or seven times a week (23.5%, chosen by 58.2% of women). After the partial easing of restrictions, the dominant forms of activity for women were fitness exercises (79.2%) and aerobic exercises (67.4%), while men more frequently opted for strength training (71.8%) and strength-endurance exercises (94.6%). Across the entire group of students, the most popular activities were strength training (22.6%), aerobic exercises (41.9%), and fitness (30.9%) (Figure 8).



Figure 8. Dominant forms of activity after partial lifting of restrictions.

However, endurance exercises prevailed (29.5%), followed by interval training (28.6%) and strength training (26.8%). A noticeable shift is evident compared to the pre-pandemic period when students favored strength training (28.6%), relaxation exercises (27.2%), endurance training (19.4%), and interval training (18%) (Figure 9).





Figure 9. Most frequently performed exercises and workouts after the lifting of restrictions.

The most frequently chosen exercises post-pandemic included fitness classes (63%, an increase compared to the pre-pandemic period), running (72%, an increase from the pre-pandemic period), table tennis (54%, an increase from the pre-pandemic period), swimming (68%), cycling (44%), and home workouts (46%). Students engaged in these activities three to four times a week for 30 to 60 minutes.

The least commonly used forms of exercise, as reported by the respondents, were rollerblading (94%), team sports (86%), CrossFit (16%), roller skating (44%), table tennis (46%), and badminton (47%). Participants allocated 30 minutes daily for these activities, and engagement in this regard occurred less than twice a week or not at all. Clear changes are visible compared to the pre-pandemic period, where team sports were significantly more popular among students. A change in body weight for 35.5% of students was less than 5 kg. Meanwhile, 28.1% of students reported a decrease in body weight of less than 5 kg. On the other hand, 27.2% of students observed an increase in body weight of more than 5 kg (Figure 10).





Figure 10. Change in body weight.

According to 48.8% of students, the pandemic period and reduced opportunities for physical activity did not impact their health. On the other hand, 51.2% of students believe that the pandemic has affected their health (Figure 11).



Figure 11. Impact of the pandemic on health.

Within the group, 30% of students experienced issues with their spine and eyesight. In the case of 26.3%, there was a decrease in physical fitness. Additionally, 34.6% of students noticed a reduction in their overall endurance (Figure 12).





Figure 12. Health problems of students.

According to 55.8% of respondents, remote classes conducted at the university had an impact on their mental well-being. These individuals experienced a high degree of feelings of depression and loneliness (18%) and reported feeling mildly overwhelmed (26.6%). Additionally, 26.3% of students stated that they did not feel any difference in this regard, and 27.2% did not pay attention to their mental well-being. The main consequences of poor mental well-being during remote classes included a lack of motivation to work (27.6%), fatigue (21.7%), and a sense of isolation (23%). In 12% of cases, students missed direct contact with lecturers. Furthermore, students noticed issues with concentration (21.2%) and material assimilation (20.3%) (Figure 13).



Figure 13. Student well-being.



Discussion

In the surveyed group, 44.2% maintained or increased their previous level of physical activity, while only 23.7% reported a decrease. A significant correlation was observed between the frequency of physical activity and well-being. Those who exercised both before the pandemic and during the lockdown restrictions experienced an improvement in mood. In contrast, individuals who started or increased physical activity during the pandemic showed positive effects (3).

In 2020, research was conducted on the lifestyle and physical activity of California university students during the pandemic. Among nearly 2000 surveyed students, over 81% did not follow a proper diet during the pandemic and remote education, and more than half of them (55.2%) significantly reduced their physical activity. The results of the study indicated a considerable impact of COVID-19-related restrictions on the lifestyle and physical activity of students. Additionally, it was observed that women engaged in physical activity more frequently than men (4).

On the other hand, the ECLB-COVID19 study revealed that the home isolation during COVID-19 had a negative impact on all levels of physical activity, leading to an increase in daily sitting time by over 28%. Furthermore, the isolation influenced the intensification or manifestation of negative eating habits, such as uncontrolled eating, snacking between meals, and an increased number of main meals. However, there was a positive aspect as well, as the isolation led to a reduction in alcohol consumption. During the pandemic and associated restrictions, there was a decrease in all levels of physical activity among respondents. Restrictions reduced the number of days and hours of physical activity, and they also adversely affected access to gyms and fitness classes. Despite an increased availability of counseling on the importance of physical activity and various online workouts on social media, the majority of respondents were unable to maintain their physical activity at pre-pandemic levels. Survey results indicate that individuals struggled to uphold their physical activity habits during home isolation. One of the conclusions and recommendations from the conducted research highlighted the need for interventions to support an active and healthy lifestyle during closure (AHCL), utilizing solutions such as home workout games and fitness apps (5). Similar changes were noticed by students majoring in tourism and recreation at the University of Pedagogy in Krakow. The lack of access to sports facilities resulted in more people starting to exercise regularly at home (an increase of 12%) or at publicly accessible outdoor gyms (an increase of 17%). Those who exercised regularly once a week for the most part did not change their habits. Only in the case of swimming, martial arts, and gym workouts was a slight decrease in activity noted, which is, of course, attributed to the lack of access to organized activities in clubs or swimming pools. The number of respondents engaging in weekly recreational activities at home decreased by 10% (12).

Cross-sectional data collected within 2 weeks from the start of the lockdown in Germany indicated that as many as 31% of Germans reduced their leisure-time physical activity during the pandemic. The number of steps recorded by them through phone applications decreased by 6% within 10 days and by 27% within 30 days. It is a fact that students often have to share a room with other family members or use spaces not intended for work, which adds additional psychological burden, hinders concentration, and disrupts fulfilling duties. Insufficient physical activity, lack of motivation for physical activity, and, above all, the lack of a habit of active relaxation further intensify the frustration and poor well-being of students (13).

In the context of the conducted research, it can be concluded that the pandemic and its associated restrictions have led to a deterioration in the quality of life of the respondents. Although they did not declare significant changes, detailed questions allowed for formulating conclusions confirming this hypothesis. A moderate impact of gender on the quality and lifestyle of the respondents was observed both before the pandemic and



during the partial lifting of restrictions. In the same context, one should consider the impact of the pandemic on the quality and lifestyle of the respondents. It cannot be unequivocally stated whether it is inversely proportional to age, meaning it is higher the younger the age of the respondents.

Conclusions

The pandemic has triggered negative changes in the habits and lifestyles of the surveyed individuals. It resulted in adverse alterations in the dietary patterns, leading to weight gain and BMI changes in over half of the examined students, including both females and males. Considering the obtained results, it is advisable to reduce the consumption of fast food, processed products, and red meat, and instead, prioritize vegetables, fruits, fish, while limiting the intake of stimulants such as coffee, tea, alcohol, and energy drinks. Additionally, an increase in mineral water consumption is recommended.

The pandemic has also influenced a shift in the structure of physical activities, training, and exercises. Students have abandoned some types of workouts or replaced them with those requiring less effort and involvement. Actions should be taken to encourage students to engage in more frequent physical activity, with a particular emphasis on aerobic and endurance exercises. The body weight of the respondents increased during the enforcement of restrictions for over half of them. Educational or preventive measures targeting students regarding maintaining a healthy body weight should be implemented.

The introduced restrictions and the shift to remote learning have resulted in a decrease in mood, worsened well-being, and difficulties in concentration and material assimilation among the respondents. Future considerations should involve limiting remote forms of teaching or conducting them in a more engaging manner to encourage students to participate actively.

Author Contributions: Authors of this article made the following contributions: Conceptualization, K.G., A.R-B.; methodology, K.G., A.R-B.; software, K.G., A.R-B.; validation, K.G., A.R-B.; formal analysis, K.G., A.R-B.; investigation, K.G., A.R-B.; resources, K.G., A.R-B.; data curation, K.G., A.R-B.; writing—original draft preparation, K.G., A.R-B.; writing—review and editing, K.G., A.R-B.; visualization, K.G., A.R-B.; supervision, K.G., A.R-B.; project administration, K.G., A.R-B.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Ethical Committee: Approval of the Bioethics Commission at the District Chamber of Physicians in Gdańsk dated February 4, 2022, Ref. No. KB-8/22.

Informed Consent: Informed consent was obtained from all study participants.

Data Availability: The data presented in this study are available upon request from the corresponding author.

Conflict of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Selected elements of general fitness and effectiveness in 1x1 test games among 12-year-old football players

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Abstract

Background: Individual duels in football are considered a difficult and risky element of the game. Effective actions of a player in a 1x1 situation allow you to gain a numerical advantage over your opponent and gain space on the pitch. The aim of the research is to assess the impact of selected elements of general fitness on the effectiveness of young football players in 1x1 test games. **Methods**: The research was conducted on a group of boys playing football at the "Hutnik" Kraków Football Academy. The group consisted of eighteen young football players born in 2010, who were 12 years old at the time of the study (Youth: D2). The research was conducted in January-February 2022. The method of observation (categorized) was used in the study. To assess the game's disposition, a general physical fitness test and a 1x1 test game were used. **Results:** Based on the correlation analysis, it was found that the general level of physical fitness of young football players has a positive impact on the effectiveness in 1x1 test game. For all analyzed elements of general fitness, significant relationships were found with the 1x1 game indicators. The highest correlations between 1x1 game indicators were recorded for speed, agility, jumping - power of lower limbs and endurance. **Conclusions:** In order to increase the effectiveness of the 1x1 game, care should be taken to develop general physical fitness, with particular emphasis on speed and agility.

Keywords: football, 1x1 game, general fitness, motor ability tests

Introduction

Football is classified as a team sport, falling under the category of collective (multientity) sports, where individual actions can be distinguished as single-player actions defined as individual, actions performed with the involvement of several players labeled as group actions, and synchronized actions of the entire team, known as team actions (1-3). In team sports, Naglak (4) considers individual actions as fundamental, which, as emphasized by Szwarc (1), define the athlete's excellence, determine the quality of their game, and influence the effective execution of group and team tasks.

Individual actions, while actively opposing the opponent, can be defined as "one-onone" situations (1x1). According to Szwarc (1), the 1x1 game should be understood as the direct interactions between two players from opposing teams, aiming to achieve conflicting goals within the rules specified by regulations. Engaging in 1x1 play in attack is undertaken to score goals, create situations for goal-scoring, with the intention of controlling the field and/or retaining possession of the ball. On the other hand, "one-on-one" play in

Received: 28.11.2023 Reviewed: 25.12.2023 Published: 14.01.2024

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The 1x1 game is considered a challenging and risky element of competition, but effective player actions in these situations lead to a numerical advantage for the team, facilitating space acquisition and further gameplay (5-6).

Analyses of football matches indicate that winning teams are characterized by a higher level of effectiveness in 1x1 play (7-8). During matches at the highest level, we observe over two hundred such duels (9-12). It is accepted that high-caliber players can engage in nearly 40 1x1 situations with a favorable win-loss ratio (11), while the best teams exhibit around 50% reliability in the discussed duels (12).

The above information highlights that 1x1 situations constitute a crucial element in football. Therefore, in the training of children and youth, special attention should be paid to the development of skills influencing the effectiveness of actions in "one-on-one" situations. Hence, this study assesses the impact of selected elements of general physical fitness on the effectiveness of young football players in the 1x1 test game.

Objective of the Study and Research Questions

The objective of this study is to assess the impact of selected elements of general physical fitness on the effectiveness of young football players in 1x1 test games, focusing on 12-year-old boys from AP "Hutnik" Kraków. Additionally, to obtain comprehensive information about the group's homogeneity, measurements of basic somatic parameters were conducted, which could, to some extent, influence the results of the conducted research.

Considering the research objective, the following research questions were formulated:

1. Does the level of general physical fitness influence the effectiveness of young football players in 1x1 games?

2. Which of the analyzed motor skills most significantly determine the effectiveness of 12-year-old players in 1x1 situations?

Material and Methods

The study group consisted of football players from the "Hutnik" Football Academy in Kraków. Eighteen boys, aged 12 (born in 2010), participated in the research. These young players were selected from Kraków and its vicinity, actively participating in the First District League of Youth organized by the Małopolski Football Association. The declared playing experience of the participants ranged from 4 to 5 years. Players underwent training sessions 3 to 4 times a week, with each session lasting 90 minutes. The team's head coach held a UEFA A license.

The research employed the method of categorized observation. According to Ryguła (13), this method holds significant importance in controlling the effects of the training process and in sports selection. The fundamental technique of this method involves conducting motor, psychological, physiological, and other standardized measurement tests.

The research was conducted in January-February 2022 at the facilities of the "Hutnik" Football Academy in Kraków: a sports hall (measurements of somatic indicators, general physical fitness) and a football pitch with artificial turf (1x1 test games). At the beginning of the study, somatic measurements and general physical fitness assessments were conducted. Subsequently, players were evaluated in 1x1 test games. All measurements were carried out with the consent of guardians and in the presence of the team's coach. Before conducting the tests, players were familiarized with the procedure for performing all trials. During measurements, participants wore appropriate sports attire and football footwear suitable for the surface. Sessions where general fitness tests and 1x1 games were conducted began with a 15-minute warm-up. All assessments were carried out in



accordance with the instructions, maintaining the unchanged format and sequence, and adhering to basic organizational and methodological guidelines (14-16).

To ensure reliable results, measurements were conducted under conditions of full participant motivation. Each general fitness trial (except endurance) was performed twice, considering the better result. The assessment of effectiveness in 1x1 test games was carried out using a "round-robin" competition system.

Standardized tests and diagnostic tools were employed in the research (14,16). To obtain credible information and check the homogeneity of the study group, measurements of basic somatic parameters were also taken (17): body height, body mass, and BMI index.

Four selected sports-motor tests were used to assess overall physical fitness (Talaga 2004):

- Jump test (lower limb power) standing long jump,
- Speed trial 30-meter sprint,
- Agility trial running around cones,
- Endurance running trial beep test.

Each trial has specific point norms for the obtained results (Table 1).

Table 1. Point norms - general fitness tests for U12 youth Source: Own compilation based on: Talaga2004, PZPN 2016.

Rating	Points	Beep Test (Level)	30m Sprint	Standing Long Jump	Running Around Cones	Rat- ing	Points	Beep Test (Level)
Very Good	5	>10.5	5.0 s	180 cm	26.0 s	5	>10.5	5.0 s
Good	4	8.6-10.5	5.2 s	142-179 cm	27.0 s	4	8.6- 10.5	5.2 s
Average	3	7.6-8.5	5.4 s	105-141 cm	28.0 s	3	7.6-8.5	5.4 s
Poor	2	6.6-7.5	5.6s	67-104 cm	29.0 s	2	6.6-7.5	5.6s
Very Poor	1	6.5-5.2	5.8 s	1-66 cm	30.0 s	1	6.5-5.2	5.8 s

To assess the effectiveness of individual actions, 1x1 test games were utilized (16). The organization of games followed a "round-robin" system. Results obtained from individual matches provided information on four indicators:

1) The number of points scored in all matches (a player received 3 points for a win, 1 point for a draw, and 0 points for a loss) – this indicator reflects the overall effectiveness in both attack and defense in 1x1 games.

2) The difference between the number of goals scored and conceded in all matches – this indicator informs about the difference in a player's effectiveness in attack and defense in 1x1 games.

3) The number of goals scored in all matches – this indicator informs about a player's effectiveness in attack in 1x1 games.



4) The number of goals conceded in all matches – this indicator informs about a player's effectiveness in defense in 1x1 games.

To address the research questions, the collected data was analyzed using descriptive statistical methods, including arithmetic mean, standard deviation, coefficient of variation, and minimum and maximum values. To calculate the relationships between the examined parameters, the Pearson correlation coefficient was employed (18). The calculations were performed using the computer programs Microsoft Excel 2013 and Statistica 13 by StatSoft.

Results

Considering that individual development levels may influence the results of the 1x1 game, the assessment included the level of somatic parameters (Table 2).

	Mean(average)	Min	Max	Standard deviation	Coefficient of variation
Body height	1.582	1.500	1.670	0.043	2.702
Body mass	48.417	44.000	51.700	2.525	5.216
BMI (Body Mass Index)	19.359	17.570	20.920	0.845	4.364

Table 2. Results of somatic parameter measurements

Based on the results presented in Table 2, it appears that the examined group demonstrated a comparable level in the analyzed somatic parameters. Therefore, it can be assumed that the young players were at a similar stage of biological development, increasing the likelihood of the reliability of the conducted analyses.

To assess the relationships between selected elements of overall physical fitness and the effectiveness of 1x1 play, a correlation analysis was applied. Test probabilities (p-values) are provided beneath the correlation coefficient values (a p-value < 0.05 indicates a statistically significant result). The research results regarding the interdependence of the discussed parameters are included in Table 3.

Table 3. Results of the interdependence between the level of overall fitness and effectiveness in the 1x1 test game.

	Explosive strength: Standing long jump	Endurance running: Beep test	Agility: Zig-zag run	Locomotor speed: 30-meter sprint	Total points from all gen- eral fitness tests
Total points in 1x1	,6775	,5940	-,7245	-,7563	,8658
games	p=,002*	p=,009*	p=,001*	p=,000*	p=,000*
Goals scored in 1x1	,7197	,4985	-,6012	-,6892	,7566
games	p=,001*	p=,035*	p=,008*	p=,002*	p=,000*
Goals conceded in	-,5152	-,6126	,6618	,6968	-,8006
1x1 games	p=,029*	p=,007*	p=,003*	p=,001*	p=,000*

Statistically significant correlations (p < 0.05) are marked with an asterisk (*).



The data presented in Table 3 indicates that statistically significant interdependencies (p < 0.05) were observed between all the analyzed 1x1 game indicators and overall fitness. These results shaped within the range of moderate, strong, or very strong correlations.

For the first of the analyzed 1x1 game indicators (total points), the highest correlations were found with the level of locomotor speed – "30m sprint" (r=-0.7563), agility – "running around cones" (r=-0.7245), followed by explosive strength – "standing long jump" (r=0.6775), and endurance – "beep test" (r=0.594).

Analyzing the indicator of goals scored in 1x1 games, it can be noted that the strongest correlations were observed with the level of explosive strength – "standing long jump" (r=0.7197), followed by locomotor speed – "30m sprint" (r=-0.6892), agility – "running around cones" (r=-0.6012), and endurance – "beep test" (r=0.4985).

The assessment of the correlation for the indicator of goals conceded in 1x1 games indicated the following order of interdependencies: locomotor speed – "30m sprint" (r=0.6968), agility – "running around cones" (r=0.6618), endurance – "beep test" (r=-0.6126), explosive strength – "standing long jump" (r=-0.5152).

For the goal difference indicator in 1x1 games, the strongest correlations were found with the values of locomotor speed – "30m sprint" (r=-0.7677), followed by agility – "running around cones" (r=-0.6999), explosive strength – "standing long jump" (r=-0.6827), and endurance – "beep test" (r=-0.6161).

Analyzing the comparison of individual 1x1 game indicators with the overall fitness score (total points obtained from all general fitness tests), very strong correlations (p < 0.05) were indicated – Table 3. Based on these results, it can be suggested that among the surveyed players, the level of overall physical fitness had a significant impact on the results in "one-on-one" test games.

Discussion

Statistics published by FIFA and UEFA from international matches indicate that frequently achieving "small victories" in 1x1 play significantly contributes to the overall success of the team (19). Therefore, this study attempted to identify which elements of physical fitness should be developed to effectively compete in 1x1 situations. The research was conducted on a group of 12-year-old football players (youth) from the "Hutnik" Football Academy in Krakow. Motor skills were assessed through measurements of jump height (explosive strength/lower limb power) – "standing long jump," speed – "30m sprint," agility – "running around cones," and endurance – "beep test" (14). Individual play was assessed using a test game, providing information on 4 indicators in 1x1 situations (20). Additionally, basic somatic parameter measurements were conducted to verify the group's homogeneity, revealing that the examined group was at a comparable level of biological development (21).

In evaluating the interdependencies, the highest relationships between overall fitness and 1x1 game indicators were observed for agility and speed measurements (strong or very strong correlation). Slightly weaker connections for individual play indicators were observed for lower limb power and running endurance (in the range of strong or moderate correlation) – see Table 3.

Comparing the results of our study to works by other authors, similar findings were uncovered in Szwarc's research (22), where positive influences of speed and agility predispositions on the development of "one-on-one" playing skills were observed in players aged 12-15. Paluszek (23) also confirmed a correlation between high-speed predispositions and effectiveness in 1x1 games among 15-year-old football players. Moreover, other studies have revealed that the level of "explosive" strength significantly influences individual play effectiveness (24).

The mentioned research results align with the opinions of experts (25-27), who indicate that dynamic forms of game fragments (including 1x1 situations) are effective tools



for developing speed and speed-strength abilities. In these dynamic forms, the coach has the opportunity to control the exercise intensity and the ratio of effort to rest time. Regarding endurance, our research findings are supported by the work of Jaworski et al. (28), who observed significant correlations between endurance and indicators of the 1x1 test game among players aged 12-13 (as well as older players). It is worth noting that, according to numerous authors (29-32), 1x1 games can be an effective form of endurance training in football player development.

Analyzing the correlations between the total points obtained from individual physical fitness tests and 1x1 game indicators, strong interdependencies are evident (Table 3). Based on these results, it seems that among young football players, a high level of overall physical fitness positively influences effectiveness in 1x1 situations. This is also confirmed by the observations of other researchers (11, 22, 28, 33), according to whom individual game effectiveness is largely conditioned by the overall level of physical fitness.

Conclusions:

- Among young football players, the level of overall physical fitness significantly influences effectiveness in 1x1 play.

- In the examined group, the highest correlations with the effectiveness of 1x1 play were found sequentially for speed abilities, agility, jump height (lower limb power), and endurance.

Practical Implication

- To increase effectiveness in 1x1 play, attention should be given to the development of overall physical fitness, with a particular emphasis on speed abilities and agility.

- In the process of football training, young players should experience numerous situations in a 1x1 setup.

Author Contributions: Authors of this article made the following contributions: Conceptualization, M.K., H.D. and M.K.; methodology, M.K., H.D. and M.K.; software, M.K., H.D. and M.K.; validation, M.K., H.D. and M.K.; formal analysis, M.K., H.D. and M.K.; investigation, M.K., H.D. and M.K.; resources, M.K., H.D. and M.K.; data curation, M.K., H.D. and M.K.; writing — original draft preparation, M.K., H.D. and M.K.; writing — review and editing, M.K., H.D. and M.K.; visualization, M.K., H.D. and M.K.; th.D. and M.K.; h.D. and M.K.; h.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; visualization, M.K., H.D. and M.K.; h.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; visualization, M.K., H.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; visualization, M.K., H.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; billing — review and editing, M.K., H.D. and M.K.; billing — review and editing at the review and editing at the review and editing at the review at th

Funding: This research received no external funding.

Ethical Committee: The study was approved by the Ethics Committee at the regional medical chamber in Krakow number: 42/KBL/OIL/2015.

Informed Consent: Informed consent was obtained from all study participants.

Data Availability: The data presented in this study are available upon request from the corresponding author.

Conflict of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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The Praxeological Characterization of the Goalkeeper Model in Defensive-Offensive Actions as a Determinant of Rational Training

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Abstract

Background: Contemporary trends in football player training emphasize the necessity of developing versatility and creativity among players, especially in the context of consciously achieving game objectives on the field. Praxeological models of sports play, particularly those based on observing masters, are crucial for creating effective training programs. **Methods:** An analysis of Polish Ekstraklasa goalkeepers' play from 2012 to 2022 was conducted, based on indicators of field sector load and qualitative indicators of efficiency. An objective observation sheet was used to categorize goalkeepers' actions in defense and attack. **Results:** Goalkeepers performed an average of 10.93 ballhandling actions in defense and 26.93 actions in attack per match. The efficiency of defensive actions was highest in the attacking zone and lowest in the middle zone. In attack, the highest effectiveness was noted in the defensive zone, and the lowest in the attacking zone. **Conclusions:** Goalkeeper training should encompass both defensive and offensive actions. The effectiveness of executing ballhandling actions in championship matches requires systematic training and perfect mastery of techniques. Support from other players and coordination of team actions are crucial for improving the goalkeeper's efficiency in offensive play. Improving footwork skills is essential for goalkeepers, especially considering the increasing involvement of foot plays in their game.

Keywords: game analysis, effectiveness of working, efficiency of working, game topography

Introduction

Contemporary trends in football development highlight the need to shape versatile and highly creative players who consciously pursue game objectives on the field (1). There is an increasingly emphasized necessity for employing intellectualized teaching methods for individual and group actions in football training (1). Training based on the conscious participation of players equipped with adequate knowledge resources and requiring player's cognitive engagement translates into the effectiveness of their actions in the game (1).

A coach aiming to train a player capable of consciously, quickly, and effectively choosing the game's objective and the way to achieve it must also have an excellent understanding of the game's structure and the requirements it imposes on players. For this purpose, observations and analyses are conducted, enabling the creation of praxeological

Received: 03.12.2023 Reviewed: 07.01.2024 Published: 20.01.2024

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models of sports play. These models, especially those replicating the play of masters and ideal models projecting play, serve the understanding of the game (2). In the case of football, various methods for assessing players' technical-tactical actions are most commonly used, allowing the determination of the structure, type, frequency, and effectiveness of players' specialized actions. Conclusions drawn from the analysis of game content allow for the elimination of intuitive actions during player recruitment and further training processes, replacing them with purposeful, deliberate actions. Data obtained during research on the assessment of technical-tactical actions of players constitute a theoretical basis for setting goals and tasks in the training process (3).

Optimization and rationalization of training based on an understanding of the game content are necessary conditions for improving the efficiency of the training process (4,5). The coach's use of observations and assessments of players' actions is justified only when the observation meets scientific observation criteria (6). Data obtained through planned, objective, and deliberately selective observation can serve both for assessing the actual state and for inference based on specific statistical methods. In the case of observing football players' actions in the game, the obtained data should be used to develop modern and rational football training (7). Analyses of the game of players at the highest global or national level hold particular value in this regard, as they can serve as a sort of template in the process of training young footballers.

This study attempts to assess the effectiveness of ball-handling actions performed by a goalkeeper during a football match. Many authors (8–10) emphasize the distinct requirements that playing football places on a goalkeeper compared to other players. This uniqueness, stemming from the specific tasks performed by the goalkeeper in the game, necessitates a thorough understanding of the structure of the actions that this player performs during the match. To achieve the research objective, analyses of the game of leading Polish Ekstraklasa goalkeepers were conducted. The topographic characteristics of these players' game were determined using indicators of field sector load in football field and qualitative indicators illustrating the effectiveness of the goalkeeper's actions (2). These indicators included activity, efficiency, inefficiency, reliability, and performance indicators. These actions were observed in the evaluation of defensive and offensive actions – as an attempt to search for a model of football goalkeeper play. In the study, the following questions were posed:

1) How do the indicators of field sector load shape up in the case of ball-handling actions performed by top Polish Ekstraklasa goalkeepers in defense?

2) How do the indicators of field sector load shape up in the case of ball-handling actions performed by top Polish Ekstraklasa goalkeepers in attack?

3) How do the activity and reliability indicators shape up regarding ball-handling actions performed by top Polish Ekstraklasa goalkeepers, considering topographic differentiation?

4) What is the level of activity, efficiency, inefficiency, and reliability regarding various types of ball-handling actions performed by top Polish Ekstraklasa goalkeepers, considering topographic differentiation?

Material and Methods

In this study, the game of 5 top goalkeepers from leading Polish Ekstraklasa football teams (team ranking in the league 1-3) during the seasons from 2012 to 2022 was observed. In the analyzed 10 matches, each goalkeeper's performance was observed in a match where their team achieved a draw, thus assessing their performance against an evenly matched opponent in competition. The observation of the game was conducted using an objective observation sheet, where the number and effectiveness of ball-handling actions performed by the evaluated goalkeeper were recorded, both in attacking and defending situations. Each observed ball-handling action was also characterized topographically.

For defensive actions, four main types of ball-handling actions were distinguished: catches and interceptions, clearances, punching, and situational interventions. Each of these groups was further detailed with regard to the technique of execution, whether with or without falling, single-handed or double-handed.

Interceptions by the goalkeeper, where the goalkeeper caught a ball that was crossed or inaccurately passed into the penalty area by the opponent, were categorized as interceptions. The same criterion for assessing effectiveness as for catches was applied.

Actions where the goalkeeper punched the ball (with one or both hands - fist, palm, forearm) after a shot or a cross into the penalty area were referred to as clearances. Effective clearances were those that prevented a goal or removed immediate danger without conceding a goal, while ineffective clearances were those that either resulted in conceding a goal or did not remove the threat of conceding a goal.

Punching the ball, where the goalkeeper punched the ball with a clenched fist, either single-handedly or double-handedly, regardless of the circumstances (shot, cross, or pass), was considered a separate category. The same effectiveness criterion as for clear-ances was applied.

Situational interventions included:

- Situational shot save - an intervention that, due to the technique of execution, could not be classified as a clearance or punching (e.g., deflection of a shot with the foot, head, shoulder).

- 1x1/foot save situation - an intervention involving the clearance or sweep of the ball from under the feet of the attacking player, as well as deflecting a shot with any part of the body after leaving the goal towards the attacking player (as opposed to situational shot save).

- Rushing out and clearing the ball - leaving the penalty area by the goalkeeper and clearing the ball (with the foot, head, or any other part of the body except the hand) to interrupt the opponent's action (as opposed to passing the ball without control in attacking actions, where the aim is to continue the team's own action).

- Penalty save - regardless of the technique of execution.

- Reducing the shooting angle - forcing the attacking player to shoot inaccurately or make an inaccurate pass by dynamically coming out of the goal. Despite the goalkeeper not touching the ball, including this type of intervention in the ball-handling actions seems justified due to its direct impact on the opponent's play.

Effective situational interventions were those that prevented a goal or removed immediate danger of conceding a goal. Actions that did not meet these conditions were classified as ineffective. Any other ball-handling actions that could not be classified into any of the above categories were referred to as "Other", for example, catching a ball accidentally deflected by another player and not in anyone's possession. This category also included a lack of any reaction to a precise opponent's shot leading to conceding a goal, with such action automatically marked as ineffective. The goalkeeper's performance in attack was analyzed with a distinction between two main categories of ball-handling actions: hand passes and foot passes. Hand passes included all passes made by the goalkeeper using their hands, taking into account the applied technique - overhead, side, or low throw. Foot passes, on the other hand, included passing actions during play, passing after a catch, and set pieces, including goal kicks. A separate category of "Other ball-handling actions" consisted of actions that could not be classified into any of the above main categories. This term also included catching balls after a pass from a teammate. The criterion for assessing the effectiveness of ball-handling actions in attack was the accuracy of passes. Effective actions were those where the ball went directly to one of the goalkeeper's teammates or where the goalkeeper's teammate contested for the ball in the air, resulting in the ball reaching the same or another teammate of the evaluated goalkeeper. Actions where the ball went directly to the opponent or went out of play were marked as





ineffective. In the analysis of results, basic statistical calculations were applied: arithmetic mean and percentage estimates of obtained praxeological indicators (effectiveness, activity, and reliability) (6).

Results

Topographic and qualitative characteristics of observed goalkeepers' game.

From the analysis of the obtained data, it can be observed that the observed goalkeepers performed an average of 10.93 ball-handling actions in defense and 26.93 ballhandling actions in attack per match. In total, an average of 37.86 ball-handling actions per match were recorded, with defensive actions accounting for 28.87% and offensive actions for 71.14%.

The average efficiency of defensive actions was 0.86, with the highest values being recorded for the attacking zone (1.0) and the lowest for the middle zone (0.81), mainly due to significantly lower efficiency in the left sector of this zone (ML), which was 0.67. On the other hand, defensive actions performed after plays from the OL, MP, and SA sectors were characterized by flawless execution.

In the group of offensive actions, the average efficiency of actions was 0.91. The highest efficiency indices were noted in the defensive zone – averaging 0.99, and the lowest in the attacking zone – 0.57. Plays directed to the central sector of the defensive zone were characterized by maximum effectiveness, while the lowest effectiveness value concerned the left sector of the attacking zone, which was only 0.33. The figures below (Figure 1-2) present the average number of ball-handling actions performed by the goalkeeper in defensive and offensive actions, considering the sector of the field from which or to which the ball was played.



Defensive actions

Figure 1. Average number of defensive ball-handling actions performed per match, considering the topography of the game.





Offensive actions

Figure 2. Average number of offensive ball-handling actions performed per match, considering the topography of the game.

Topographic and qualitative characterization of the goalkeeper's game in defense.

Among the ball-handling actions performed by the observed goalkeepers during the match, four main categories were distinguished: catches and interceptions, clearances, punches, and situational interventions. Within the catches and interceptions category, catches after shots, interceptions after crosses, and interceptions after perpendicular opponent passes were further specified. Analysis of the data collected during observations revealed that in defensive actions, the majority of ball-handling actions were performed by the evaluated players after plays from the defensive zone, accounting for 64.1% of all defensive ball-handling actions. Nearly twice fewer actions were executed after plays from the middle zone (33.3%), while only 2.6% of all defensive ball-handling actions were attributed to the attacking zone. Within both the defensive and middle zones, the central sectors were the most burdened during defensive play, constituting 43.8% and 18.3% of all ball-handling actions in defense, respectively. The distribution of the workload across different field sectors in terms of defensive play by the observed goalkeepers, considering its effectiveness, is graphically presented in Figure 3.





Figure 3. Burden of field sectors in terms of ball-related defensive activities performed by top goal-keepers of the Polish Ekstraklasa.

Analyzing the goalkeeper's game topography in defense through the lens of individual types of ball-related activities, it was found that in all categories of activities, interventions following plays from the defensive zone had by far the largest share. The only exception was interceptions after perpendicular passes, where the share of plays originating from the midfield zone was the highest at 64.7% (Figure 4).



Defensive actions

Figure 4. Burden of field zones depending on the type of ball-related defensive activity: Ball catches after shots.

In the group of defensive activities classified as ball catches after shots, it was observed that these interventions occurred exclusively after plays from the central sectors of two zones: defense (87%) and middle (13%). No shots were taken from the side sectors that led to the evaluated goalkeeper making a ball catch. The ball catches made by the evaluated goalkeeper were characterized by one hundred percent reliability.



Ball interceptions after crosses

Among ball interceptions after crosses, the share of interventions after plays from the defensive zone was 72.4%, with the majority of interventions in this group occurring after crosses from the side sectors of this zone – left defensive (37.9%) and right defensive (31.0%). Among ball interceptions following crosses from the middle zone (27.6%), there was no dominance of plays from the side sectors over plays from the middle sector (left middle – 10.3%, middle – 10.3%, and right middle – 6.9%). Ball interceptions after crosses were characterized by a high level of reliability, equal to 0.97, with the only sector where the effectiveness was not one hundred percent being the right defensive sector. The reliability index for ball interceptions after crosses from this sector was 0.89.

Ball interceptions after perpendicular passes

The ball interceptions made by the observed goalkeepers after perpendicular passes from opponents were characterized by a greater involvement of the middle zone compared to the defensive zone. The share of interceptions after plays from the middle zone in all such actions was 64.7%. However, there was a clear disproportion within this zone. Interceptions after passes from the left and middle sectors (left middle and middle) accounted for 21.6% and 33.3% of all actions in this category, respectively, while the percentage of interceptions after plays from the right sector (right middle) was only 9.8%. The share of plays from the defensive zone, after which the goalkeeper intercepted the ball after a pass, was 29.4%, with all of these actions occurring in the middle sector of the defensive zone. Additionally, it was observed that the evaluated player also intercepted the ball after passes from the middle sector of the attacking zone (middle attacking – 5.9%). Ineffective interceptions after passes were only observed in the middle sector of the defensive zone, where the reliability index was 0.93.

Ball clearances

The observed goalkeepers performed ball clearances significantly more often after plays from the defensive zone (81.8%) and less frequently after plays from the middle zone (18.2%). Over half of all ball clearances were interventions after plays from the middle sector of the defensive zone (54.5%). Ball clearances from the left sector accounted for 18.2%, while those from the right, left middle, and middle sectors were 9.1% each. No ball clearance was observed after a play from the right middle sector. Ineffective clearances were only observed in the case of the middle sector of the defensive zone, where the reliability index was 0.50, and in the case of the left sector, where the reliability index was 0.00. However, it is important to note the relatively low activity rates in terms of ball clearances. The evaluated goalkeeper performed only one ball clearance after a play from the left middle sector, which turned out to be ineffective.

Fist clearances

During the study, it was observed that the evaluated goalkeepers performed fist clearances significantly more often after plays from the defensive zone (88.9%) than from the middle zone (11.1%). Within the defensive zone, no fist clearances were observed after plays from the left sector, while the percentage of fist clearances after plays from the middle and right sectors was equal, at 44.4%. Within the middle zone, fist clearances were only observed after plays from the left sector (11.1%). Ineffective fist clearances were only observed after plays from the middle sector of the defensive zone, where one in four clearances turned out to be ineffective (reliability index equal to 0.75).

Situational interventions

Situational interventions were the second group of actions, after interceptions of perpendicular passes, in which interventions after plays from all three zones of the field were observed. They were significantly more frequently executed after plays from the defensive zone (76.2%), less frequently from the middle zone (19.0%), and interventions after



plays from the attacking zone accounted for only 4.8% of all situational interventions. Conducting a more detailed topographic analysis, it was found that situational interventions occurred after plays from the middle sectors of all zones and the OP sector. The highest number of such actions was observed for the OS sector, accounting for 66.7% of all situational interventions. The reliability for the OS sector was 0.79, and for the SS sector, it was 0.75. In the remaining cases, situational interventions were executed effectively.

Figure 5 graphically presents the reliability index values for the main categories of ball actions performed by the observed goalkeeper in defense, depending on the sector of the field from which the play forcing him to make a certain intervention originated.



Figure 5. Average reliability index values for individual types of ball actions in defense, depending on the sector of the field.

Characterization of the topographic and qualitative aspects of the goalkeeper's play in attacking

Among the ball actions performed by the observed goalkeepers in attack, two main types of plays were distinguished: handball plays and kicks. The latter group was further divided into foot passes in action, kicks after previous catching, and execution of set pieces. Observations revealed that in offensive play, the average score of the evaluated goalkeepers directed slightly over half of the plays to the defensive zone (52.8%), followed by 39.3% of plays going to the midfield zone, with only 8% of plays directed to the attacking zone. In all zones, the central sectors of the observed goalkeeper were most burdened in terms of offensive actions (OD - 31.8%, MD - 17.8%, AD - 4.0%). The distribution of the field sectors in terms of offensive play by the observed goalkeeper is presented graphically in Figure 6.





Figure 6. Distribution of field sectors in terms of ball actions in attacking performed by the goal-keeper.

Analyzing the topography of the various types of ball actions observed in the game of the evaluated goalkeepers, it was observed that in the case of ball kicks and foot passes in action, the ball was more often directed towards the defense area (74.7% and 49.7% respectively) than towards the midfield area (25.3% and 42.4% respectively). On the other hand, in the case of foot kicks after catching the ball and when executing set pieces, including goal kicks, the ball was more frequently directed towards the midfield area (45.5% and 51.9% respectively) than towards the defense area (9.1% and 39.5% respectively). The burden on the attack zone was consistently lowest except for foot kicks after catching, when the percentage of plays directed to this zone was 45.5% and equal to the burden on the midfield zone.



Offensive actions

Figure 7. Distribution of field sectors based on the type of ball action during attacking plays.



Throws with the Hand

The evaluated goalkeepers made the most throws with the hand towards the central sector of the defense area (40.7%) and the right sector of the same area (28.6%). The majority of these throws were executed with a low trajectory. All throws made by the observed goalkeeper with the hand were completely reliable, regardless of the sector towards which the ball was directed.

Foot Passes in Action

Analyzing the topography of foot passes executed by the observed goalkeeper, there was no clear disproportion between passes directed towards the defense area (49.7%) and the central area (42.4%). However, distinguishing two subcategories within this group of actions – passes without ball reception and passes after ball reception – revealed some differences. In the case of passes without ball reception, the ball was more often directed towards the central area, while in the case of passes after ball reception, the player more often directed it towards the defense area. Also, in terms of reliability, there were differences between passes without ball reception (reliability at 0.56) and passes after ball reception (reliability at 0.82). Common for both types of foot passes in action was a higher burden on central sectors than on lateral ones in the respective areas.

Foot Passes after Ball Reception

Among the actions involving the ball in this category, the observed goalkeepers directed the ball equally often towards the central area and the attacking area (both at 45.5%). They only directed the ball towards the defense area after ball reception in 9.1% of cases. In the case of foot passes after ball reception, there was a visible decrease in reliability with an increase in the distance to which the player directed the ball. Reliability for the defense area was 1.0, for the central area 0.80, and for the attacking area – only 0.60.

Set Pieces

Set pieces included goal kicks (79% of all set pieces) and free kicks (21%). When executing goal kicks, the observed goalkeepers more often directed the ball towards the central area, then towards the defensive area, while plays towards the attacking area were rare (0.07 per match). The reliability of executing goal kicks was 0.96 for the defensive area and 0.50 for both the central and attacking areas. For free kicks, the observed goalkeepers most often directed the ball towards the defensive area (47% of free kicks), then towards the attacking area (29%), and least often towards the central area (24%). In the defensive area, a reliability of 1.00 was noted for free kicks, while in the central area it was 0.75, and in the attacking area it was only 0.40. The table below provides a detailed summary of reliability indicators describing the execution of various types of attacking actions performed by the observed goalkeepers, considering the sectors to which the ball was directed. The reliability indicators for the main types of offensive actions are graphically presented in Figure 8.







Figure 8. Average reliability indicators for various types of ball actions in attacking, depending on the sector.

Discussion

Due to various methodological approaches, comparative analysis of goalkeepers' play is very difficult. Peterson and Bruton (11) have shown that only a few indicators characterizing goalkeeping can be compared. The main barrier is the discrepancy in defining individual goalkeeper behaviors. Therefore, this study attempts to describe and characterize the effectiveness of goalkeepers' actions in the game, taking into account a consistent definition of these actions and a methodological interpretation. The effectiveness, activity, and reliability of these players were examined in terms of the goals set in both offensive and defensive play.

From the analysis of the conducted research, it follows that actions related to defense are significant in achieving sports goals, while actions related to attacking constitute the dominant part of a modern goalkeeper's activity with the ball, so they cannot be overlooked in specialized training. This thesis is consistent with the findings of Liu et al. (12) and Honza & Cepkova (13), who argue that in modern play, the goalkeeper has many more offensive tasks. According to these authors, the modern goalkeeper engages in offensive actions 3-4 times more often than in defensive play, and the results presented in our research are consistent with this statement. Therefore, in rational training, time should be devoted not only to typically defensive actions but also to offensive actions, as the effectiveness of these actions affects the overall sports performance of the team positively. It should be remembered that the goalkeeper, by initiating the game, is the first player to start the attack, so the success of the offensive action depends on effective and rational passing decisions. In this context, the results of our research confirm previous observations regarding the structure of goalkeepers' play, namely the dominance of positioning actions in attack and preventing goals in defense. However, to fully exploit the versatility of actions in the goalkeeper's play, all actions dominant in other players in the field should also be perfected. It has been proven (also from our research) that the goalkeeper, in initiating, building, and even finalizing actions in the game, must possess skills as high as any player in the team. These observations rationalize soccer training, as they define a close cooperation between the goalkeeper and the other players in the team in selecting training methods and jointly achieving the training goals of the soccer team.



Conclusions

- In specialized goalkeeper training, it is necessary to consider not only defensive actions but also offensive ones. Actions related to attacking constitute the dominant part of a modern goalkeeper's activity with the ball, so they cannot be omitted in specialized training.

- The selection of methods in specialized goalkeeper training for defensive actions should take into account both actions performed frequently in matches (catches, interceptions) and those performed sporadically (clearances, punches, some types of situational interventions).

- Actions performed frequently in the game must be included in training precisely because of their common occurrence. Achieving and maintaining high reliability in performing these types of actions in top-level matches is only possible through systematic inclusion in training.

- Including in goalkeeper training actions performed infrequently in matches is important due to the consequences of ineffective execution. In the case of clearances, for example, one ineffective execution often results in conceding a goal. Therefore, sporadically performed actions in matches should be mastered perfectly to minimize the risk of conceding a goal immediately after their erroneous execution.

- Specialized goalkeeper training for offensive actions should include both hand and foot plays, taking into account tactical objectives preferred by players of all formations during the game.

- The choice of how to restart or continue the game by the goalkeeper, both in terms of technique selection and direction of the pass, should align with the general principles used in offensive play by their team. Efforts should be made to eliminate unprepared and random goalkeeper plays leading to ball loss.

- Field players should be properly instructed and prepared to receive the ball in the appropriate sector of the field. Only cooperation and collaboration between the goal-keeper and other players can increase the reliability of their offensive actions. Therefore, it seems necessary for specialized goalkeeper training not only to be conducted in the form of isolated, individual training but also to overlap with team training.

- The significant involvement of foot plays in a goalkeeper's game requires this player to have well-mastered elements of general soccer technique, not just specialized goalkeeper skills. At the same time, it should be noted that early specialization of players in this position with poorly conducted training sometimes leads to neglecting the improvement of foot playing skills.

Author Contributions: Authors of this article made the following contributions: Conceptualization, M.K., H.D.,G.J. and A.S.; methodology, M.K., H.D.,G.J. and A.S.; software, M.K., H.D.,G.J. and A.S.; validation, M.K., H.D.,G.J. and A.S.; formal analysis, M.K., H.D.,G.J. and A.S.; investigation, M.K., H.D.,G.J. and A.S.; resources, M.K., H.D.,G.J. and A.S.; data curation, M.K., H.D.,G.J. and A.S.; writing—original draft preparation, M.K., H.D.,G.J. and A.S.; writing—review and editing, M.K., H.D.,G.J. and A.S.; visualization, M.K., H.D.,G.J. and A.S.; supervision, M.K., H.D.,G.J. and A.S.; project administration, M.K., H.D.,G.J. and A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Ethical Committee: The study was conducted periodically from 2015 to 2016. The study was approved by the Ethics Committee at the regional medical chamber in Krakow number: 42/KBL/OIL/2015.

Informed Consent: Informed consent was obtained from all study participants.

Data Availability: The data presented in this study are available upon request from the corresponding author.

Conflict of Interest: The authors declare no conflict of interest. The funders had no role in the design



of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Original Research Articles

Investigation of Chronotypes Of Individuals Engaging In Exercise in Terms of Certain Variables

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Abstract

Background: While it is evident from the literature that inter-individual differences in chronotypes have a significant impact on various variables, it is crucial to continue these studies to gain a better understanding of chronotype mechanisms. In this context, the aim of our research was to examine the relationship between the chronotypes of individuals engaged in exercise and factors such as the timing of their exercises, exercise frequency, and daily sleep duration. Methods: This research was designed using quantitative research methods, employing a survey model. The sample size for this study was determined using G*Power 3.1.9.7 (University of Düsseldorf, Düsseldorf, Germany) software. The population of this study consisted of 800 individuals, with a sample size of 182 individuals. Data collection tools in the study included a demographic information form and the "Turkish form of MESSi" scale, which was developed by Randler et al. (2016) and adapted into Turkish by Demirhan et al. (2019) for assessing morningness-eveningness stability. The data obtained from the research were analyzed using IBM Statistics (SPSS version 25.0, Armonk, NY) software. Results: Findings from the study indicated that when examining the mean scores participants obtained from the Turkish form of MESSi, there was a statistically significant difference only in the Evening subscale in terms of the timing of exercise. However, no statistically significant differences were found regarding exercise frequency and daily sleep duration. Conclusions: As a result of this research, it was concluded that there is a relationship between exercise time and chronotype, and that individuals with Evening chronotype prefer to exercise between 12:00-18:00 in the afternoon and 18:00-24:00 in the evening. Therefore, it can be said that our chronotype is an important factor affecting our choice of time to exercise. It is recommended that future researchers conduct research on this subject with larger sample groups.

Keywords: Exercise Timing, Exercise Duration, Daily Sleep Duration, Chronotype, Circadian Rhythm

Introduction

The chronotype, which is characterized as an individual's predisposition towards either morning or evening (1), is a highly complex phenomenon influenced by various factors such as biological factors like body temperature, cortisol, and melatonin levels; technological and social factors like media device usage, lighting, and daily life activities; and environmental factors like climate, latitude, and longitude(2–5).

Chronotypes are generally classified into three different types: morning types (M-types), evening types (E-types), and neither types (N-types) (1,2,6). In this classification, M-type individuals prefer to be active in the early hours of the day, while E-type

Received: 25.12.2023 Reviewed: 16.01.2024 Published: 09.02.2024

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individuals prefer to be active in the later hours of the day. N-type individuals, on the other hand, do not exhibit any preference for morning or evening activities (7).

Investigations into studies on chronotypes have revealed that individuals with the same chronotype tend to share certain common characteristics. In this context, M-type individuals have been found to be more attentive (8–10) and inclined toward healthier behaviours (11). On the other hand, E-type individuals are prone to behavioural issues (such as depression, loneliness), personality disorders (substance use, eating disorders, internet addiction, daytime sleepiness), and lower academic performance (12–14).

When reviewing the literature regarding sports performance, it has been observed that individuals with M-type chronotypes perceive less effort during strenuous morning sports activities, whereas M-type and N-type individuals report perceiving higher effort and exhibiting higher levels of fatigue during demanding morning sports activities (15–17). Similarly, it has been reported that E-type individuals produce more torque in the afternoon or evening compared to the morning (15). In other studies, it has been reported that M-type individuals achieved higher performance levels in half-marathon and full-marathon races (16), 2000-meter rowing (17), and 200-meter swimming trials (18) compared to N and E chronotypes.

The literature summary presented above clearly indicates that inter-individual differences in chronotypes are influenced by numerous factors. However, it is essential to continue these studies to gain a better understanding of chronotype mechanisms. In this context, the aim of our research is to examine the relationship between the chronotypes of individuals who engage in sports and factors such as the timing of their exercises, exercise frequency, and daily sleep duration.

Material and Methods

Research Design

This study utilized a survey model, which is a research design aimed at understanding and presenting an existing situation or a past event in its natural state. The research was conducted with the participation of voluntary individuals after obtaining ethical approval from the Ethics Committee of İnönü University Faculty of Health Sciences Malatya, Türkiye.

Population and Sample

The population of this research consists of 800 individuals who participate in training sessions at the Kaptan-Fit sports club in Malatya, Türkiye. To determine the sample size for the study, the ANOVA: fixed effects omnibus one-way test was employed using G*Power 3.1.9.7 software (University of Düsseldorf, Düsseldorf, Germany). In this context, with α error level set at 0.05, effect size at 0.25, and 1- β error probability at 0.80, it was determined that the sample size should be a minimum of 159 individuals to achieve an 80% confidence level. In this context, 182 individuals participated in the research. Demographic information for the sample group is presented in Table 1.

Table 1. Demographic characteristics of the sample group

	Variables	f	%
	Male	110	60.4
Gender	Female	72	39.6
	Total	182	100.0
Frequency of exercise	At least 1-2 days	79	43.4
	At least 3-4 days	68	37.4
	At least 5-6 days	26	14.3



	Everyday	9	4.9
	Total	182	100.0
	Morning 06-12 am	46	25.3
Timin a of anomaios	Afternoon 12-18 pm	96	52.7
Timing of exercise	Evening 18-24 pm	40	22.0
	Total	182	100.0
	6 hours or less than 6 hours	50	27.5
	7 hours	57	31.3
Daily sleep duration	8 hours	43	23.6
· · ·	9 hours or more than 9 hours	32	17.6
	Total	182	100.0

Table 1 shows the demographic information of the participants as frequency (f) and percentage (%).

Data Collection Tools

In this research, data were collected using a form that gathered participants' demographic information and the "Turkish form of MESSi" scale, which was developed by Randler et al. (2016) (19) and adapted into Turkish by Demirhan et al. (2019) (20). The scale is called the "Morningness–Eveningness Stability Scale." The Turkish form of MESSi scale consists of three subscales: morning affect (MA), eveningness (EV), and distinctness (DI).

Statistical Analysis

The data were analysed using IBM Statistics (SPSS version 25.0, Armonk, NY) software package. After testing the normality of the data with the Shapiro-Wilk's test and checking homogeneity with Levene's test, it was determined that the data did not follow a normal distribution. Therefore, for pairwise comparisons, the Mann-Whitney U and chisquare tests were used, and for comparisons involving more than two groups, the Kruskal-Wallis H test was employed. The statistical significance level was set at p<0.05. To determine which variables contributed to the observed differences, the Tamhane's T2 post-hoc test was used.

Results

According to Table 2, when examining the mean ranks obtained from the Turkish form of MESSi for participants, a statistically significant difference was observed in the EV subscale. However, there was no statistically significant difference in the MA, DI subscales, or the total scale score.

Table 2. Kruskal-Wallis H Test Results for the Relationship Between Participants' Exercise Timing and Turkish form of MESSi Subscales

Subscales	Timing of exercise	n	M.R.	χ^2	р	D
NTA	1) Morning 06-12 am	46	102.20	_		
MA	2) Afternoon 12-18 pm	96	93.02	5.700	.058	
	3) Evening 18-24 pm	40	75.56	_		
	1) Morning 06-12 am	46	68.91	_	.001*	0.1
EV	2) Afternoon 12-18 pm	96	94.71	13.711		2>1 2>1
	3) Evening 18-24 pm	40	109.76	-		3>1
DI	1) Morning 06-12 am	46	87.42			
	2) Afternoon 12-18 pm	96	92.59	.381	.826	
	3) Evening 18-24 pm	40	93.58	_		



Total scale - score -	1) Morning 06-12 am	46	83.50	_	
	2) Afternoon 12-18 pm	96	93.86	1.438	.487
	3) Evening 18-24 pm	40	95.03	_	

*p<.05; M.R: Mean Rank; χ2: Chi-Square; D: differences

According to Table 3, when examining the mean ranks obtained from the Turkish form of MESSi for participants, there was no statistically significant difference in the EV, MA, DI subscales, or the total scale score.

Table 3. Kruskal-Wallis H Test Results for the Relationship Between Participants' Exercise Frequency and Turkish form of MESSi Subscales

Subscales	Frequency of exercise	n	M.R.	χ^2	р
	1) At least 1-2 days	79	83.08		
MA	2) At least 3-4 days	68	94.57	- 4 602	202
	3) At least 5-6 days	26	106.60	4.602	.203
	4) Every day	9	98.61		
	1) At least 1-2 days	79	89.57		
EV	2) At least 3-4 days	68	96.78	1.532	.675
EV	3) At least 5-6 days	26	88.44		
	4) Every day	9	77.39		
	1) At least 1-2 days	79	86.05		
DI	2) At least 3-4 days	68	96.83	- 1.026	586
	3) At least 5-6 days	26	96.46	1.930	.380
	4) Every day	9	84.72		
	1) At least 1-2 days	79	84.59		
Total scale	2) At least 3-4 days	68	97.67	2 504	220
score	3) At least 5-6 days	26	100.44	- 5.504	.320
	4) Every day	9	79.67		

*p<.05; M.R: Mean Rank; χ2: Chi-Square

According to Table 4, when examining the mean ranks obtained from the Turkish form of MESSi for participants, there was no statistically significant difference in the EV, MA, DI subscales, or the total scale score in relation to participants' daily sleep duration.

Table 4. Kruskal-Wallis H Test Results for the Relationship Between Participants' Daily Sleep Duration and Turkish form of MESSi Subscales

Subscales	Daily Sleep Duration	n	M.R.	χ^2	р
	1) At least 6 hours	50	94.35	_	
MA	2) At least 7 hours	57	86.12	1 71 /	624
	3) At least 8 hours	43	98.45	1./14	.034
	4) At least 9 hours or more	32	87.28	_	
	1) At least 6 hours	50	77.38	_	
EV	2) At least 7 hours	57	98.35	5.474	.140
ΕV	3) At least 8 hours	43	92.37		
	4) At least 9 hours or more	32	100.19	-	
DI	1) At least 6 hours	50	89.85	010	075
	2) At least 7 hours	57	90.13	.213	.975



	3) At least 8 hours	43	93.53		
	4) At least 9 hours or more	32	93.78	=	
Total scale score	1) At least 6 hours	50	83.06	- 1.991	.574
	2) At least 7 hours	57	93.25		
	3) At least 8 hours	43	97.76		
	4) At least 9 hours or more	32	93.17	-	

*p<.05; M.R: Mean Rank; χ2: Chi-Square

Discussion

The findings of this research, which examined the relationship between the chronotypes of individuals and factors such as the preferred time for exercise, exercise frequency, and daily sleep duration among individuals who exercise, have indicated that an individual's chronotype is a significant factor influencing the preferred time for exercise. In this context, individuals with an Evening chronotype were found to prefer exercising between afternoon (12:00-18:00) and evening (18:00-24:00). However, no statistically significant relationship was detected between chronotype and exercise frequency or daily sleep duration (p<.05).

The chronotype, which reflects individuals' tendency to be more alert and active during the morning (morningness) or evening (eveningness) hours, is influenced by both genetic and environmental factors. It plays a crucial role in determining an individual's energy levels and productivity throughout the day (2,7,20). Additionally, physiological processes with approximately 24-hour cycles, such as blood pressure, body temperature, hormonal secretion, and energy metabolism of nutrients, can have significant effects on athletic performance (21). These factors may influence the exercise timing preferences of individuals with different chronotypes.

Most of the studies in the literature related to our research have reported that both professional and amateur athletes exhibit maximum athletic performance around the late afternoon, approximately between 16:30 and 19:00 (22–26). This increase in athletic performance is considered a result of synchronization between physiological, psychological, and metabolic rhythms (27,28). In this context, the optimal time of day for any physical exercise according to circadian rhythms is around 16:30-19:00 (29). The findings of our research also indicate that individuals with an evening chronotype prefer to exercise in the late afternoon or evening. In this regard, it is believed that the exercise preferences of individuals with evening chronotypes are influenced by physiological, psychological, and metabolic factors.

While differences in psychophysiological responses to physical activity can be partially explained by some variables being objective and others subjective (30), the mechanisms behind chronotype are not yet fully understood. Therefore, it is important for studies like these to continue in order to gain a better understanding of chronotype mechanisms.

Conclusion

In conclusion, it is a fact that our chronotype is an important factor influencing our preference for the timing of exercise. It is believed that adjusting the timing of exercise according to individuals' chronotypes has a significant impact on maximizing the benefits of exercise. In addition, determining the chronotypes of especially professional athletes and planning training programs accordingly is considered to be a significant factor in improving sports performance. Therefore, it is recommended for coaches to take into account the chronotypes of athletes when making their plans. For future researchers in this area, it is recommended to conduct research with larger sample groups.



Author Contributions: Conceptualization, I.I.; methodology, I.I. and B.G.; software, I.I.; validation, I.I., S.S. and B.J.; formal analysis, I.I. and S.S.; investigation, I.I.; resources, I.I.; data curation, I.I. and B.G.; writing—original draft preparation, I.I. and S.S.; writing—review and editing, I.I., B.G. and B.J.; visualization, I.I.; supervision, I.I., B.J. and S.S; project administration, B.G and I.I.; funding acquisition, I.I. All authors have read and agreed to the published version of the manuscript. **Funding:** This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of İnönü University Faculty of Health Sciences Malatya, Türkiye (approval No. 2023/4972).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data are included in the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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