

Central European Journal of Sport Sciences and Medicine

a quarterly journal



University of Szczecin
Faculty of Health
and Physical Education

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IMPROVISING CARDIOVASCULAR AND NEUROMUSCULAR FUNCTION AMONG OLDER ADULTS WITH NON-COMMUNICABLE DISEASES — A STUDY PROTOCOL FOR SPORTS DRIVEN INTERVENTIONAL APPROACH

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Abstract Background: The World Health Organization has declared physical inactivity as the fourth leading cause of death and a major risk factor for non-communicable diseases. Studies suggest that the higher prevalence of non-communicable diseases adds to extreme health and financial burden to the United Arab Emirates and the promotion of physical activities could help combat this situation. Sports play a significant role in the promotion of physical activity. Among all sports, badminton targets the cardiovascular, musculoskeletal, and neurological systems significantly

Methodology: An Experimental, double-blinded, non-randomized controlled trial would be conducted at the Body and Soul Sports Complex, Gulf Medical University, UAE. A total of 120 older adults (40 to 70 years) would be divided into three groups of 40 each, viz., with non-communicable disease (WCN), without non-communicable disease (WICN), and a healthy control group (HCG). Physical activity intervention consists of two months (8 weeks), 3 days a week of Badminton sessions to WCN and WICN groups for major cardiovascular and neuromuscular parameters.

Discussion: The study is aimed to design a sports-driven interventional approach to determine the effects on cardiovascular and neuromuscular functions of older adults in UAE. The immediate impact can be seen in drawing the attention of the authorities and changes in the status of non-communicable diseases among the UAE population with the introduction of such programs on a larger scale. The impact could also be seen with the development of necessary infrastructure and instrumentation in other parts of the world encouraging older adults to actively participate in physical activity.

Trial Registration: The study has been registered under the Clinical Trial Registry (REF/2022/02/051455), February 8th, 2022, <http://ctri.nic.in>

Key words: cardiovascular, neuromuscular, older adults, UAE, sports, badminton

Background

The success of well-being has been attributed to the higher level of Physical activities in our day-to-day routine activities. The true meaning of fitness for humankind has a wider spectrum. It can be correlated with being free from various disorders, including cardiovascular, musculoskeletal, neurological, and psychosocial conditions, and thus leads to an enhanced quality of life, which can be significantly achieved by incorporating adequate physical activities. The World Health Organization has declared physical inactivity as the fourth leading cause of death and a major risk factor for non-communicable diseases. Studies suggest that the higher prevalence of non-communicable diseases adds to extreme health and financial burden to the United Arab Emirates, and the promotion of physical activities could help combat this situation (Al-Kaabi et al., 2009). Physical activity not only can reverse the course of non-communicable diseases but also prevent the progression of the disease. Research from a variety of scientific fields suggests that physical activity in nature and feelings of connection to nature enhance psychological health and well-being (Lawton et al., 2017). Outdoor physical activity has higher benefits in lowering the levels of stress, anxiety, depression, and parameters related to non-communicable diseases. In the current era, physical activity has been considered as medicine for non-communicable diseases (Saqib et al., 2020). It is well known that the presence of non-communicable disease has a higher correlation with morbidity in Arab countries (Rahim et al., 2014) related to cardiovascular disorders, and aerobic training directly reflects the cardiovascular fitness of an individual (Schroeder et al., 2019). Given that adherence to physical activities is poor among older adults in the form of general aerobic training, engaging them in outdoor sports activities could be more useful to enhance cardiovascular functions, thereby dampening the course of the non-communicable disorders as well as preventing future complications. In addition, older adults are the most susceptible age group for developing neuromuscular and psychosocial disorders due to a lack of physical activity (Wilkinson et al., 2018). Loss of muscle strength, muscle tightness, reduced agility, poor balance and coordination, hand-eye coordination, etc., are very commonly seen as a factor of reduced physical activity among older adults in addition to aging effects (Hunter et al., 2016). Literature also suggests that the ill effects of aging can be controlled with physical activity promotion (Bernardelli et al., 2019).

Sports play a significant role in the promotion of physical activity. Badminton holds a significant position in popularity among outdoor sports. Among all sports, badminton targets the cardiovascular, musculoskeletal, and neurological systems significantly (Indora et al., 2022). The game requires the constant engagement of the individual, which also improves their psychological and mental abilities and makes them more social. The non-contact nature of the sport makes it safer and suitable for any age group. The gender-friendly nature of sports, which is also widely accepted by various age groups, allows using it as a priority sport to enhance physical activity in research. Research has suggested that Badminton puts significant demands on the cardiovascular and neuromuscular systems. The cardiovascular fitness parameter can be assessed by analyzing the VO₂ max capacity, considered the primary indicator for cardiovascular fitness. Thus, the purpose of the study is to analyze the effects of a physical activity interventional protocol using Badminton sports on Cardiovascular and neuromuscular functions among older adults (with and without non-communicable disease) in the United Arab Emirates (UAE). The proposed research is focused on improving the physical activity and well-being of older adults in the UAE and thereby reducing the burden of non-communicable diseases in the country. The findings could be used for standardized protocols and guidelines for Physical Activity using Badminton sports in other age groups, based on the scope of future studies.

Methodology

Study design and setting: An Experimental, non-randomized controlled trial would be conducted at the Body and Soul Sports Complex, Gulf Medical University, UAE.

Inclusion criteria

1. Age group – older adults within the age group 40 years – 70 years would be recruited for the study. The definition for older adults in this study has been given as per the operational definition. Since participants with non-communicable diseases would be recruited, a lower age group of 40 years has been considered, whereas to avoid aging effects and reduce the risk of injury upper age limit of 70 years would be set.
2. Both genders – we would focus on increasing female participants, as the data among older female adults is scarce.
3. Participants without a history of non-communicable disease and with non-communicable disease (diabetes mellitus, hypertension, and obesity only) would be taken. The healthy control group would be selected from participants without non-communicable diseases using a convenience sampling method.

Exclusion criteria: Any joint disorders, cancer, neurologically unstable, chronic alcohol, active pregnancy, and prior physically active participants would be excluded.

Sample population and size: A total of 120 participants would be equally divided into three groups viz. (1) with non-communicable diseases (WCN, $n = 40$) and (2) without non-communicable diseases (WICN, $n = 40$), and healthy control (HCG, $n = 40$). The sample size was calculated using the formula for comparison of means with a power of 80% power for a two-sided test with a level of significance of 0.05 and an effect size of 0.5 (Nugroho et al. 2021). The total calculated sample size was 98. Considering a 20% dropout, the final sample size for the study would be 120, with 40 in each group. Initial screening of participants would be done to consider them in either group, i.e., with non-communicable (based on recent medical history and investigation for diabetes, blood pressure, and BMI not more than six months) or without non-communicable, and healthy control (age, gender-matched). Without non-communicable and healthy control would be double-blinded and randomly selected for badminton sessions using a simple randomization technique. Those not selected under the WICN group would be considered under the healthy control group. The recruitment and allocation would be done by a registered physical therapist who would be supervising the session.

Study procedure: Both the groups (with non-communicable disease and without non-communicable disease) would engage in badminton sports as per the specific inclusion and exclusion criteria. Confidentiality of the participant's information would be maintained without revealing the identity of any individual for data analysis. Following this, participants would be recruited under purposive sampling from all seven emirates of the United Arab Emirates. WCN and WICN groups would be allowed to play Badminton on the University's indoor court for 45–60 minutes per day. The protocol would be followed for 3 days a week at mild to moderate intensity under a supervised coach and physiotherapist for 2-month duration (8 weeks) (Yuksel et al., 2015). The baseline physical activity and exertional level would be monitored for each participant using the IPAQ and Borg's scale, respectively. The comparative changes in the cardiovascular and neuromuscular parameters shall be done at the baseline value and post 2 months. Baseline comparison would be done with a controlled group of healthy participants.

Participant preparation: All participants would be instructed to follow suitable sports clothing for each badminton session. Non-marking shoes would be provided to each participant in line with the instructions for use

of the indoor badminton sports court. A participant information sheet would be given to all participants to understand the procedure and details of the required protocol for the session. Information regarding the precautionary measures and contact for help would also be provided to all participants, considering the risk of general injury to all and exercise-induced hypoglycemia among participants with non-communicable diseases. The testing procedure would be conducted free to all participants, and informative feedback and consultation would be given to each participant regarding their physical health and activity level. This could help to enhance adherence and commitment to the research. The participants in the WCN and WICN would be restricted to using only Badminton as their physical activity and not allowed to play any other outdoor games during the trial period to avoid biases in the result. Any adverse events during the trial would be immediately reported. The study setting has associated tertiary care hospitals to manage any such events. The present study protocol has been reported using the SPIRIT guidelines (Chan et al., 2013), and the schedule of the recruitment, allocation, and intervention is shown in the schematic diagram below (Figure 1).

	STUDY PERIOD							
	Enrolment	Allocation	Post-allocation (11th–15th month)					Close-out (15th–20th month)
TIMEPOINT	0–6 months	6th–10th month	11 th	12 th	13 th	14 th	15 th	
ENROLMENT:								
Institutional Review Board Approval	X							
Eligibility screen								
Informed consent	X							
	X							
Allocation		X						
INTERVENTIONS:			X	X	X	X	X	
Intervention to WCN group								
Intervention to WICN group								
[Healthy Control group]								
ASSESSMENTS:								
Demographics and Pre Intervention-variables -	X	X						
Post Intervention Variables]								X

Figure 1. Schematic presentation for participants enrolment, intervention, and assessment.

Outcome Variables: The primary outcome variables of the study would consist of Cardiovascular and Neuromuscular parameters as listed below:

Cardiovascular Parameters:

- estimated Vo2 max
- 6 minutes walk distance

Neuromuscular Parameters:

- Lower and Upper limb muscle strength
- Lower limb muscle length
- Agility
- Lower Limb Joint Power- hip, knee, and ankle
- Muscle peak force for Quadriceps and Hamstring
- Proprioception
- Balance and Coordination
- Reaction time
- Hand eye-coordination

Statistical Analysis

The descriptive analysis would be done for demographic data in all groups, followed by the test for normality. If the data is normally distributed, a parametric test, i.e., paired and unpaired test, would be used for the statistical comparison within and between groups using the SPSS package V21. If the data is not normally distributed equivalent nonparametric test would be conducted. The post hoc test would be conducted to find larger differences between the specific groups. The effect size would also be calculated using Cohen's d for a better understanding of the results in clinical practice. The data analyst would be blinded to the allocation of the specific group. The data would be stored in a hard drive at the university's research database. Any missing data would not be included for data analysis and needs to be excluded from the results.

Data Acquisition

The outcome variables suggested above would be acquired for all three groups as explained below:

The lower limb joint power will be calculated using the inverse dynamics at the BTS force plate during the gait analysis with 8 video cameras (BTS SMART-DX system) (Riley et al., 2001). Retroreflective markers will be placed on the joint centers using the Halen-Hayes MM model. All the participants will be asked to walk at their normal speed from a set start line. Three successful trials will be taken, and the peak power at the hip, knee, and ankle will be taken for data analysis.

The peak muscle force for the Quadriceps and Hamstring will be calculated through the isokinetic device (Isomove, TecnoBody, Italy) with a flexion angle set at 90 degrees and extension at 0 degrees (Torque 60 deg. Sec⁻¹) (Kannus, 1994). Participants would be instructed to generate their maximum force of push for the Quadriceps and pull for the Hamstring. Three complete cycles will be taken, and the peak muscle force will be used for data analysis.

The proprioception and balance will be calculated using the ProKin device (PK 254, TecnoBody, Italy) while standing on the embedded vowel board (Felicetti et al., 2003). The participants will be asked to stand barefoot with eyes closed and with eyes open for stability assessment on both right and left lower limbs. The stability will be assessed in the Anteroposterior (A-P) and Medio-Lateral (M-L) directions. Proprioception will be assessed for individual limbs while creating a 360-degree arc using the different compartments of the foot, stable over the platform.

The reaction time and hand-eye coordination will be calculated using the D Wall system (TecnoBody, Italy), where the specific task will be given to all participants (Buote et al., 2022).

The assessment for the six-minute walk test will be done using the standard guidelines given by the American Thoracic Society over a 15 m walkway (Larsson & Reynisdottir, 2008). Agility would be tested with the Modified T Test (Sassi et al., 2009). Muscle length for the quadriceps, hamstrings, gastro-soleus, and shoulder range of motion would be assessed using physical therapy clinical examination. Muscle strength for upper and lower limbs would be conducted using the Oxford Manual Muscle strength grading method (Ferreira et al., 2011). Participants would be encouraged to adhere to the intervention and allowed to skip the session for a maximum of 2 consecutive times (one week) for any unforeseen reasons, after which they would not be included in data analysis. The participant who wishes to discontinue the project for any reason would be allowed at any stage, and an alternative participant would be recruited.

Discussion

The study intends to explore the unrevealed areas for cardiovascular and neuromuscular improvement using Badminton sports in the older adult age group in the UAE. To the best of our knowledge, no such previous studies have been conducted in the given geographic region. The aerobic nature of the Badminton sport can specifically target cardiovascular endurance and help in weight management for obesity. The most common neuromuscular parameters that are expected to show change include agility, speed, power, muscle strength, muscle length, muscle recruitment pattern, and peak force (Cinhuja et al., 2015). In addition, it could also enhance neural functions such as body balance, coordination, response time, reaction time (hand-eye coordination), and proprioceptive feedback (Hülsdünker et al., 2019). The combination of such improvements ultimately has a positive impact on the quality of life overall (Chan et al., 2020).

The comparative analysis within and between groups would be done at the baseline value and findings after 2 months of badminton sessions. The important neuromuscular parameters and cardiovascular parameters are expected to show a significant difference for both WCN and WICN groups in comparison to the HCG group. As the physical activity among the participants engaged in badminton sessions would have increased, the physiological adaptation to increased demand could be expected with better cardiovascular endurance and enhanced neuromotor skills. The six-minute walk distance and estimated VO₂ max are expected to increase significantly with enhanced oxygen capacity and the ability to sustain for longer during the exercise intervention. Improvement in cardiovascular endurance could help to reduce the ill effects of non-communicable diseases in older adults. Increased physical activity through Badminton sessions would have a positive impact on the blood sugar level with efficient glucose utilization. Simultaneous activation of upper and lower limb muscles could help to enhance blood flow in the body and thus could have a positive impact on the blood pressure profile among the WCN group of participants. Also, as per the nature of the game, participants would be expected to move swiftly and quickly on the badminton court, which would have a positive impact on the agility of all participants involved in the badminton session. In addition, balance and coordination are expected to improve during the session as participants would be expected to demonstrate better muscle synergies and strategies with the badminton sessions. Nevertheless, muscle strength and muscle length are also expected to improve with increased activation of muscles during the badminton session. Understandably, adherence to physical activity is poor among older adults with general aerobic training methods; thus, engaging in sports and leisure activities could be a better alternative. This would not only map the benefits of the physical activity program on their non-communicable disease status but also make them more socially active. The engagement of female participants would be more encouraging. The comparative analysis would be done

between the WNC group, WNC group, and HCG groups, and we expect significant improvement in both WCN and WINC communicable groups compared to the HCG group.

Conclusion

Since physical activity has been proven to be beneficial to control non-communicable diseases, we expect a maximum change in the WCN group. The findings of the study would be disseminated to research and healthcare via publication in reputed journals. As per the dissemination policy, authorship of results findings would vest with the funder.

List of Abbreviations:

WCN- with non-communicable disease
 WICN- without non-communicable disease
 HCG- healthy control group
 UAE- United Arab Emirates

Ethics approval and consent to participate: All methods for this protocol would be carried out under the Declaration of Helsinki guidelines and regulations. Ethical approval for the given project has been obtained from the Institutional Review Board, Gulf Medical University (Ref. no. IRB/COHS/FAC/67/Sept-2021). Informed consent would be obtained from each participant before the data collection procedure.

Availability of data and material: Individual data and supplementary files can be made available upon request to the corresponding author after the publication of complete research findings through email -dr.animesh@gmu.ac.ae

Funding: The project has been partially funded by Badminton World Federation, Malaysia. Funding is limited to data collection procedures, badminton court booking, and the daily expenses of the researcher. Additional support would be provided by Gulf Medical University.

Acknowledgment: We acknowledge the support provided by the Body and Soul Sports Complex, Gulf Medical University, for rendering its services towards this project.

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Cite this article as: Hazari, A., Kandakurti, P. K., & Jalgoum, S. (2025). Improving Cardiovascular and Neuromuscular Function among Older Adults with Non-communicable Diseases – A Study Protocol for Sports Driven Interventional Approach. *Central European Journal of Sport Sciences and Medicine*, 4(52), 5–12. <https://doi.org/10.18276/cej.2025.4-01>



Ministry of Science and Higher Education
Republic of Poland

The publication was co-funded from the state budget under the Ministry of Science and Higher Education's program entitled "Science for Society II", project no. NdS-II/SP/0523/2023/01, funding amount: 1 000 000 PLN, total project value: 1 000 000 PLN (Poland).

EFFECTS OF "NEW YEAR — HEALTHY YEAR" ONLINE TRAINING PROGRAM ON PHYSICAL ACTIVITY LEVELS OF WOMEN EMPLOYED IN OFFICE-BASED OCCUPATIONS

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Abstract The "New Year – Healthy Year" program is a multi-stage initiative supporting physical activity implemented in the form of an online training platform and addressed to women employed in office-based occupations. The aim of the study was to evaluate the impact of the first, three-month stage of the program on participants' physical activity levels. The analysis was based on the results of the International Physical Activity Questionnaire (IPAQ), completed before and after the intervention stage. A statistically significant decrease was observed in the number of days of moderate physical activity during leisure time ($Z = 2.80$; $p = 0.01$), along with an increase in the number of hours spent sitting on both weekdays ($Z = 2.31$; $p = 0.02$) and weekends ($Z = 2.67$; $p = 0.01$). No significant changes were found in the average duration of moderate activity on active days ($Z = 1.78$; $p = 0.07$). The obtained findings suggest that the mere availability of an online program in its initial phase was insufficient to increase the frequency of engaging in physical activity, highlighting the need for additional strategies to sustain commitment. Such strategies may include reminders, personalized training plans, and modifications to work and daily living environments that facilitate a reduction in sedentary time. Furthermore, the first stage of the program may be too short to induce lasting behavioural changes, thereby justifying continued monitoring of participants in subsequent stages, as well as supportive consultations after three and six months of program duration.

Key words: physical activity, IPAQ, pro-health intervention, sedentary behavior, public health

Introduction

The contemporary lifestyle, dominated by sedentary work, stress, and limited physical activity, poses a significant public health challenge, particularly among professionally active women.

Women employed in office-based positions belong to the groups particularly vulnerable to the adverse effects of hypokinesia. Empirical evidence reveals that office workers spend typically 6–8 hours a day in a seated position, which accounts for more than 80% of their time at work and significantly reduces the activation of the musculoskeletal, circulatory, and respiratory systems (Parry & Straker, 2013; Booth et al., 2012).

Lifestyle factors, including physical activity, constitute key determinants of adult health (Friedenreich et al., 2021; Rhodes et al., 2021). Numerous studies confirm the association between regular physical activity and improved bodily functions, as well as reduced risk of chronic diseases (WHO, 2020; Strain et al., 2020; Biswas et al., 2015).

The World Health Organization recommends a minimum of 150 minutes of moderate-intensity activity per week, which can markedly reduce the risk of premature mortality, type 2 diabetes, hypertension, cancers, and mental disorders (WHO, 2020; Umpierre et al., 2011; Penedo & Dahn, 2005). Findings from a systematic review by Ekelund et al. (2016) further indicate that even 60–75 minutes of daily activity may offset the negative effects of sedentary lifestyle.

Regular physical activity also exerts beneficial psychophysiological effects, including improvements in sleep quality, mood, and reductions in depressive symptoms (Brand et al., 2010; Kandola et al., 2019; Kredlow et al., 2015). Nevertheless, many working women do not meet WHO recommendations for physical activity levels (Strain et al., 2020).

Consequently, increasing attention has been directed toward modern health-supporting tools such as mobile applications, online platforms, and virtual training programs, which offer personalization, flexibility, and greater accessibility for women with limited time and access to traditional forms of support, such as gyms, group classes, or consultations with trainers and physiotherapists in healthcare facilities (Coughlin et al., 2015; Feter et al., 2019; Carraça et al., 2021). Jurado-Fasoli et al. (2020) and Weyh et al. (2020) emphasize the need for further evaluation of the effectiveness of such tools in promoting long-term lifestyle changes.

Research by Anderson et al. (2016) and Fitzsimons et al. (2013) has shown that health promotion programs using digital technology can effectively support behavioural change and may have a lasting impact on the physical activity levels of working women. Features such as individualized planning, goal-setting, feedback, and group interaction components substantially enhance participant engagement, and the effectiveness of behaviour change programs (Pavey et al., 2011; Firth et al., 2017; Michie et al., 2009).

Despite growing awareness of the health benefits of physical activity, too few women engage in regular exercise. Contributing factors include a lack of appropriate, accessible, and tailored tools to support lifestyle modification (Sniehotta et al., 2005; Fukuoka et al., 2011; Stockwell et al., 2019).

The response to this issue was the implementation of the “New Year – Healthy Year” program, within which a free health and training platform was developed for women employed in office-based positions in public institutions. Its aim was to promote health-oriented physical activity and support lifestyle modification. The platform was designed specifically for women with limited leisure time and professional responsibilities, in line with recommendations for the development of effective health promotion programs for this target group (Sloan et al., 2013).

The aim of the present study was to evaluate the impact of the “New Year – Healthy Year” program, delivered in the form of an online training platform, on physical activity levels among adult women employed in office-based

occupations. The analysis covered two time points: prior to program implementation and three months afterwards. The data obtained provide an important contribution to the development of women's health-supporting tools and may be applied both in public health practice and in future preventive programs.

Primary research question:

Will the implemented tool, i.e. the online training program contribute to an increase in the physical activity levels in women participating in the study?

Materials and methods

The study was conducted as part of the "New Year – Healthy Year" project, the aim of which was to promote physical activity and support lifestyle changes among women employed in office positions in public institutions in the West Pomeranian Voivodeship. This group was selected due to the nature of their work, which involves remaining in a seated position for a prolonged time. The program was designed as a nine-month research project with four measurement points: before the start of the exercises and following 3, 6, and 9 months of implementation. The present analysis covers the results of the first two measurements – the baseline and after three months – which makes it possible to assess the impact of the initial stage of participation in the program.

The program was implemented with the use of a specially developed online training and educational platform. The platform contained exercise sets and training plans supporting physical activity, available at any convenient time and with intensity adjusted to individual capabilities. The sets were personalized on the basis of data provided during registration. In addition, participants could take advantage of special motivational and instructional consultations conducted by the research team, which included a sports coach. All participants were informed about the purpose and course of the study.

The study initially involved 81 women employed in public institutions of the West Pomeranian Voivodeship, performing sedentary work. The prerequisite for participation was an informed consent to participate in a health promotion program and absence of medical contraindications to engage in physical activity. After three months of regular use of the online training platform, complete post-intervention data were obtained from 61 participants.

The International Physical Activity Questionnaire (IPAQ) was used in the study, which makes it possible to measure various forms of physical activity as well as the time spent in a sitting position. It should be emphasized that this questionnaire assesses activity during the seven days preceding its completion, not throughout the entire duration of the program.

The IPAQ allows for the determination of the number of days per week and the daily time (in minutes) devoted to: (1) physical activity related to occupational activities, (2) physical activity related to commuting and transportation, (3) household, domestic, and caregiving activities, (4) leisure-time recreation, sports, and physical activity and (5) time spent in a seated position.

The research data was collected prior to the commencement of the program (measurement 1) and following the completion of the first stage, i.e. 3 months after the use of the online training platform (measurement 2). The results were presented in pairs (measurement before and after) to analyse individual changes. The questionnaire included open-ended questions, allowing participants to independently report the number of days or minutes devoted to specific activities. This approach enabled the collection of a more individualized and realistic picture of participants' actual behaviours.

The program was implemented as part of the project entitled “New Year – Healthy Year,” co-financed from the state budget funds awarded by the Minister of Science and Higher Education under the “Science for Society II” Program (project no. NdS-II/SP/0523/2023/01). The study received approval from the Research Project Ethics Committee at the University of Szczecin (decision no. KB 29/2023).

Results

The analysis of the collected data made it possible to assess changes in physical activity and time spent in a sitting position between the baseline measurement and the measurement taken after three months of participation in the “New Year – Healthy Year” program.

Responses provided by participants had a numerical format (number of minutes or days) and were compared across the two time points. For the statistical analysis, the Wilcoxon signed-rank test was applied to paired data in order to assess the significance of differences between pre- and post-intervention measurements. The level of statistical significance was set at $p < 0.05$.

Additionally, a descriptive analysis was performed on the complete dataset, focusing on changes in numerical values reported by participants regarding physical activity and leisure-time organization.

Analysis of questions 1–23 of the questionnaire, which covered a broad spectrum of routine activities – including occupational tasks, commuting, household and caregiving responsibilities, as well as selected aspects of work organization – did not reveal statistically significant changes after three months of participation in the program. This outcome was expected, as these questions referred to everyday behaviours and conditions that typically remain stable in the short term. The data obtained from these measurements are presented in Table 1.

The analysis of questions 24–27 of the questionnaire, relating to leisure-time physical activity and time spent in a sitting position, revealed significant changes between the baseline measurement and the measurement taken after three months (data presented in Table 2).

In the area of moderate leisure-time physical activity, a statistically significant decrease was observed in the number of days per week during which participants engaged in such activity ($Z = 2.80$; $p = 0.01$). This result indicates that, compared with the baseline measurement, after three months participants engaged less frequently in moderate leisure-time physical activity (data presented in Chart 1).

The analysis of the duration of moderate physical activity on active days did not show significant differences between the baseline measurement and the three-month measurement ($Z = 1.78$; $p = 0.07$), suggesting that participants engaging in moderate activity maintained a similar duration of this activity (data presented in Chart 2).

With regard to sedentary behaviours, a significant increase was found in the time spent sitting. On working days, this time increased in a statistically significant way ($Z = 2.31$; $p = 0.02$). A similar result was also observed for non-working days ($Z = 2.67$; $p = 0.01$). These findings indicate that during the analysed period sedentary behaviours among the women studied intensified (Charts 3 and 4).

In summary, during the first stage of the program (comparison between the baseline and three-month measurements), the following were observed: (1) a significant decrease in the number of days with moderate leisure-time physical activity, (2) no significant changes in the average duration of moderate activity on active days, and (3) a significant increase in the number of hours spent sitting on both working and non-working days.

Discussion

The results of the first stage of the study conducted under the “New Year – Healthy Year” project demonstrate the impact of a health-promotion program based on remote access to a training platform on the level of physical activity undertaken and the time spent sitting by women employed in public institutions.

The research tool employed—a questionnaire containing 27 open-ended questions—enabled detailed data collection, though participants’ responses were subjective and based on self-assessment.

Analysis of questions 1–23 of the questionnaire, which covered a broad spectrum of routine activities – including occupational tasks, commuting, household and caregiving responsibilities, as well as selected aspects of work organization – did not reveal statistically significant changes after three months of participation in the program. This outcome was expected, as these questions referred to everyday behaviours and conditions that typically remain stable in the short term.

At the same time, the results may serve as a starting point for future comparisons across different regions or organizational units, which may allow for the identification of differences stemming from employer health-promotion policies or the specific characteristics of local employment conditions.

Analysis of the results concerning leisure-time physical activity and sedentary behaviours (questions 24–27 of the questionnaire) demonstrated, among others, a significant reduction in the number of days with moderate physical activity during leisure time, an increase in the number of hours spent sitting on both on working days and on non-working days, and no statistically significant changes in the duration of physical activity on the days when it was actually undertaken. These findings are complex and require interpretation in light of the existing literature on the subject.

The first concerning observation is the reduction in the number of days on which participants engaged in moderate physical activity during their leisure time. This suggests that the program may have had limited effectiveness in increasing motivation for regular physical activity outside of the provided training materials.

As demonstrated by previous studies, programs that are effective in supporting physical-activity require not only the delivery of educational content but also strategies for maintaining commitment, such as personalized reminders, goal-setting, and social support (Howlett et al., 2019; Lyons et al., 2014).

Conversely, the significant increase in the time spent sitting – both on working and non-working days—indicates the limited effectiveness of the intervention in reducing sedentary lifestyle. This is consistent with systematic reviews, which show that people performing office work are particularly prone to prolonged sedentary time, and even well-designed preventive programs do not always yield the expected reduction in sitting hours (Owen et al., 2010; Chu et al., 2016; Shrestha et al., 2018; Biswas et al., 2015). This points to the necessity of broader organizational support, including ergonomic workplace adjustments that facilitate standing and movement at work.

The lack of significant changes in the duration of moderate physical activity on days when it was performed indicates that the previous level of effort was maintained. This is consistent with literature reports, which emphasize that interventions may improve the intensity and quality of activity but do not always lead to more frequent engagement (Direito et al., 2017; Jakicic et al., 2019).

It is important to stress that the effectiveness of physical-activity support programs for women in office-based occupations depends on multiple factors such as motivation level, health habits, or psychological workload. Organizational factors also play an important role, including workplace health culture, supervisor support, and flexibility of working hours (Pronk et al., 2021; Kilpatrick et al., 2014).

In the case of women employed in public institutions, engagement in physical activity is limited by numerous factors. These primarily include prolonged sitting and high levels of occupational stress. An additional barrier is the limited availability of spaces conducive to physical activity in the workplace (Biernat & Piątkowska, 2023; Ginoux et al., 2019).

Research findings indicate that changes in health-related behaviours, especially in populations burdened with professional and psychosocial responsibilities, require a longer period and integrated support in order to become established as habits (Wood & Neal, 2016; Feil et al., 2021; Gardner, 2023; Ma et al., 2023).

Scientific evidence indicates that while short-term interventions can increase knowledge and motivation, sustained habit formation demands systematic reinforcement and gradual incorporation of behaviours into daily routines.

The “New Year – Healthy Year” program was designed for a longer period than three months, with participants granted continuous access to the training platform. The present analysis pertains to the first three-month research phase, followed by consultation meetings aimed at reinforcing motivation to maintain physical activity. Subsequent follow-up assessments, conducted after six and nine months, will provide a more comprehensive evaluation of the program's effectiveness in achieving long-term health behaviour change.

Although the program employed a modern format and ensured easy accessibility, it may not be sufficient unless complemented by environmental and socio-organizational components. Previous studies have shown that workplace health-promotion programs are most effective when embedded in broader organizational strategies—encompassing employer health policies, managerial engagement, and ergonomic adjustments such as activity breaks or height-adjustable workstations—in order to achieve lasting effects (Proper et al., 2002; Lassen & Fagt, 2018; Grmani et al., 2019).

In light of these findings, further modifications to the “New Year – Healthy Year” program should be considered. These may include reminders, interactive elements (e.g., progress visualizations, short motivational videos), as well as functions that support self-regulation and health-behaviour planning. Previous studies have clearly shown that interventions incorporating behavioural techniques such as self-monitoring, feedback, and goal-setting demonstrate higher effectiveness in sustaining regular physical activity (Michie et al., 2009; de Santis et al., 2022).

The limitations of this study must also be accounted for in the interpretation of the results. The absence of the control group from the analysis results in a limited ability to draw conclusions regarding the direct effects of the intervention. The reliance on self-reported data introduces the possibility of recall bias and subjective reporting errors. Future research should incorporate objective measures (e.g., accelerometry) and an analysis of effects in subgroups differing in participants' baseline levels of physical activity.

Summing up, the obtained findings confirm that workplace health-promotion programs for women employed in office-based occupations, although promising, require a broader framework—encompassing not only educational content delivery but also behavioural-change components integrated into the occupational environment. Combining digital tools with systemic workplace support may represent an effective strategy to reduce sedentary behaviour and promote physical activity among women employed in public entities.

In future programs targeting this group of employees, it would be advisable to supplement the program with elements such as content personalization, reminders, or gamification components, as the current project – implemented over a nine-month cycle – does not allow for adjustments during its course.

It must be emphasize that the results presented here relate solely to the initial three-month stage of the “New Year – Healthy Year” program. This is an early phase of observation, allowing only a preliminary assessment of the intervention's effects. Subsequent measurements, planned after 6 and 9 months of participation, will provide a more comprehensive picture of the program's effectiveness and enable an evaluation of its impact on lasting changes in the health behaviours of the women studied. A longer observation period may reveal positive trends both in terms of increased physical activity and reduced time spent sitting.

Conclusions:

1. The results of the first stage of the “New Year – Healthy Year” program reflect an unfavourable trend in physical activity, manifested by a decrease in the number of days with moderate leisure-time activity and an increase in time spent sitting, with no significant changes in the duration of moderate activity on active days.
2. Continued observation at 6 and 9 months will allow for an assessment of the program's long-term effectiveness and will determine whether an extended period of participation leads to positive changes in physical activity levels and a reduction in sedentary behaviours.

Table 1. Data for questionnaire items 1–23: averages, minimum and maximum before joining the program (start) and after three months

	Start			After 3 months		
	Avg.	Min	Max	Avg.	Min	Max
Please indicate the number of days in the last 7 during which you performed vigorous physical activity at work or study (e.g., lifting heavy objects, digging, construction work, climbing stairs)	1	0	7	1	0	7
Please indicate how much time on one of those (average) days you usually spent on vigorous physical activity at work.	00:06	0	4:00	1:00	0	4:00
Please indicate the number of days in the last 7 during which you performed moderate physical activity at work (comparable to carrying light loads, cycling at a regular pace)	2	0	7	2	0	7
Please indicate how much time on one of those (average) days you usually spent on moderate physical activity at work	0:96	0	06:03	01:36	0	6:30
Please indicate the number of days in the last 7 during which you walked for at least 10 minutes at a time during work.	3	0	7	3	0	7
Please indicate how much time you usually spent walking during one of those (average) workdays	01:18	0	06:01	01:18	0	06:01
Please indicate the number of days in the last 7 during which you travelled by car, bus, train, tram or another vehicle (excluding cycling).	5	0	7	5	0	7
Please indicate how much time you usually spent on one of those (average) days travelling by car, bus, train, tram or another vehicle (excluding cycling).	01:21	0	6:00	01:21	0	6:00
Please indicate the number of days in the last 7 during which you cycled for at least 10 minutes (to or from work, or for other purposes).	0	0	3	0	0	3
Please indicate how much time you usually spent cycling on one of those (average) days.	00:26	0	4:00	00:26	0	4:00
Please indicate the number of days in the last 7 during which you walked for at least 10 minutes at a time (to or from work, or for other purposes).	4	0	7	4	0	7
Please indicate how much time you usually spent walking on one of those (average) days.	01:24	0	8:00	01:24	0	8:00
Please indicate the number of days in the last 7 during which you performed vigorous physical activity in the garden or around the house (e.g., carrying heavy objects, chopping wood, shovelling snow, digging)	1	0	7	1	0	7

Please indicate how much time you usually spent on one of those (average) days doing vigorous physical activity in the garden or around the house	0:66	0	5:00	01:06	0	5:00
Please indicate the number of days in the last 7 during which you performed moderate physical activity in the garden or around the house (e.g., carrying light loads, sweeping, window cleaning, raking, tidying up around the house).	1	0	7	1	0	7
Please indicate how much time you usually spent on one of those (average) days on moderate physical activity around the house.	01:11	0	10:00	01:11	0	10:00
Please indicate the number of days in the last 7 during which you performed moderate physical activity at home (e.g., carrying light loads, window cleaning, floor washing, cleaning).	4	0	7	4	0	7
Please indicate how much time you usually spent on one of those (average) days doing moderate physical activity at home.	1:66	0	10:00	00:08	0	10:00
Please indicate the number of days in the last 7 during which you walked for at least 10 minutes at a time during leisure time (do not include walking already mentioned above).	3	0	7	3	0	7
Please indicate how much time you usually spent walking during leisure time on one of those (average) days.	01:32	0	12:00	01:32	0	12:00
Please indicate the number of days in the last 7 during which you engaged in vigorous leisure-time activity (e.g., aerobics, running, fast cycling, fast swimming).	1	0	7	1	0	7
Please indicate how much time you usually spent on one of those (average) days engaging in vigorous leisure-time activity.	00:07	0	08:33	00:07	0	08:33

Table 2. Wilcoxon signed-rank test results (items 24–27). T, Z – test statistics

*statistically significant ($\alpha = 0.05$)

	T	Z	p
Please indicate the number of days in the last 7 during which you engaged in moderate leisure-time activity (e.g., cycling at a regular pace, swimming at a regular pace, volleyball).	0,00	2,80	0,01*
Please indicate how much time you usually spent on one of those (average) days engaging in moderate leisure-time activity.	10,00	1,78	0,07
During the last 7 days, please indicate how much time on average you spent sitting on a weekday.	3,00	2,31	0,02*
During the last 7 days, please indicate how much time on average you spent sitting on a weekend day.	0,00	2,67	0,01*

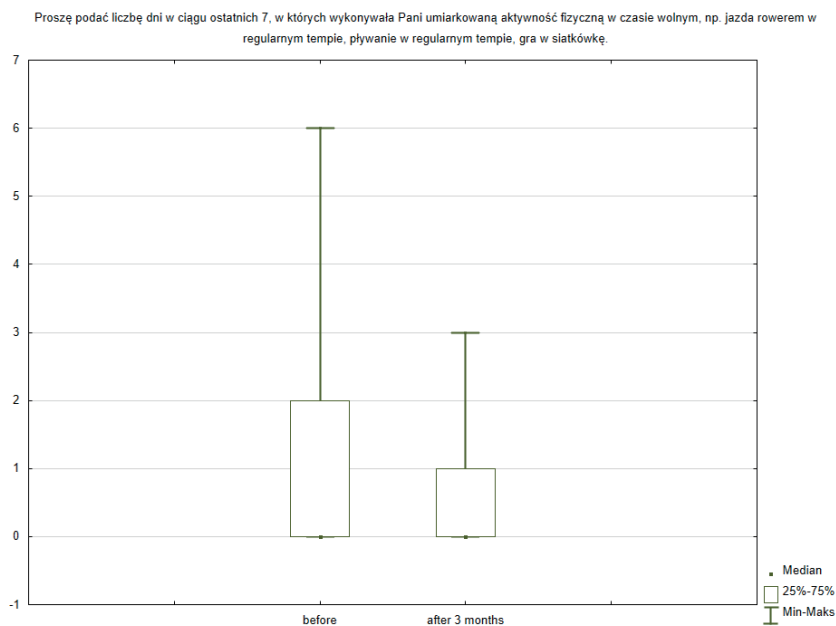


Figure 1. Median, first and third quartiles, minimum and maximum for the number of days with moderate leisure-time activity (e.g., cycling at a regular pace, swimming at a regular pace, volleyball) — at start and after three months

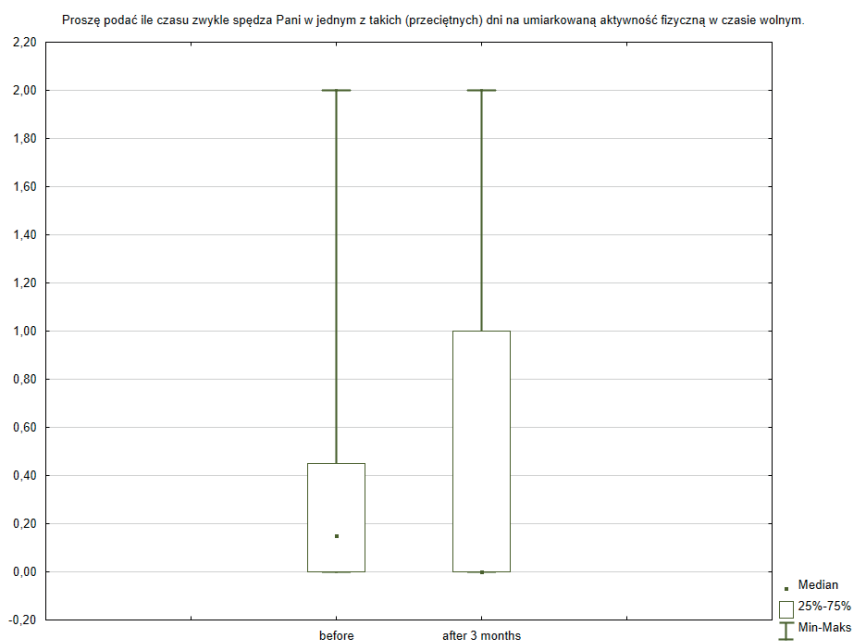


Figure 2. Median, first and third quartiles, minimum and maximum for time on a typical day engaging in moderate leisure-time activity — at start and after three months.

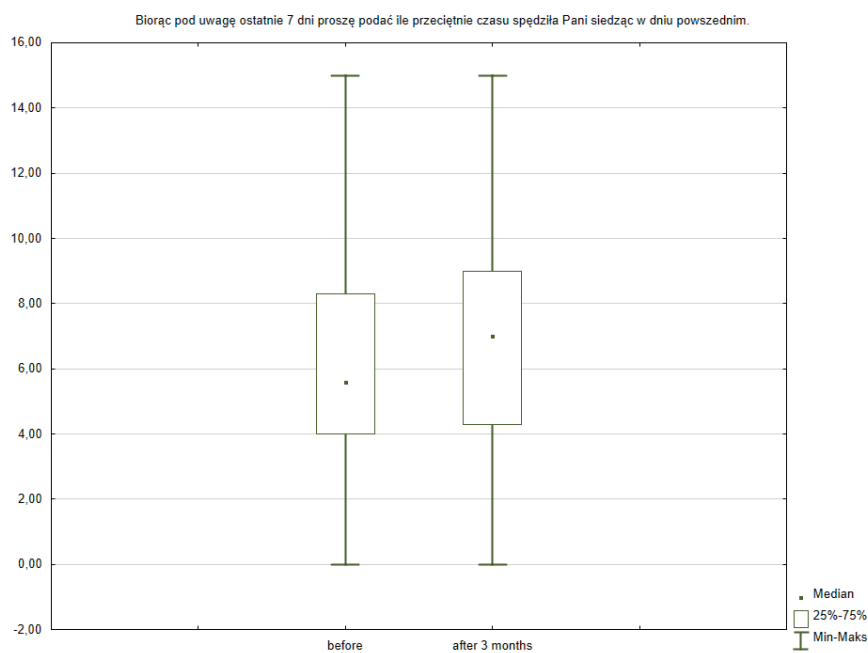


Figure 3. Median, first and third quartiles, minimum and maximum for average time spent sitting on a weekday — at start and after three months

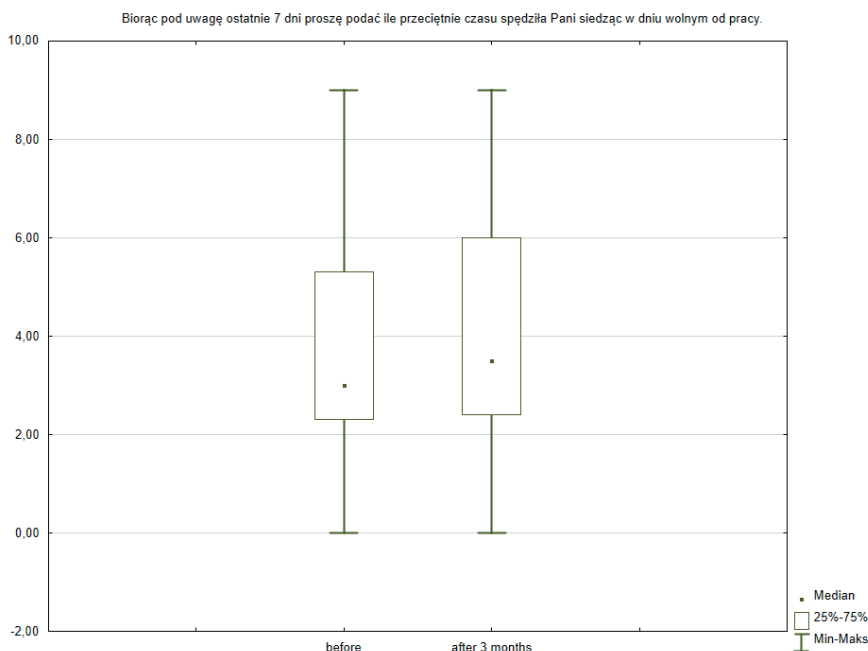


Figure 4. Median, first and third quartiles, minimum and maximum for average time spent sitting on a weekend day — at start and after three months.

Table 1 presents basic descriptive statistics (arithmetic mean, minimum and maximum) for the items included in the questionnaire. Both the number of days and the time spent on physical activity were taken into account.

Table 2 presents the results of the Wilcoxon signed-rank test for paired samples (items 24–27). A result was considered statistically significant at $\alpha = 0.05$. Statistically significant effects were observed for items 24, 26 and 27.

Figures 1–4 illustrate the Wilcoxon test results. They show the median, the first and third quartiles, and the minimum and maximum values.

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Cite this article as: Romaniuk, K., & Galant, G. (2025). Effects of "New Year – Healthy Year" online training program on physical activity levels of women employed in office-based occupations. *Central European Journal of Sport Sciences and Medicine*, 4(52), 13–25. <https://doi.org/10.18276/cej.2025.4-02>

RELATION BETWEEN PERFECTIONISM AND STATE ANXIETY DURING PRACTICE EXAMS (RHYTHMIC GYMNASTICS AND HANDBALL) FOR PHYSICAL EDUCATION AND SPORT STUDENTS

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Abstract This study aimed to examine the relationship between perfectionism- a personality trait- and state anxiety experienced by Physical Education students during practical exams, and to explore how this relationship, viewed as part of an experiential learning process, could enhance their professional readiness for coaching. A total of 305 students (146 male and 159 female) participated in the study. They completed questionnaires on demographics and perfectionism, and before each exam they completed the STAIC-2. The results indicated significant differences in somatic anxiety and self-confidence between rhythmic gymnastics (RG) and handball exams, as well as between female and male participants. Furthermore, the negative dimension of perfectionism emerged as the primary predictor of somatic and cognitive anxiety. Practical implications are discussed in relation to the professional development of future coaches.

Key words: anxiety, perfectionism, rhythmic gymnastics, handball, exams

Introduction

Anxiety is an emotion involving nervousness, worry, and physiological arousal (Weinberg & Gould, 2023) triggered by how an individual interprets and evaluates a situation (Cox, 2007). On the other hand, perfectionism is

related to anxiety, as a predictor. The phenomenon of anxiety has been the focus of extensive research, as related experiences affect not only the specific situation in which they occur (e.g., exposure, competition, examination) but also their long-term consequences.

Theoretical approaches to interpreting the stress-performance relation led to the multidimensional theory of anxiety (Cox, 2007; Martens et al., 1990). Anxiety has both a trait component and a state component. The trait component refers to anxiety as a characteristic of a person's personality, whereas the state component refers to a temporary reaction to a specific situation (Cox, 2007). Trait anxiety is the individual's predisposition to perceive certain situations as threatening and thus to react with increased situational anxiety and this is characterized by worry, fear, tension as well as an increase in physiological arousal. State anxiety is an immediate emotional state that is characterized by apprehension (Cox, 2007).

Precompetitive state anxiety occurs prior to a competitive situation. Factors that cause state anxiety include fear of failure or negative social evaluation (Dunn, 1999), the perceived importance of the competition (Marchant, et al., 1998), perceived threat, perceived lack of control and coping resources (Hammermeister & Burton, 2001), and situation ambiguity (Beauchamp, et al., 2003). Furthermore, personality variables have been as predictors of competitive state anxiety, such as trait anxiety, goal orientation, perfectionism (Cox, 2007), self-esteem, and social physique anxiety (Weinberg & Gould, 2023).

Precompetitive cognitive anxiety starts high and remains stable as the event approaches (Cox, 2007). In contrast, somatic anxiety stays low until about 24 hours before the event, then rises sharply and dissipates once the event begins, whereas cognitive anxiety fluctuates according to the athlete's perceived chances of success or failure (Cox, 2007).

Research consistently shows that male athletes report lower levels of anxiety than female athletes (Dias et al., 2010; Kristjánsdóttir et al., 2018; Masten et al., 2006), a pattern evident even in childhood (Psychoutaki et al., 2003). Men tend to exhibit lower somatic anxiety and higher self-confidence compared to women (Krane & Williams, 1994), a trend also observed among Greek athletes (e.g., Rokka et al., 2012). However, some studies report no significant gender differences (e.g., Hammermeister & Burton, 2004), possibly due to variations in sport type. For example, in Hammermeister and Burton (2004) study, participants were triathlon athletes, an intensive and high demanding sport. Finally, anxiety appears to be higher in individual sports than in team sports (Ramis et al., 2015; Terry et al., 1996). Multiple studies have found significantly higher cognitive anxiety among individual sport athletes (Ariffin et al., 2025; Martens et al., 1990; Palgunadhi et al., 2024; Soltani et al., 2015). This may be attributed to the solitary nature of individual sports, where athletes bear full responsibility for performance (Soltani et al., 2015; Palgunadhi et al., 2024), whereas team sports involve shared responsibility and emotional support, potentially reducing anxiety levels (Palgunadhi et al., 2024).

At the same time, experience in sports affects anxiety levels. Athletes with less experience tend to show higher levels of cognitive and physical anxiety (Crane & Williams, 1994; Masten et al., 2006), whereas more experienced athletes exhibit higher self-confidence and lower levels of negativism (Vasconceloa-Raposo et al., 2024). In Rhythmic Gymnastics (RG) athletes, self confidence was a factor in pre-competition anxiety, differing among higher-level athletes, but it did not affect somatic or cognitive anxiety (Tsopani et al., 2011). Nassib and his colleagues (2017) found that RG athletes with international experience and at least eight years of training exhibited higher somatic and cognitive anxiety during competition compared to training, while self-confidence remained similar in both situations. Artistic Gymnastics is a gymnastics discipline that has been extensively studied. Gould

and his colleagues (1984) found that somatic anxiety was higher in competition than training situation, but there were no differences in cognitive anxiety or self-confidence between the two situations (Gould et al., 1984). On the other hand, Matheson and Mathes (1991) found higher somatic and cognitive anxiety, as well as lower self-confidence, during the competition situation. Jones et al. (1993) examined anxiety in female artistic gymnasts specializing in beam, a discipline with specific demands. No differences were found between high- and lower-performing athletes in the intensity of anxiety, except for cognitive anxiety direction: higher-performing athletes perceived it as more facilitative and less debilitating.

Like in sports, anxiety is common during exams, which are especially stressful for both male and female students (Šimic & Manenica, 2012). It was observed that 15% – 20% of students reported moderate to high levels of anxiety in exam situations (Hahne et al., 1999). Anxiety causes several physiological changes and affects health behaviors, as it reduces students' perceived ability to self-regulate (Mane, 2012). Similar to sports situations, female students have been found to experience higher anxiety than male students (Zisi, 2017).

As mentioned above, perfectionism is a personal variable identified as a predictor of anxiety. It involves setting exceptionally high-performance standards for oneself (Cox, 2007) and is also characterized by a tendency to hold high expectations for oneself and others (Matsumoto, 2019). As a personality trait, perfectionism influences various domains of a person's life (Dunn et al., 2005; McArdle, 2010), particularly those that are significant to the individual, such as sports for athletes. Therefore, research should focus on specific domains (Dunn et al., 2005). Perfectionists are characterized by a striving for flawlessness and setting of excessively high standards for performance (Stoeber & Rambow, 2007). This may lead to both positive and negative consequences. Setting high standards may lead to greater motivation and higher achievement (Bieling et al., 2003) but being overly self-critical may reduce well-being and put individuals at risk for depression (Dunkley et al., 2006). Initially, perfectionism was viewed negatively and linked to psychopathology, largely due to the measurement tools used (Stoeber & Otto, 2006; review: Flett et al., 2002). With newer instruments treating perfectionism as multidimensional, two types emerged: positive perfectionism, in which individuals derive satisfaction from striving for perfection, and negative perfectionism, characterized by distress and worry. Stanley et al. (2001) incorporated both forms in their assessment tool. Their instrument consists of three subscales: High Standards, Discrepancy, and Order. The High Standards subscale measures the high personal standards one sets for oneself. The Discrepancy subscale assesses respondents' perceived inadequacy in meeting personal standards. And the third subscale, Order, refers to one's preference for neatness and orderliness.

Socially prescribed perfectionism is the dimension of perfectionism that applies to individuals who are under intense pressure to meet extreme expectations of perfection, often imposed by demanding people or society (Flett et al., 2022). This dimension has been most closely linked with components of state and trait anxiety, especially under conditions of ego threat (Flett et al., 1994).

There is a moderate to high positive correlation between perfectionistic strivings and sports performance, as well as a moderate to high negative correlation between perfectionistic concerns and sports performance (Núñez et al., 2024). Perfectionism varied across anxiety disorders (Antony et al., 1998) and maladaptive perfectionism was positively related to all anxiety factors (Kawamura et al., 2001). For male college athletes, perfectionism positively affected anxiety (Hwang, et al., 2019). Minarik and Ahrens (1996) suggested that perfectionism may be more specific to depression than to anxiety.

The aim of this study was to investigate potential differences in state anxiety among students of Physical Education Department when assessed in different sports (RG and handball), and to examine the relationship between perfectionism and state anxiety under these two conditions. The research hypotheses were the following:

- Female students will exhibit higher levels of anxiety than male students in both sports situations.
- Students with prior athletic experience will show lower levels of anxiety compared to students without athletic experience.

Anxiety in the teaching of the RG condition will be higher than in the teaching of the handball condition. Perfectionism will consistently predict dimensions of state anxiety across both conditions.

Materials and Methods

Participants

A total of 307 Physical Education University students from two Departments, Thessaloniki and Serres participated in the present study. The mean age of participants was $M = 20.88$ years ($SD = 3.31$). Of these, 146 were male (47.9%), 159 were female (52.1%) and two participants did not declare their gender. Eighty-nine participants (29.6%) had no prior sport experience, while 218 participants (71%) had previous sport experience. Of those with sport experience, 37.1% had experience up to 10 years and 29% had more than 10 years. Among participants with prior sport experience, 77 individuals (25%) had achieved notable sport success (placing 1st to 3rd at the national level or higher). Regarding the type of sport, 31.7% of these students participated in individual sports, and 38.9% in team sports.

Measures

The present study used a quantitative method and two self-reported questionnaires.

The first questionnaire was completed at least 15 days before the examination period and the second was completed twice, once immediately before each examination. The first questionnaire included demographics questions (gender, year of birth), questions about the participants' athletic background (whether they were athletes, training age, higher athlete winning) and the Perfectionism Scale. Before the examinations, participants completed the Competitive State Anxiety Inventory was completed (CSAI-2).

Perfectionism was measured using the Almost Perfect Scale Revised (Slaney et al., 2001), which was adapted for the Greek population by Diamantopoulou and Platsidou (2014). The scale included 3 factors ($KMO = 0.84$, $Bartlett's Test = 2142.39$, $p < 0.001$): high standards (7 items), order (4 items) and discrepancy (12 items). Answers were given in a five-point Likert scale (1: I strongly disagree 5: I strongly agree). Internal consistency was measured by Cronbach's alpha and ranged at acceptably high levels at high acceptable levels ($0.76 < \alpha < 0.89$).

State anxiety was measured with the questionnaire STAI-2 (Martens et al., 1990), adapted for Greek population (Tsozbatzoudis et al., 1998; Stavrou et al., 1998). Three factors emerged from the questionnaire: cognitive anxiety, somatic anxiety, and self-confidence. Responses were given on four-point Likert scale (from 1: not at all to 4: very much) and were completed for both the condition of exams in teaching RG and the condition of exams in teaching handball. Factor Analyses revealed the appropriate three factors (somatic, cognitive self-confidence) for RG ($KMO = 0.88$, $Bartlett's Test = 1115.765$, $p < 0.001$) and for Handball ($KMO = 0.89$, $Bartlett's Test = 840.636$, $p < 0.001$). Internal consistency was measured by Cronbach's alpha and was at acceptably high levels for RG ($0.71 < \alpha < 0.89$) and handball ($0.78 < \alpha < 0.88$). Specifically, Cronbach's alpha was for somatic factor in RG .85 and

in Handball 0.86, for cognitive factor in RG 0.71 and in Handball 0.78, and for self-confidence in RG 0.89 and in Handball 0.88.

Evaluation process

The present study was approved by the Ethic Committee of the Department (138/2023). The study was conducted at the end of the winter semester, which was the first semester in which students were involved with the two modules. After the participants were informed about the purpose and methods of the research (i.e. participation included only completing anonymous questionnaires) they completed and signed the consent form. The research was carried out in two phases: preliminary evaluation, examination evaluation. In the first phase (preliminary), participants completed a questionnaire that included demographic information and the Perfectionism Scale. Approximately 15 days later, the practical exams of the modules took place, marking the second phase. Each participant completed the STAI-2 immediately before their examination in RG and immediately before their examination in Handball. Some participants were randomly tested first in RG and on another day in Handball, while others followed the reverse order (first in Handball and then in RG). All participants were familiar with how they would be assessed in each module.

Description of the examination procedure of the practical part of “teaching handball”: students were asked to perform technical and tactical skills of Handball, in pairs or in triads, depending on the skill. At the same time, they were examined orally in the teaching methodology of the skills, on identifying mistakes during the execution of the skills by their fellow students, and on correcting them. At the end, they were assessed in a full game situation, including defense and attack, as well as their knowledge of the most basic regulations.

Description of the examination procedure of the practical part of “teaching RG”: students were asked to present an individual choreography that they had prepared beforehand, which had to include body skills and handling skills of one apparatus (rope or ball) with musical accompaniment. They had to choose a 1-minute piece of music, prepare an individual choreography, prior to the exams, and present it. They were instructed to perform the best they could their choreography, which had to include jumps, balances, turns, handling skills, dancing steps and other movements. Three to four fellow students and the examiner were present during the performance. During the semester and lessons, students were taught the relevant principles and teaching methods, as well as how to organize the connections they needed to present, with sufficient examples. At the same time, during practice, they took part in informal peer observation. For almost all students, the process of arranging and placing the elements (body and handling) in space, time, and music, in a creative way by their own, was their first such experience. They were asked to effectively use motor creativity, memory, and self-learning.

Statistical Analyses

IBM SPSS 29 was used for data analysis. Cronbach's alpha criterion was calculated to assess the reliability of the measures. Independent-sample t-tests were used to examine possible differences between male and female students in anxiety and perfectionism, while paired-samples t-tests were used to examine differences in anxiety and perfectionism under the two different conditions. One-way ANOVAs were performed to examine differences among participants with different training experience. Correlations among all factors were tested using the Pearson correlation coefficient (r). Finally, after checking assumptions (Ntoumanis, 2001; Tabachnick & Fidell, 1996), regression analyses were conducted to predict each anxiety factor (somatic, cognitive, self-confidence) from perfectionism (high standards, order, discrepancy) in RG and handball conditions for both participants, and separately for females and males.

Results

Descriptive statistics

In Table 1 are presented M (SD) for age, training age, STAI-2 factors in RG, STAI-2 in handball, perfectionism factors, for all participants as well as separately for males and females. Differences between males and females were not significant for age and training age ($p > 0.05$).

Table 1. Mean (SD) in age, training age, factors of state anxiety and factors of perfectionism for the total of participants, males and females

M (SD)		All participants M (SD)	Males M (SD)	Females
Age		20.88 (3.31)	21.19 (3.51)	20.61 (3.12)
Training age		8.94 (3.81)	9.49 (3.88)	8.48 (3.71)
State anxiety rhythmic gymnastics	Somatic	1.97 (0.72)	1.67 (0.53)	2.21 (0.76)
	Cognitive	2.05 (0.64)	1.85 (0.62)	2.20 (0.62)
	Self-confidence	2.66 (0.68)	2.73 (0.65)	2.59 (0.70)
State anxiety handball	Somatic	1.54 (0.58)	1.39 (0.50)	1.66 (0.62)
	Cognitive	1.98 (0.65)	1.77 (0.58)	2.16 (0.65)
	Self-confidence	3.00 (0.70)	3.21 (0.61)	2.85 (0.71)
Perfectionism	High standards	4.14 (0.59)	4.18 (0.63)	4.11 (0.55)
	Order	4.00 (0.68)	3.87 (0.77)	4.10 (0.58)
	Discrepancy	2.74 (0.76)	2.75 (0.71)	2.74 (0.79)

Table 2. Mean (SD) for state anxiety factors and perfectionism factors for participants practicing individual or team sports, and among participants with different training experience

Factors M (SD)		Individual sports M (SD)	Team sports No M (SD)	Training experience			
				Yes M (SD)	<10 years M (SD)	≥10 years M (SD)	
State Anxiety Rhythmic Gymnastics	Somatic	2.04 (0.53)	1.93 (0.76)	1.80 (0.73)	2.06 (0.70)	2.13 (0.75)	1.98 (0.63)
	Cognitive	1.88 (0.56)	2.13 (0.66)	2.05 (0.65)	2.05 (0.63)	2.16 (0.65)	1.96 (0.61)
	Self-confidence	2.91 (0.73)	2.58 (0.60)	2.69 (0.73)	2.64 (0.66)	2.60 (0.61)	2.64 (0.69)
State Anxiety Handball	Somatic	2.04 (0.53)	1.41 (0.70)	1.53 (0.52)	1.92 (0.64)	1.52 (0.59)	1.56 (0.63)
	Cognitive	2.00 (0.61)	1.71 (0.62)	2.10 (0.65)	1.92 (0.64)	1.92 (0.70)	1.93 (0.57)
	Self-confidence	2.90 (0.74)	3.19 (0.68)	2.93 (0.76)	3.01 (0.70)	3.06 (0.71)	3.03 (0.65)
Perfectionism	High Standards	4.14 (0.57)	4.18 (0.55)	4.02 (0.75)	4.28 (0.50)	4.11 (0.48)	4.22 (0.63)
	Order	4.06 (0.67)	3.96 (0.66)	4.03 (0.80)	4.14 (0.63)	3.96 (0.67)	4.04 (0.64)
	Discrepancy	2.74 (0.77)	2.79 (0.72)	2.45 (0.79)	2.72 (0.74)	2.82 (0.75)	2.77 (0.72)

Differences in anxiety (somatic, cognitive, self-confidence) in different conditions

Differences in anxiety were tested with respect to the two different conditions of examination (examination in teaching RG and examination in teaching handball), using paired t-tests.

Statistically significant differences were observed in somatic anxiety, $t(61) = 6.13$, $p < 0.001$, $d = 0.64$, and in self-confidence, $t(61) = -3.07$, $p = 0.003$, $d = 0.78$. Comparing the means, it was shown that "somatic anxiety" in the RG exam was higher, while "self-confidence" in the handball exam was higher (Table 1).

Males / females: among females, only somatic anxiety showed a statistically significant difference, $t(38) = 5.76$, $p < 0.001$, $d = 0.60$, with higher the somatic anxiety during the RG exam (Table 1).

Participants with or without training experience: statistically significant differences were observed in the group with no training experience and only in somatic anxiety, $t(18) = 3.50$, $p = 0.00$, $d = 0.60$, whereas for the group with the training experience, differences were found in somatic anxiety, $t(42) = 4.99$, $p < 0.001$, $d = 0.67$, and in self-confidence, $t(42) = 2.91$, $p = 0.006$, $d = 0.73$.

Experience in individual/ team sports: the group with experience in individual sports differed statistically significantly only in somatic anxiety, $t(18) = 3.00$, $p = 0.008$, $d = 0.69$, whereas the group with experience in team sports differed in all three factors (cognitive anxiety: $t(22) = 2.41$, $p = 0.02$, $d = 0.84$, somatic anxiety: $t(22) = 4.08$, $p < 0.001$, $d = 0.62$, self-confidence: $t(22) = -5.15$, $p < 0.001$, $d = 0.57$). More precisely, they presented higher cognitive and somatic anxiety in the RG exam and higher self-confidence in the handball exam (Table 2).

Different training experience: for the group with no experience, somatic anxiety was the factor that differed between the two conditions (RG and handball exam), $t(21) = 3.46$, $p = 0.002$, $d = 0.57$. For the group with up to ten years training experience, differences were noticed in somatic anxiety, $t(16) = 3.66$, $p = 0.002$, $d = 0.5$ and self-confidence, $t(15) = -2.71$, $p = 0.01$, $d = 0.67$. The group with ten or more years of experience differed only in somatic anxiety, $t(23) = 3.64$, $p < 0.001$.

Differences in state anxiety's factors (somatic anxiety, cognitive anxiety, self-confidence) and in perfectionism's factors (high standards, order, discrepancy)

Independent-sample t-test were conducted to examine possible differences between male and female students in somatic anxiety, cognitive anxiety, self-confidence, high standards, order, and discrepancy.

Anxiety

Male/female: Regarding anxiety, (somatic, cognitive and self-confidence) all differences were statistically significant except from self-confidence in "RG" ($p = 0.18$). More precisely, compared to men, women reported a) higher cognitive anxiety in RG, $t(191) = -3.80$, $p < 0.001$, $d = 0.62$ and higher cognitive anxiety in handball, $t(117) = -3.36$, $p = 0.001$, $d = 0.62$, b) higher somatic anxiety in RG, $t(191) = -5.45$, $p < 0.001$, $d = 0.67$ and in handball, $t(117) = -2.57$, $p = 0.01$, $d = 0.57$ and c) higher self-confidence in handball, $t(117) = -2.33$, $p < 0.01$, Cohen's $d = 0.67$.

Training experience in individual / team sport: No statistically significant differences were observed.

Participants with and without training experience: only in somatic anxiety related to RG was the difference between participants with and participants without training experience statistically significant, $t(193) = -2.33$, $p < 0.02$, $d = 0.71$.

Different training experience: among groups with different training experience (no experience, up to 10 years, and 10 or more years), statistically significant differences were observed only in somatic anxiety in the condition

of “RG”, $F(2,192) = 3.52$, $p = 0.03$, $\eta^2 = 0.04$, and the difference was detected between the no experience group and the group of up to 10 year experience (Table 2).

Perfectionism

Males /female: a significant gender difference was found, $t(236) = -2.62$, $p = 0.009$, $d = 0.67$, only for the factor of order, with females reporting higher levels compared to males (Table 1).

Training experience in individual / team sport: No statistically significant differences were observed.

Participants with or without training experience: statistically marginally significant differences were observed in the factor of “high standards”, $t(236) = -1.98$, $p = 0.04$, $d = 0.58$, with participants who had training experience scoring a higher mean compared to those who had no experience at all.

Different training experience: among the groups of different training experience (no experience, up to 10 years, and 10 years or more) statistically significant differences were observed only regarding the factor “discrepancy”, $F(2,235) = 3.66$, $p = 0.03$, $\eta^2 = 0.03$. More precisely, the Scheffé test revealed difference between the no experience group and the up to 10-year experience group, with the no experience group showing a lower mean (Table 2).

Correlations between factors

Pearson correlation coefficients (r) were calculated to examine correlations among all factors for the total sample. Anxiety factors were found to be significantly associated with perfectionism factors under different conditions (RG and handball). In particular, ‘high standards’ was positively correlated with self-confidence in both RG and handball, whereas ‘discrepancy’ was positively correlated with cognitive and somatic anxiety in RG exam but negatively correlated with self-confidence in handball exam (Table 3).

Table 3. Correlations among all factors and regarding the total of participants

	1	2	3	4	5	6	7	8	9
1. Somatic RG	1								
2. Cognitive RG	0.57**	1							
3. Self-confidence RG	-0.33**	-0.42**	1						
4. Somatic Handball	0.52**	0.29*	-0.21	1					
5. Cognitive Handball	0.22	0.28*	-0.15	0.55**	1				
6. Self-confidence Handball	-0.29*	-0.27*	0.48**	-0.43**	-0.56**	1			
7. High standards	-0.03	-0.08	0.24**	-0.11	-0.13	0.26*	1		
8. Order	0.03	-0.07	0.15	-0.03	-0.09	-0.01	0.43**	1	
9. Discrepancy	0.23**	0.26**	-0.15	0.18	0.09	-0.33**	0.09	-0.05	1

** : $p < 0.01$, * : $p < 0.05$

Prediction of anxiety based on perfectionism

For all participants, as well as separately for men and women, regression analyses were conducted for each anxiety factor (somatic, cognitive, self-confidence) and training age under each condition (RG and handball).

Somatic anxiety

In RG: prediction was statistically significant, $R = 0.31$, $R^2 = 0.09$, $F(3,117) = 3.09$, $p = 0.02$, with “discrepancy” being the only significant predictor $B = 0.27$, $t = 3.34$, $p = 0.001$. When analyzed separately by gender, the prediction was not statistically significant.

In handball: prediction was not statistically significant for the total sample or for either gender. *Cognitive anxiety*

In RG: prediction was statistically significant, $R = 0.34$, $R^2 = 0.11$, $F(4,117) = 3.75$, $p = 0.007$, with “discrepancy” being the only significant predictor, $B = 0.25$, $t = 3.34$, $p = 0.001$. For males and females separately, prediction was significant only for females, $R = 0.43$, $R^2 = 0.18$, $F(4,70) = 3.90$, $p = 0.006$, with “discrepancy” being the only significant predictor, $B = 0.23$, $t = 2.75$, $p = 0.008$.

In handball: prediction was not statistically significant, neither for the total sample or for either gender. *Self-confidence*

In RG: prediction was not statistically significant, neither for the total sample or for either gender.

In handball: prediction was statistically significant, $R = 0.46$, $R^2 = 0.21$, $F(4,69) = 4.72$, $p = 0.002$ and the most significant predictor was “high standards”, $B = 0.45$, $t = 2.91$, $p = 0.005$ and “discrepancy”, $B = -0.33$, $t = -3.22$, $p = 0.002$. For each gender separately, prediction was significant only for women, $R = 0.56$, $R^2 = 0.31$, $F(4,35) = 3.99$, $p = 0.009$ and the most significant predictor was “high standards”, $B = 0.48$, $t = 2.34$, $p = 0.02$ and “discrepancy”, $B = -0.54$, $t = -3.34$, $p = 0.002$.

Discussion

The aim of the present study was to explore the state anxiety of university students from Departments of Physical Education and Sport under different exam conditions, as well as its relation to its relation to perfectionism. Student state anxiety during academic exams has been widely studied, mainly because of its negative effects on students' self-regulation and on their physiology and health (Zisi, 2017; Oaten & Cheng, 2005; Šimic & Manenica, 2012). Moreover, exam-related anxiety shares many similarities with anxiety experienced in sports competitions (Šimic & Manenica, 2012), as both situations require concentration and effort to achieve high performance (whatever “high” may mean in each context). Students who participated in the present study were pre-service coaches, so they should be “trained” in using skills to manage anxiety. State anxiety was examined under two different conditions, RG and handball. The results of the present study revealed that somatic anxiety in RG was higher than in handball for all participants, whereas self-confidence was lower. For all the participants, familiarity with handball from school at all educational levels was greater, while for most of them RG was unfamiliar. Their first contact with the sport was during university lessons. In addition, the skills of RG are not similar to the skills used in other sports and therefore students cannot apply learning transfer.

As shown by the results of this study, female students exhibited higher levels of both somatic and cognitive anxiety than male students in both sports. Regarding self-confidence, there were no differences between genders in RG, whereas in handball, female students reported higher self-confidence than male students. These results partially confirm the results of a previous research with student participants (Zisi, 2017), where female students manifested a higher levels of anxiety than male students. Moreover, these results partially confirm those of previous research with student participants, in which female students demonstrated higher levels of anxiety than male students (Dias et al., 2010; Kristjánsdóttir et al., 2018; Masten et al., 2006). However, in previous studies, it has been

observed that female athletes typically exhibit lower levels of self-confidence compared to male athletes (Crane & Williams, 1994; Rokka et al., 2012). In our study, specifically focusing on RG, no significant gender differences in self-confidence were observed. Conversely, in handball, women exhibited higher levels of self-confidence than men. This difference may be attributed to the teaching methods and instructional structure used in RG, which appear to address both genders equally. In contrast, in handball, the instructor's gender—being female and serving as a role model—may have positively influenced the confidence levels of female participants. It is also possible that, for male participants, the course content itself played a greater role in shaping their confidence levels. Another variable explored in the present study was training experience and its relationship with anxiety. The participants were fourth-semester students from the Department of Physical Education and Sport Science at Aristotle University of Thessaloniki, with an average age of 21 years and approximately nine years of experience in various sports. Their extensive background in sports can be explained by the fact that individuals who choose to study “Physical Education and Sports” are typically motivated by a strong interest in the field and the desire to pursue it professionally. Consequently, it is reasonable to assume that most of them have already been active athletes. Secondly, the admissions system in Greek universities tends to favor candidates who are, or have been, distinguished athletes. Yet, some students have no athletic background, with their only exposure to physical education and sports limited to the lessons they attended during compulsory schooling (primary and secondary education). The results indicated that the only statistically significant difference between students with and without sports experience was in somatic anxiety during the RG examination, with students lacking sports experience reporting lower somatic anxiety. This could be explained by two factors: a) students without sports experience may have had lower expectations for the RG subject, and/or b) the examination's difficulty may not have been sufficient to influence somatic anxiety. Importantly, both the teaching content and examination demands focused on learning rather than performance. Somatic anxiety also varied according to years of training experience. Students with no experience exhibited lower somatic anxiety than those with some experience (up to ten years), but showed no significant difference compared to students with extensive experience (ten years or more). These findings contrast with previous studies, which found that athletes with less experience tend to report higher cognitive and somatic anxiety than more experienced athletes (Crane & Williams, 1994; Masten et al., 2006). Notably, the studies cited examined anxiety in sports contexts rather than in examination settings.

One possible interpretation of this result is as follows: students without prior training experience, since they have not faced competitive conditions and are learning RG primarily as teachers during the semester, tend to evaluate their feelings based on their practical lesson experiences. Conversely, students with less training experience are more likely to liken the RG exam to sport competition and either have higher expectations that create increased physical stress, or they do not have enough experience to transfer stress management skills they've acquired from their sport, in another condition/sport.

According to the multidimensional theory of anxiety, perfectionism is a personality trait that can predict anxiety. Perfectionism, however, has a positive dimension and a negative dimension (high standards, discrepancy, order) (Slanley et al., 2001). The results of the present study showed that the negative dimension of perfectionism, discrepancy, was the main predictor of anxiety and specifically, discrepancy predicted both somatic and cognitive aspects of negative anxiety. The RG exam introduced novel requirements for nearly all participants, which meant that stable personality traits had a greater influence than previously acquired course skills. This is understandable,

as personality is relatively stable, and completing 13 units or modules (prerequisite for participating in the exams) is not sufficient to modify it.

Respectively, regarding self-confidence, the predictive effect was significant for handball but not for RG. This may be due to the content of physical education programs in Greece, where students develop handball skills in primary and secondary school. As they enter tertiary education, these skills—and possibly personality traits—continue to play a role in shaping self-confidence. In contrast, in RG, students' self-confidence appears to be influenced more by situational factors than by stable personality traits.

This study has several limitations. First, not all sports were represented. Although the exams included both individual and team sport scenarios, participants' prior sport experience may have influenced the results. Additionally, it was not possible to recruit participants from every sport. While most participants had training experience and the examination closely mirrored real sport situations, their anxiety levels in their own sport may differ from those experienced during the examination.

As with all studies using written questionnaires, participants' responses may not have been entirely accurate due to social desirability (no social desirability scale was used), misunderstandings of the questions, or lack of interest. To address this, researchers made efforts to clarify any potential misunderstandings and to emphasize the significance of the study for participants, who would be informed about the results and their potential implications.

Finally, the exams provided an opportunity for participants to practice stress-reduction techniques experientially, which could later be applied when coaching their athletes. It is imperative for students aspiring to become coaches and future coaching other professionals to develop practical expertise in anxiety management techniques, while concurrently addressing the influences of external factors on their personalities, including familial dynamics. Mastery in anxiety management is essential for coaches to effectively navigate challenging circumstances, such as examinations, enabling them to transmit these skills to their prospective athletes. To optimize their learning and eventual success, it is recommended that these individuals engage in practice environments deliberately designed to be unfamiliar, facilitating the receipt of authentic and constructive experiential feedback. The differences between genders should be taken into account in order to experimentally teach them how to use anxiety management techniques. On the other hand, perfectionism is a rather stable characteristic so it should be considered when implementing interventions for anxiety, and more specially, high standards and discrepancies.

The Departments of Physical Education and Sport Science have, among other responsibilities, the responsibility of preparing future coaches through experiential learning on how to manage state anxiety, based on stable personality traits and their previous experiences. The present research endeavor constitutes an example of such a process as the results of the present study revealed, somatic anxiety in an unfamiliar sport was higher than in a more familiar sport, for all participants, whereas self-confidence was lower. Furthermore, the negative dimension of perfectionism emerged as the primary predictor of somatic and cognitive anxiety and the positive dimension of perfectionism emerged as the primary predictor of self-confidence. Based on the study's findings, future coaches should be systematically guided in developing effective strategies for managing state anxiety, through repeated experiential learning, so that they are able to internalize and automate the most efficient techniques for future instructional and coaching contexts. The Departments of Physical Education and Sport Science should consider the above findings and suggestions when designing their curricula.

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Cite this article as: Kosmidou, E., Drakou, A., Papadopoulou, Z., & Moscha, D. (2025). Relation between perfectionism and state anxiety during practice exams (Rhythmic Gymnastics and Handball) for Physical Education and Sport students. *Central European Journal of Sport Sciences and Medicine*, 4(52), 27–40. <https://doi.org/10.18276/cej.2025.4-03>

EFFECTIVENESS OF PILATES ON POSTURAL CONTROL IN MENOPAUSAL WOMEN: A SYSTEMATIC REVIEW

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Abstract During menopause, women face notable physical changes and a higher risk of musculoskeletal disorders. Pilates exercises can improve balance, benefiting this population. This study aimed to evaluate the specific impact of Pilates on postural control in menopausal women. The search for relevant studies encompassed Web of Science, PubMed, and Scopus databases, covering the period until August 2, 2025. Additionally, the reference lists of included studies were manually searched for further identification of relevant articles. The selection of studies, data extraction, and assessment of methodological quality using the Downs and Black checklist were conducted independently by two authors. This review included five studies with 284 menopausal women, examining the effect of Pilates on postural control. The most commonly implemented Pilates exercises across the included studies consisted of 2 sessions per week, each lasting approximately 50 to 60 minutes, conducted at low to moderate intensity, and sustained for a minimum intervention duration of 12 weeks. Postural control variables were evaluated using a stabilometric platform, force plate, timed up-and-go test, and Mini-BESTest. Pilates may improve postural control in menopausal women, with factors like time since menopause, activity level, and exercise characteristics influencing outcomes.

Key words: exercise therapy, core stability, balance, motor control, menstruation, hormone replacement therapy, menopause

Introduction

Menopause, the permanent cessation of menstruation due to loss of ovulation follicular function (Sutton-Tyrrell et al., 2005), is a natural process in aging women. The average age for menopause onset is around 50 years, and the majority of women typically enter the postmenopausal stage by the age of 52 (Viljoen & Christie, 2015). However, approximately 2 to 7.6 percent of women experience early menopause within the age range of 40 to 45 years (Lambrinoudaki et al., 2022). Menopause brings significant changes to a woman's body, often leading to troublesome symptoms that affect their quality of life. Postmenopausal women also experience a decline in muscle strength, flexibility, and overall physical fitness, which contributes to musculoskeletal disorders (Sutton-Tyrrell et al., 2005). Aging itself results in a normal decline in physical efficiency, including muscle strength (Yassierli et al., 2007) and peak power output (Runge et al., 2004). These changes are attributed to age-related factors and neuromuscular alterations (Kim & Sapienza, 2005). These factors increase the risk of falls, a major public health issue associated with high healthcare costs, disability, hospitalization, nursing home admission, and mortality among older adults (Patel et al., 2014).

Approximately 75% of women experience acute symptoms following menopause, which can have a negative impact on their quality of life. During the transition from menopause, physical and mental health may be adversely affected (Elavsky, 2009). As women enter their sixth decade of life, there is a gradual deterioration in their ability to maintain bodily stability and postural control (Choy et al., 2003). Common postural changes, which may lead to postural deformities (Karimi et al., 2023; Sedaghati et al., 2024), can negatively impact balance, gait, and overall postural function (Cunha-Henriques et al., 2011; Sedaghati et al., 2023). To maintain health and functional capacity, physical exercise is widely recommended for older women (Geirsdottir et al., 2015; Liao et al., 2025). It's important to note that balance limitations in older adults involve deficits in the proprioceptive system, leading to altered movement patterns and difficulties in walking and maintaining postural control. This, in turn, affects their ability to perform daily activities and impacts their quality of life (Critchley et al., 2011; De Almeida et al., 2024). Balance disorders are a significant cause of falls in older adults, resulting in injuries, disabilities, loss of independence, and limitations (Casonatto & Yamacita, 2020). Recent studies have shown that physical exercise programs can improve both basic and instrumental activities of daily living among older women (Langhammer et al., 2018; Leirós-Rodríguez et al., 2019). Individuals with a good standard of living constantly strive to find a balance to maintain their current situation.

The body's systems, such as the nervous and endocrine systems, work collaboratively to maintain balance during physical activities, sports, and training (Demirezer & Biçer, 2023). Mat Pilates has been shown in recent studies to offer various advantages for older adults, including improved dynamic balance, increased lower limb muscle strength, enhanced hip and lower back flexibility, and cardiorespiratory fitness (Bergamin et al., 2015; Buttelli et al., 2021; da Silva Rocha et al., 2022; de Souza et al., 2018). Pilates has demonstrated significant effects on flexibility and dynamic balance, as well as moderate effects on muscular endurance in healthy adults (Byrnes et al., 2018). It is considered a safe and adaptable exercise approach that holds promise in improving muscle strength, balance, functional mobility, and postural stability in older adults (Bergamin et al., 2015; Meikis et al., 2021; Patti et al., 2021).

Julian Casonatto et al. (2019) conducted a study (Casonatto & Yamacita, 2020) examining the impact of Pilates exercise on postural balance in older adults. Their findings, along with those of Fernández-Rodríguez et al. (Fernández-Rodríguez et al., 2021), demonstrated that Pilates exercise has significant benefits for balance, strength, flexibility, functionality, and fall risk reduction among older adults compared to non-exercise or habitual activity. Although the certainty level of these findings ranged from low to moderate, they collectively support the

effectiveness of Pilates training programs in improving balance in older adults. Building upon the existing evidence, the present systematic review aimed to evaluate the effectiveness of Pilates specifically on postural control in menopausal women. By focusing on this specific population, we aimed to provide valuable insights into the potential benefits of Pilates for enhancing postural control in women experiencing menopause.

Methods

Design

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021). The study protocol was registered prospectively with the International Prospective Register of Systematic Reviews (PROSPERO), registration number CRD42023450682.

Search strategy

A literature search was conducted using Web of Science, PubMed, and Scopus databases from inception until August 2, 2025. Two authors, M.A. and M.D., performed the search independently. A comprehensive search strategy was used, combining keywords related to Pilates, exercise movement techniques, mind-body, posture, balance, menopause, and logical operators “AND” and “OR”. Discrepancies were resolved by a third independent author (P.S.). Reference lists of identified studies were also checked for additional relevant articles. A grey literature search was conducted to include unpublished or non-peer-reviewed sources. Selected studies were imported into Endnote software (Thomson Reuters, Endnote 20, 2020) and duplicate records were removed for accuracy and uniqueness of data. To supplement the search for relevant studies, Connected Papers (<https://www.connectedpapers.com/>) was utilized. Also, a comprehensive grey literature search was conducted using Google Scholar to identify conference proceedings, dissertations, clinical trial registries, and preprints. The specific search strategy for each database is detailed in Table 1.

Table 1. Search strategy[illegible]

Scopus (ALL (pilates OR "exercise movement techniques" OR mind-body) AND ALL (posture OR "postural control" OR "postural sway" OR "postural stability" OR "postural steadiness" OR balance OR equilibrium OR sway) AND ALL (menopause OR menopausal OR premenopause OR premenopausal OR postmenopause OR postmenopausal))

Inclusion and exclusion criteria

The studies were chosen based on specific criteria for the population, intervention, comparators, outcomes, and study design (referred to as the PICOS framework) (Methley et al., 2014) as outlined in Table 2.

Table 2. Inclusion and exclusion criteria based on PICOS

	Inclusion criteria	Exclusion criteria
Population	Menopausal women Age mean ≥ 30 years	Experienced any form of a systemic condition History of stroke and physical restrictions affecting exercise capabilities
Intervention	At least 8 weeks of Pilates exercise protocol	Additional physical interventions taking place simultaneously
Comparators	At least a control group without exercise, a group with sham exercise, or a condition for comparison	Studies that lack a control group or conditions for comparison.
Outcomes	Postural control variables (must include one of the following measures: center of pressure, the center of gravity, the center of mass, and other functional scales of postural control). RCT and Non-RCT	Studies that have not explored the direct relationship between Pilates exercise and postural control
Study design	Published in English Published up to August 2, 2025	Not original articles Animal studies

Data extraction

Two authors (M.D. and M.A.) extracted study details (author, year of publication, location), design of study, demographic variables of participants (sample size, groups, age, years of menopause), intervention of non-pilates group, exercise duration, exercise characteristics or frequency, intensity, time, and type (FITT), postural control measures, assessment tool, main outcomes, conclusion, and study quality score (Downs and Black score) from retrieved papers. If any crucial information was found to be absent, the corresponding authors were contacted via email, with a maximum of three attempts made to obtain the necessary details.

Quality assessment

The quality of evidence was assessed by two authors (M.A. and M.D.) using the Downs and Black checklist (Downs & Black, 1998). This checklist is widely regarded as the best tool for evaluating the quality and risk of bias in both randomized and non-randomized controlled trials (RCTs and non-RCTs) (Deeks et al., 2003). The checklist consists of 27 questions grouped into five categories: reporting (10 items), external validity (3 items), bias (7 items), confounding (6 items), and power (1 item). One item in the checklist evaluates statistical power based on the presence or absence of sample size calculation. To simplify this, a modified item for statistical power (item 27) was used, where a score of 1 was given for presence and a score of 0 for absence. The maximum score achievable with this modification is 28. The scores on the checklist are categorized as excellent (26–28), good (20–25), fair (15–19), and poor (≤ 14). In case of disagreements, a third author (P.S.) participated in discussions to reach a consensus.

Data synthesis

In this study, narrative data synthesis was used to ensure comprehensive reporting and transparency. To maintain methodological rigor, the systematic review followed the PRISMA statement guidelines, enhancing the reliability and validity of the findings. Due to diverse outcome measures across the included studies, conducting a meta-analysis was not feasible. Instead, a Synthesis Without Meta-Analysis (SWiM) approach was adopted, aligning with the recommended reporting standards outlined in the SWiM reporting guideline (Campbell et al., 2020).

Results

Study search results

Figure 1 displays the PRISMA 2020 flowchart, which outlines the process of study inclusion. The systematic search provided 486 articles, with 39 duplicates, resulting in 447 articles for screening. After reviewing the abstracts, 18 full texts were screened, leading to the exclusion of 13 studies, and 5 were found eligible for inclusion in the review. Additionally, 10 reports from Connected Papers, hand searching, and citation searching were assessed for eligibility. Ultimately, only 5 studies met the eligibility criteria and underwent a comprehensive quality assessment.

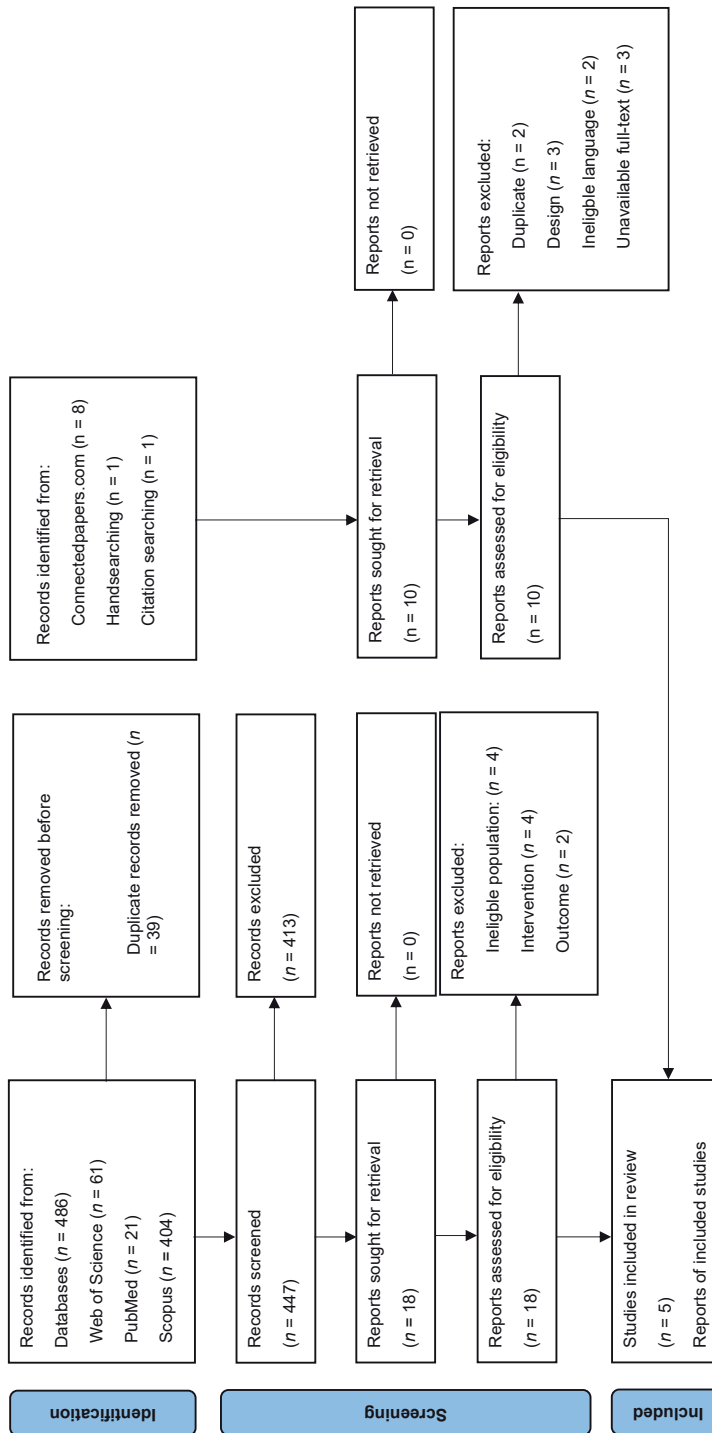


Figure 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers, and other sources

Study characteristics

Our review encompassed RCTs and Non-RCTs that examined the impact of Pilates exercise on women going through menopause. These studies were published between 2015 and 2024, with sample sizes ranging from small pilot studies involving 25 participants (Bergamin et al., 2015) to larger RCTs with 110 participants (Aibar-Almazán et al., 2019). Various outcomes were investigated across the studies, such as static balance, dynamic balance, fall risk, physical performance, and functional mobility. The studies included a total of 284 women at different stages since the onset of menopause, ranging from 12 months to more than a decade. Table 3 provides a summary of the characteristics and data retrieved from all five studies. The following paragraphs will compare various domains of outcomes in the results.

Outcomes

All the studies in the review (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Da Silva et al., 2022; Oliveira et al., 2020; Waer et al., 2024) have shown positive effects on postural control or balance in menopausal or postmenopausal women. One study stated that Pilates alone is insufficient to determine a clinically meaningful improvement in static balance (Bergamin et al., 2015). Three studies (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Da Silva et al., 2022) incorporated a Pilates exercise intervention for 12 weeks, twice a week. One study conducted a 12-week program with three sessions per week (Waer et al., 2024). Another study employed a Pilates exercise program for 24 weeks, with sessions three times per week (Oliveira et al., 2020). Each Pilates exercise session lasted for 60 minutes in four studies (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Oliveira et al., 2020; Waer et al., 2024), while one study utilized a 50-minute exercise duration (Da Silva et al., 2022). Stabilometric platforms (Aibar-Almazán et al., 2019; Bergamin et al., 2015) and a force plate (Oliveira et al., 2020; Waer et al., 2024) were utilized to evaluate postural balance variables and other tools such as the timed up and go test and Mini-BESTest (Da Silva et al., 2022) were employed for this purpose.

Quality appraisal of included studies

The quality assessment results, presented in Table 4, show that the included studies received scores ranging from 18 to 25, with an average score of 21.80. The authors of the study demonstrated complete agreement across all 27 items, as indicated by a Cohen's kappa value of 1. Interpreting the kappa value within established criteria, it reflects perfect agreement (0.81–1.00), while poor agreement is represented by values between 0 and 0.20, fair agreement between 0.21 and 0.40, moderate agreement between 0.41 and 0.60, and good agreement between 0.61 and 0.80 (McHugh, 2012). All studies demonstrated high external validity (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Da Silva et al., 2022; Oliveira et al., 2020; Waer et al., 2024). Sample size calculations were performed for all studies except one (Bergamin et al., 2015). Four studies were categorized as having good methodological quality (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Oliveira et al., 2020; Waer et al., 2024), while one study was conducted with fair methodological quality (Da Silva et al., 2022).

Table 3. Characteristics of included studies

Study details	Design of study	Participant demographics	Intervention of non-pilates group	Exercise duration (weeks)	Exercise characteristics of pilates group	Postural control measures	Assessment tool	Main outcomes	Conclusion
Wear et al. (2024) Romania	RCT	N: 51 Groups: Pilates, Zumba, and Control. Age: [50.6–61.3] Years of menopause: 55	Control: NA. Zumba: 3 one-hour zumba training sessions per week.	12	F: 3 times a week I: 40–55 % of the HR max T: 60 min T: Pilates	Postural control	Force plate	CoP mean velocity: $p < 0.05$	Zumba appears more effective than Pilates for improving postural control and autonomy in postmenopausal women.
Silva et al. (2022) Brazil	Non-RCT	N: 47 Groups: Pilates-COG and Control Age: [57.62–74.56] Years of menopause: NA	Control: daily routine and educational materials on health-related Topics. Groups: Pilates, Whole body vibration, and Control. Age: [48.7–62.7] Years of menopause: 8.76 ± 6.40	12	F: 2 times a week I: Participant's self-limits T: 50 min T: Mat Pilates and multisensory cognitive stimulation	Dynamic balance Functional mobility	Mini-BEST Timed up & go test Timed up & go test with dual-task	Mini-BEST test: $p < 0.001$ Timed up & go: $p < 0.001$ Timed up & go with dual-task: $p < 0.001$	Pilates and cognitive stimulation in dual tasks improve physical functional performance among healthy postmenopausal women.
Oliveira et al. (2020) Brazil	RCT	N: 51 Groups: Pilates, Whole body vibration, and Control. Age: [48.7–62.7] Years of menopause: 8.76 ± 6.40	Control: usual routine. Whole body vibration: was exposed to whole-body vibration for five minutes.	24	F: 3 times a week I: 5<Borg<6 T: 60 min T: Pilates and whole-body vibration	Static balance Dynamic balance Fear of falling	Force plate Timed up & go test The Brazilian version of the falls efficacy scale-international	Average oscillation speed in the anteroposterior and mid-lateral directions: $p > 0.05$ COP displacement area: $p > 0.05$ Timed up & go: $p = 0.032$ Fear of falling: $p = 0.055$	Pilates and WBV can be recommended to improve postural balance in postmenopausal women.
Albar-Almazan et al. (2019) Spain	RCT	N: 110 Groups: Pilates and Control Age: [56.65–77.81] Years of menopause: 20.40 ± 9.34	Control: day-to-day lifestyles. Pilates: 12 sessions of 30 minutes	12	F: 2 times a week I: Basic to intermediate level, to the maximum capacity and resistance of the subject T: 60 min T: Pilates	Postural balance Fear of falling	Stabilometric platform Fear of falling	Anteroposterior displacements of the CoP: $p = 0.004$ Velocity of the CoP displacements: $p = 0.012$	A 12-week Pilates training program has beneficial effects on balance confidence, fear of falling, and postural stability in elderly women.
Bergamin et al. (2015) Italy	Non-RCT	N: 25 Groups: Pilates Age: [59–66] Years of menopause: 12.04 ± 4.26	Control: NA Pilates: 12 sessions of 30 minutes	12	F: 2 times a week I: Very low-intensity T: 60 min T: Pilates	Static balance Dynamic balance	Stabilometric platform 8ft up and go test	Medio-lateral oscillations in open eyes condition: $p < 0.001$ Anterior-posterior oscillations in open eyes condition: $p = 0.598$ 8ft up and go: $p = 0.025$	A 12-week of mat Pilates is not sufficient to determine a clinically meaningful improvement in static balance.

Abbreviations: RCT: Randomized Control Trial, N: Number, COG: Cognitive, F: Frequency, I: Intensity, T: Time, T: Type, CoP: Center of Pressure, and N/A: not applicable.

Table 4. The quality assessment of included studies

Author (year)	Reporting (10 items)	External validity (3 items)	internal validity (bias) (7 items)	internal validity (selection bias) (6 items)	Statistical power (1 item)	Quality score	Quality level
Wear et al. (2024)	9	3	6	5	1	24/28	Good
Silva et al. (2022)	8	3	4	2	1	18/28	Fair
Oliveira et al. (2020)	10	3	5	3	1	22/28	Good
Aibar-Almazan et al. (2019)	9	3	7	5	1	25/28	Good
Bergamin et al. (2015)	9	3	6	2	0	20/28	Good

Note: The Downs and Black checklist score categories are as follows: excellent (26–28), good (20–25), fair (15–19), and poor (≤ 14).

Discussion

The primary objective of this systematic review was to investigate the impact of Pilates exercises on the postural control of menopausal women. The findings of the study revealed a positive relationship, indicating that engaging in Pilates activities has a beneficial effect on enhancing postural control in menopausal women. To gain a comprehensive understanding of the interconnection between the utilization of Pilates and the improvement of postural control in menopausal women, it is crucial to consider several significant factors.

Different menopausal ages

The time since the onset of menopause may influence the effects of physical exercise on menopausal symptoms in women. Previous studies have shown that physical exercise can have positive effects on various aspects of menopausal symptoms, such as depression (Ribeiro et al., 2022), cardiovascular parameters (dos Santos et al., 2020), blood lipid status (Zanescio & Zaros, 2009), and postural balance parameters (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Da Silva et al., 2022; Oliveira et al., 2020). For instance, a randomized placebo-controlled trial found that physical exercise could significantly reduce menopausal symptoms and improve blood lipid status and body weight in middle-aged female medical staff experiencing perimenopausal syndrome (Zanescio & Zaros, 2009). However, a systematic review of the effect of physical exercise on the mental health of women in menopause found that medium- and long-term aerobic and resistance exercise interventions did not show a positive effect on stress (Fausto et al., 2023). Another study investigated the effects of different volumes of moderate aerobic exercise training on metabolic, hemodynamic, and autonomic parameters in an experimental model of menopause and obesity, but did not specifically analyze menopausal symptoms (Ribeiro et al., 2022). Furthermore, despite the acknowledged positive impact of Pilates exercises on the postural balance of menopausal women (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Da Silva et al., 2022; Oliveira et al., 2020; Waer et al., 2024), none of the included studies have compared the effects of time since the onset of menopause.

Different levels of physical activity

The effect of exercise on the human body can vary depending on the individual's physical activity level. Athletes, for example, have a different physiological response to exercise compared to non-athletes (Ángyán et al.,

2005). It is important to note that all the included studies in the inclusion criteria mentioned that the participants were not athletes. Oliveira et al. (Oliveira et al., 2020) required participants to not have practiced physical exercise for at least six months. Similarly, Bergamin et al. (Bergamin et al., 2015) specified that subjects should not have engaged in any structured physical activity or exercise program during the preceding six months. Likewise, Aibar-Almazan et al. (Aibar-Almazán et al., 2019) excluded individuals who had participated in Pilates exercise programs within the past year. Da Silva et al. (Da Silva et al., 2022) required participants to report a sedentary lifestyle for at least six months, and finally, Wear et al. (Waer et al., 2024) noted that participants had neither engaged in exercise training nor recreational sports in the previous six months and presented no contraindications to exercise, as confirmed by a comprehensive physical examination. Given these criteria, it is possible that if the included studies had investigated the effect of Pilates exercise on athlete menopausal women, they may not have demonstrated the positive effects of Pilates on postural control. This is because athletes have a different baseline level of physical fitness and may respond differently to exercise compared to non-athletes. Therefore, it is important to consider the physical activity level of the participants when interpreting the results of studies investigating the effects of exercise on the human body.

Different FITT of Pilates exercise

Engaging in physical activity, such as exercising, multiple times a week, can significantly contribute to improved fitness and overall health. By exercising three times a week, individuals create more opportunities to enhance their physical well-being, leading to more noticeable progress and results (Ralston et al., 2018). On the other hand, exercising twice a week can still yield benefits, but the pace of progress and results may be slower compared to a higher frequency (Thomas & Burns, 2016). The study by Oliveira et al. (Oliveira et al., 2020) revealed that participating in Pilates exercise three times a week for a longer duration over 24 weeks significantly enhanced postural control in menopausal women. This finding suggests that the frequency and duration of exercise may have a substantial impact on specific health outcomes. By comparing it to studies with a lower frequency of two times a week (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Da Silva et al., 2022), the importance of finding a sustainable exercise routine that fits individual lifestyles and commitments is emphasized. Therefore, individuals, especially menopausal women, should consider the potential benefits of engaging in Pilates exercise at a frequency and duration that aligns with their circumstances and health goals.

Static balance in women with menopause

As menopausal women experience a decline in estrogen, their ability to maintain stability while standing can be affected due to reductions in muscle mass and strength, as well as proprioceptive acuity (Im et al., 2019). Changes in body composition, such as increased body fat and decreased bone density, can also impact static balance (Ibeneme et al., 2018). Therefore, it is crucial to understand these mechanisms to develop interventions that can improve balance and reduce the risk of falls in menopausal women. De Souza et al. (de Souza et al., 2018) conducted a meta-analysis that included nine studies, four of which used functional tests and force platforms to evaluate static balance. However, none of the studies found a statistical increase in the measured variables after the training period. On the other hand, Casonatto and Yamacita's (Casonatto & Yamacita, 2020) systematic review and meta-analysis, which included six RCTs, demonstrated significant effects of the Pilates method on static postural balance. It is important to note that both studies had a limited number of RCTs, which restricts the generalizability

of the results. The intervention time in all the studies was a maximum of 12 weeks. Interestingly, Oliveira et al. (Oliveira et al., 2020) extended the Pilates intervention to 24 weeks but did not observe significant results for static postural balance. Despite the non-significant results, the clinical effect of Pilates exercises is noticeable when compared to no treatment ($d > 0.80$). Additionally, Bergamin et al. (Bergamin et al., 2015) discovered that Pilates exercises did not result in any significant statistical differences in anterior-posterior oscillation. The controversy in the included studies may be attributed to the use of different assessment tools (force plate and stabilometric platform) or the influence of different menopausal ages. Nonetheless, the findings suggest that Pilates exercises may be a beneficial intervention for improving static postural balance in menopausal women.

Dynamic balance in women with menopause

According to several meta-analyses, Pilates exercises are effective in improving dynamic balance, especially in older adults. One study (Sampaio et al., 2023) found that Pilates interventions yielded various favorable outcomes, including improvements in balance, while another (Casonatto & Yamacita, 2020) concluded that Pilates training significantly improved dynamic postural balance. A systematic review (Barker et al., 2015) also found that Pilates exercise improved balance and falls in older adults. Additionally, a meta-analysis (de Souza et al., 2018) indicated a large effect of mat Pilates on dynamic balance, muscle strength, and cardiovascular endurance in elderly individuals. Therefore, the evidence suggests that Pilates exercises can be beneficial for improving dynamic balance, particularly in older adults. The high-quality evidence mentioned above is in line with the findings of all five studies (Aibar-Almazán et al., 2019; Bergamin et al., 2015; Da Silva et al., 2022; Oliveira et al., 2020; Waer et al., 2024) that were included in this systematic review.

Mechanisms of pilates for improving postural control in menopausal women

Pilates enhances postural control through targeted activation of the core muscles, including pelvic floor, abdominal, and lumbar stabilizers, which are affected by menopause-related hormonal changes (Cury et al., 2021). It improves proprioception and neuromuscular coordination via mechanoreceptor stimulation, aiding balance and reducing fall risk (Dlugosz-Boś et al., 2021; Hyun et al., 2014). Pilates also induces neuroplastic changes that optimize muscle recruitment and motor control (Carrasco-Poyatos et al., 2019). These exercises strengthen slow-twitch muscle fibers critical for sustained postural stability and correct pelvic alignment (Phrompaet et al., 2011; Poncela-Skupien et al., 2020). These adaptations collectively promote improved balance and functional movement in menopausal women, as demonstrated by our study results.

Strengths and limitations

The strength of this systematic review is rooted in its compliance with the PRISMA guidelines, which guarantee the utilization of optimal methods for conducting and reporting systematic reviews. However, it is important to acknowledge some limitations. The findings are based on a narrative synthesis rather than a meta-analysis, which may introduce subjectivity and limit the precision of effect estimates. The heterogeneity in Pilates exercise content may introduce a significant risk of bias, as the variation in FITT of the exercise could have influenced the balance mechanisms, leading to inconsistent outcomes in terms of postural control. Most interventions were relatively short (12–24 weeks), and the absence of long-term follow-up data restricts our understanding of the sustainability of Pilates benefits. The limited number of included studies further highlights the need for additional high-quality

research, particularly with longer follow-up periods to assess sustained effects on postural control in menopausal women.

Conclusion

Pilates exercises may have a positive influence on postural control in menopausal women; however, given the limited number of studies with small sample sizes and the narrative synthesis approach, the certainty of this evidence remains cautious. When examining the effects of Pilates, factors such as time since menopause onset, physical activity levels, and exercise variations should be considered. Further high-quality research is needed to better understand these relationships and to explore the effects of exercise on diverse populations, including both athletes and non-athletes.

Abbreviations

Non-RCTs	Non-randomized controlled trials
RCTs	Randomized controlled trials
FITT	Frequency, intensity, time, and type

Acknowledgments The authors are sincerely grateful to the reviewers for their valuable feedback.

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Cite this article as: Alghosi, M., Dibazar, M., Sedaghati, P., & Daneshmandi, H. (2025). Effectiveness of Pilates on postural control in women with menopause: a systematic review. *Central European Journal of Sport Sciences and Medicine*, 4(52), 41–55. <https://doi.org/10.18276/cej.2025.4-02>

METABOLIC AND NEUROMUSCULAR RESPONSES TO HIGH-INTENSITY TRAINING WITH AND WITHOUT TAOPATCH® NANOTECHNOLOGY: A PILOT RANDOMIZED CONTROL STUDY

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Abstract High-intensity training (HIT), such as CrossFit® training, causes metabolic and neuromuscular stress. Wearable devices, such as Taopatch®, which combine photobiomodulation and proprioceptive stimulation, have been proposed to enhance metabolic responses during HIT. Our pilot study investigated the acute effects of Taopatch® on metabolic (blood lactate and glycemia) and neuromuscular (handgrip strength and push-up performance) markers in six trained female CrossFit® athletes. Participants were assigned to either experimental group (TAO), who received the Taopatch® device, or the control group (CC), who received the Taopatch® placebo device. Each athlete completed a 15-minute CrossFit® training session. Lactate and glycemia levels were measured at baseline before device application (T0). The Taopatch®, active or placebo, was then applied, and post-training measurements were collected 45 minutes after the end of training (T1), and 90 minutes after the end of training (T2). Strength tests were performed before and after the application of Taopatch®. The results showed no statistically significant differences between groups. However, TAO group showed a stable glycaemic profile and a less marked lactate peak than CC group after the workout, suggesting a potential effect of Taopatch® on metabolic regulation. In neuromuscular parameters, there were no relevant changes between the groups. A small improvement in left-hand grip strength test was observed in TAO group, suggesting that Taopatch® can improve the non-dominant limb. However, the absence of evident effects on neuromuscular parameters could be related to the small sample size and short duration of the study. These preliminary findings suggest a potential modulatory effect on metabolic response that warrants verification in larger, fully-powered trials.

Key words: Taopatch®, AMRAP, High-intensity training, CrossFit®, blood lactate levels, blood glucose, handgrip, push-up, physiological response, motor performance

Introduction

In recent years, high-intensity training (HIT) has gained increasing attention as an effective method for enhancing physical performance and positively influencing many health factors, such as cardiovascular, metabolic and cognitive health. CrossFit®, in particular, is based on the principles of HIT (Ben-Zeev & Okun, 2021) by combining high-intensity resistance exercises with functional movements to improve muscle strength and aerobic capacity while reducing body fat (Ficarra et al., 2022; Escobar et al., 2017). Among the most commonly used programs in CrossFit® is AMRAP (As Many Rounds/Repetitions As Possible), which involves performing as many repetitions or rounds of predefined exercises as possible within a set time frame, usually between 10 and 20 minutes (Barba-Ruiz et al., 2024). From a metabolic perspective, CrossFit® workouts produce important physiological responses, particularly with regard to blood lactate and glucose levels. The HIT and short recovery times, characteristic of this program, promote a rapid shift towards anaerobic energy pathways. Consequently, substantial increases in blood lactate concentrations are evident, reflecting the significant metabolic demand and glycolytic activity during exercise (De-Oliveira et al., 2021; Toledo et al., 2021). Additionally, acute CrossFit® sessions can lead to transient glycemia variations, with levels often rising during exercise due to increased hepatic glucose production. This is followed by a post-exercise decrease as glucose uptake by skeletal muscles increases (Camacho et al., 2005; Rose & Richter, 2005). In this context, innovative technologies are designed to enhance physical performance and physiological efficiency during HIT. One such technology is the Taopatch®

a wearable nanotechnology-based device that combines photonic stimulation with proprioceptive input to influence neuromuscular function (Campoli et al., 2025; Messina et al., 2022). Preliminary evidence suggests that Taopatch® may modulate biological responses by enhancing postural control and muscle coordination, as well as potentially improving metabolic efficiency during physical activity (Amato et al., 2021; Lomeo et al., 2019). However, there are limited data available regarding its acute effects during HIT, such as CrossFit® workout. The pilot study aims to evaluate the metabolic and neuromuscular responses following a CrossFit® training, with Taopatch® and a placebo device. By examining the metabolic effects, this research aims to fill a gap in the literature by exploring if Taopatch® can improve performance and recovery in HIT reducing metabolic stress. These findings are expected to advance scientific knowledge of the metabolic and neuromuscular effects.

Materials and Methods

Study Design

This study was designed as a pilot study aimed at evaluate protocol feasibility and preliminary variability of physiological response. Therefore, no a priori power calculation was performed. We aimed to focus on acute physiological markers, specifically lactate and glycemia levels, handgrip strength and muscular endurance by push-up performance. These markers are well established in capturing key neuromuscular and metabolic adaptations during high-intensity functional exercise. These parameters are directly involved in anaerobic energy metabolism, neuromuscular activation and short-term performance output, all of which are critical in CrossFit® training (Scoubeau et al., 2023). Specifically, blood lactate concentration provides insight into anaerobic glycolysis and the metabolic load imposed by intense effort (Jacob et al., 2023), while glycemia reflects acute fluctuations in carbohydrate metabolism and endocrine regulation under physical stress. Both are key indicators of the body's ability to mobilize and utilize energy during HIT (Jacob et al., 2022; Peter Adams, 2013). The handgrip strength test is a reliable indicator of isometric muscular force and neuromuscular efficiency and is associated with overall upper body strength in athletes (Vaidya & Nariya, 2021). Finally, the push-up performance test provides a functional assessment of muscular endurance and coordination under fatigue (Nasrulloh et al., 2022). Together, these outcome measures provide insight into how neuromuscular performance and metabolic responses can be modulated acutely by non-invasive technologies such as Taopatch®, paving the way for future applications in optimising training and recovery strategies for high-intensity modalities.

Participants

Six female advanced athletes were enrolled in our study. The anthropometric characteristics of the participants are shown in Table 1. The inclusion criteria were as follows: absence of musculoskeletal injuries, chronic illnesses, or any condition that could compromise either safety or performance during the study, aged between 21 and 49, right dominant limb and at least two years' experience of performing CrossFit®. Exclusion criteria included recent pharmacological treatments affecting metabolism or muscle performance, and pregnancy. The participants were randomly assigned to two groups: the experimental group (TAO) with Taopatch® (n = 3) and the control group (CC) with placebo Taopatch® (n = 3). This was done randomly via "wheel of names" software. All participants were fully informed about the study protocols before its commencement and provided written informed consent for all tests. The study was conducted following the Declaration of Helsinki and approved by the Ethics Committee of Palermo 1

(Approval No. 240/2024), Department of Psychological, Educational and Movement Sciences, University of Palermo. Upon enrolment, participants completed a questionnaire to gather anthropometric and training habit data.

Table 1. Means and standard deviations (SD) of the participants' anthropometric characteristics.

Characteristics	Control Group (CC)	Experimental Group (TAO)
	Mean $\pm$ SD	Mean $\pm$ SD
Age (years)	30.3 $\pm$ 16.2	39 $\pm$ 14.8
Body mass (kg)	60.3 $\pm$ 2.5	60 $\pm$ 7
Body height (cm)	165 $\pm$ 5	160.7 $\pm$ 5.5
BMI (kg $\cdot$ m ⁻²)	22.2 $\pm$ 1.9	23.2 $\pm$ 1.5

BMI = body mass index.

Assessments

Participants of both groups performed a hand grip test and push-up test before and after the application of Taopatch®. In addition, lactate and glucose levels were evaluated in all participants at baseline (T0), 45 minutes after the Crossfit® training (T1) and 90 minutes after the end of training program (T2), with a passive recovery, during which no stretching, eating, or excessive hydration was allowed. Blood samples were placed on test strips for quantification of glucose and lactate (Accutrend® Plus Glucose and Accutrend® Plus BM-Lactate, Roche). Handgrip test (KERN MAP Version 1.2 08/2012, Hand Grip Dynamometer) was used to assess the strength of the flexor muscles through maximum isometric grip (MIG), an important indicator of musculoskeletal function. Participants performed three trials per hand with their elbow flexed at 90°. The mean value obtained from the three trials for each hand was used for data analysis. A push-up test was conducted based on the maximum number of repetitions that each participant could perform in one minute. Participants performed push-ups from a prone position with their legs fully extended and their hands placed directly under their shoulders. Each repetition required them to touch their chest to the floor and then return to the starting position with their arms fully extended. They had to maintain a straight body line throughout, without bending at the hips or knees.

Intervention

Before starting the Crossfit® training, two Taopatch® devices, containing a mixture of nanotechnology with nanocrystals called "quantum dots," were applied one below the vertebrae C7 posteriorly and one on the xiphoid process anteriorly (Amato et al., 2021; Carbonari et al., 2021). The experimental group (n = 3) used the active devices. The control group (n = 3) used a placebo device, that is identical in appearance and texture to the active one, but without photobiomodulatory activity. It was applied to the same area of the body, in the same way as the active Taopatch® to ensure that no subjects could distinguish between the active treatment and the placebo.

2.5 Crossfit® Program

The AMRAP (As Many Rounds As Possible) session was structured as a single HIT based on a 15-minute of Crossfit® training protocol, aimed at enhancing muscular endurance, strength, and cardiorespiratory fitness. The study was carried out under the supervision of a kinesiologist to ensure the appropriate technique of the exercises and belaying. Immediately before the Crossfit® training, all participants performed an identical warm-up. The purpose of the warm-up was to prepare the muscles and joints for heavy effort, while minimizing fatigue during it, so as not to reduce the size of the weight lifted in the maximum repetition (Durkalec-Michalski et al., 2022).

The session was organized to allow two participants to begin at a time, with a staggered start every 5 minutes to ensure optimal space utilization and individualized supervision. The circuit included the exercises shown in Table 2.

Table 2. CrossFit® protocol

CrossFit®	Characteristics	Aim	Total duration
10 Shuttle runs	Covering 7 meters out and 7 meters back per repetition	To assess aerobic fitness and to stimulate agility and cardiovascular effort (Ambroży et al., 2022; Cataldi et al., 2021; Cruz-León et al., 2025)	15 min
Ladder +2	For each round completed, participants increased the number of repetitions of each exercise by 2	Promoting progressive overload and muscular endurance.	
6 down & up	A simplified burpee variation without the push-up phase	Developing full-body coordination and anaerobic capacity	
2 dumbbell thrusters	Combining a front squat and an overhead press using dumbbells	To targeting both lower and upper body strength	

Participants were instructed to complete as many rounds as possible within the 15-minute time limit, maintaining proper form and safety throughout. The Crossfit® training was chosen for its ability to individualize intensity based on each participant's fitness level, while ensuring a consistent workload for comparison across subjects.

Statistical Analysis

Statistical analysis was performed with “Jamovi” software version “2.6.26.0”. Data in descriptive statistical analysis were expressed as means and standard deviations. The Shapiro-Wilk test was used to check for normal distribution, showing that all variables were normally distributed ($p > 0.05$), supporting the use of parametric tests. Repeated measures ANOVA was used to assess the effects of time (T0, T1, T2), group (CC vs. TAO), and their interaction on glycemia, lactate, handgrip and push-up test. Post-hoc test Bonferroni was used to compare these differences in the two groups. A 5% probability level was considered significant. Due to the preliminary nature of the pilot and the very small sample size, statistical analyses are exploratory.

Results

Metabolic parameters, as glycemia (mg/dL) and lactate (mmol/L) levels, were assessed at three times: at baseline (T0), 45 minutes after the Crossfit® training (T1) and 90 minutes after the end of training (T2), to observe the response of HIT in the control group (CC) and experimental group (TAO) with the application of Taopatch® (Table 3). Results showed that glycemia levels increased more markedly in the CC group than in the TAO group. In particular, in CC group, glycemia increased from T0 (88.3 ± 21.1 mg/dL) to T1 (126.7 ± 60.1 mg/dL), while in TAO group, glycemia levels increased from 73.7 ± 16.8 mg/dL to 86.0 ± 42.1 mg/dL. Regarding lactate levels, both groups showed an increase after the training program; nevertheless, in CC group, the lactate level rose to 9.9 ± 2.7 mmol/L, whilst in TAO group lactate increased up to 7.9 ± 3.8 mmol/L at T1 time point.

Table 3. Metabolic parameters (mean $\pm$ SD) in experimental (TAO) and control group (CC) at baseline (T0), 45 minutes after the Crossfit® training program with the application of Taopatch® device (T1) and 90 minutes after the training (T2).

Parameters	Group	T0	T1	T2
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Glycemia (Mg/dL)	TAO	73.7 $\pm$ 16.8	86.0 $\pm$ 42.1	59.7 $\pm$ 17.1
	CC	88.3 $\pm$ 21.1	126.7 $\pm$ 60.1	79.0 $\pm$ 7.8
Lactate (Mmol/L)	TAO	1.1 $\pm$ 0.5	7.9 $\pm$ 3.8	3.4 $\pm$ 2.4
	CC	1.2 $\pm$ 0.6	9.9 $\pm$ 2.7	2.6 $\pm$ 1.6

In addition, to determine whether Taopatch® had an immediate impact on strength, neuromuscular parameters were assessed before and after the Taopatch® application through isometric strength (handgrip) and a muscle endurance test (Table 4). In the right handgrip test, CC group showed a slight increase from 29.7 $\pm$ 5.7 kg to 31.6 $\pm$ 6.2 kg, while it didn't change in TAO group (27.6 $\pm$ 2.0 kg vs 27.8 $\pm$ 2.6 kg). An opposite situation was highlighted for the left hand in which there was an increase just in TAO group from 25.4 $\pm$ 3.3 kg to 27.1 $\pm$ 3.2 kg. As concerns the push-up test, TAO group showed a slight improvement in performance before (21.7 $\pm$ 6.7) and after (23.3 $\pm$ 7.0), while in CC group, the performance remained almost unchanged.

Table 4. Neuromuscular parameters (mean $\pm$ SD) in experimental (TAO) and control group (CC) before and after the application of Taopatch®.

Parameters	Group	Before	After
		Mean $\pm$ SD	Mean $\pm$ SD
Handgrip R (kg)	TAO	27.6 $\pm$ 2.0	27.8 $\pm$ 2.6
	CC	29.7 $\pm$ 5.7	31.6 $\pm$ 6.2
Handgrip L (kg)	TAO	25.4 $\pm$ 3.3	27.1 $\pm$ 3.2
	CC	27.6 $\pm$ 4.8	28.4 $\pm$ 5.1
Push-Up (n° Reps)	TAO	21.7 $\pm$ 6.7	23.3 $\pm$ 7.0
	CC	34.0 $\pm$ 6.1	35.3 $\pm$ 1.5

Discussion

This pilot study investigated the acute effects of Taopatch® on the metabolic and neuromuscular responses of trained female athletes to high-intensity CrossFit® training. The physiological responses to Crossfit® training are well documented in the literature (Hafidz et al., 2022; Wibowo et al., 2022). HIT is known to increase metabolic stress, influence muscular endurance, and briefly alter blood parameters such as lactate and glycemia. In our pilot study, both groups, TAO and CC, performed a 15-minute Crossfit® workout, aiming to investigate whether the combination of Taopatch® with physical activity could enhance functional and physiological responses in healthy subjects, reducing the metabolic stress. The results suggest a potentially favourable impact of the device on the metabolic responses to intense exercise. As expected, following the Crossfit® training, glycemia levels increased in both groups, suggesting an initial increase linked to metabolic response to exercise, with subsequent redistribution and possible utilisation of glucose in muscle tissue during the recovery phase. This tendency can be attributed to the body's physiological response to high-intensity exercise that involves an increase in catecholamines (adrenaline

and noradrenaline), which stimulate glycogenolysis and gluconeogenesis, and inhibit the action of hypoglycaemic hormones, resulting in a temporary increase in blood glucose levels. During exercise, glucose uptake by skeletal muscle increases; this is mediated by an increase in insulin-sensitive GLUT4 transporters, with a consequent reduction in plasma glucose level. In high-intensity training, a glycaemic threshold can be identified that indicates the relationship between effort intensity, muscle glucose utilisation and reduced hepatic availability (Mota et al., 2021). TAO group showed a more stable glycemia profile compared to CC group. In particular, glycemia levels in TAO group increased moderately from T0 to T1, without showing a marked peak compared to CC group (CC 88.3 ± 21.1 vs 126.7 ± 60.1 ; TAO 73.7 ± 16.8 vs 86.0 ± 42.1). This suggests that the device may modulate the glycaemic response to HIT and, consequently, promoting a more efficient exercise metabolic response. Therefore, as expected, in response to HIT, both groups showed a marked increase in lactate levels at T1; however, CC group reached a higher lactate peak than TAO group, suggesting a greater activation of the anaerobic pathway and metabolic stress induction. This may reflect a more balanced metabolic recovery and a better metabolic tolerance, in which lactate reuse is more efficient in TAO group than in CC group (Meier et al., 2021; Eroglu et al., 2023). It is possible that Taopatch® could influence pathways related to AMPK/PGC-1 α activation and GLUT4 expression, contributing to better glycemia control and efficient muscle glycogen synthesis (Chen et al., 2025). These results suggest that Taopatch® may modulate the metabolic response to HIT, thereby reducing excessive lactate accumulation. As muscle fatigue can influence neuromuscular performance, particularly in strength-based tasks, it was important to evaluate changes in upper limb function. In the strength test, the TAO group showed no significant change on the right side, while on the left side, it showed a greater improvement compared to CC group (TAO 27.1 ± 3.2 vs CC 28.4 ± 5.1). This could be a power-up of the non-dominant limb, for a better adaptation and improvement. Regarding muscular endurance, the push-up test didn't show any marked change between the groups. These results, while not statistically significant, suggest that the use of Taopatch® in combination with HIT may enhance short-term metabolic responses. However further studies are needed to confirm these assumptions.

Conclusions

The pilot study aimed to investigate the acute metabolic and functional effects of a 15-minute Crossfit® workout in trained subjects, with and without the use of Taopatch® technologies, to understand if there should be a synergistic effect able to reduce metabolic stress with better glycaemic control, lactate management, and upper body performance. However, either the results didn't show a significant statistical change, or they laid a starting point for future investigation to better define the potential role of Taopatch® in improving the metabolic response to HIT. The results obtained in TAO group suggest that Taopatch® may have contributed to modulating the metabolic response to exercise, reducing excessive lactate accumulation and promoting more efficient post-workout glycaemic regulation. This pilot study could open new setups on improving performance by improving the metabolic response to HIT. The main limitations of the study are the small sample size ($n = 6$) and short duration of the intervention, which prevents any firm statistical conclusions and may have limited the detection of more subtle changes, particularly those associated with neuromuscular function and performance relating to the use of the device. Further studies into long-term integration of Taopatch® into structured training programmes could provide more insights into its impact on metabolic and neuromuscular parameters, such as strength, endurance and motor control. This pilot study should therefore be interpreted as a feasibility investigation, providing preliminary insights

and generating hypotheses for future to more definitive assessments of the effects of Taopatch® on metabolic and neuromuscular responses.

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Cite this article as: Boatta, A., Pagliaro, A., Messina, G., Alioto, A., Mingrino, O., Kostrzewa-Nowak, D., Nowak, R., & Proia, P. (2025). Metabolic and Neuromuscular Responses to High-Intensity Training with and without Taopatch® Nanotechnology: A Pilot Randomized Control Study. *Central European Journal of Sport Sciences and Medicine*, 4(52), 57–65. <https://doi.org/10.18276/cej.2025.4-05>

PREDISPOSITION TO EATING DISORDERS AMONG BALLET DANCERS: AN ANALYSIS USING THE EAT-26 AND EDE-Q QUESTIONNAIRES

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Abstract Eating disorders (EDs) are complex psychiatric conditions with consequences extending to both somatic and psychosocial domains. Their prevalence among physically active individuals, particularly within artistic environments, has attracted considerable scientific attention. Ballet dancers constitute one of the groups especially predisposed to these disorders. Ballet requires not only exceptional physical fitness but also the fulfillment of specific aesthetic standards, including the maintenance of a slender body shape. Consequently, ballet dancers are at elevated risk of developing anorexia nervosa, bulimia nervosa, and other forms of disordered eating.

The aim of this study was to analyze the predisposition to eating disorders among ballet dancers using validated diagnostic tools (EAT-26 and EDE-Q). The study included 25 adult ($20,7 \pm 2,3$ years) female ballet dancers from Poland.

The results revealed that more than half (52%) of the participants obtained scores indicative of a high risk of EDs (≥ 20 points, indicating predisposition to eating disorders). These findings highlight the need for further investigation of this issue and underscore the importance of implementing preventive and therapeutic interventions.

Key words: ballet, eating disorders, anorexia, bulimia

Introduction

Eating disorders (EDs) are defined as chronic, persistent, and abnormal eating behaviors of psychological origin that result in impaired intake and absorption of nutrients (Mróz & Korek, 2020). In the ICD-10 classification, they are categorized as behavioral disorders associated with psychological, physiological, and physical factors (Mikołajczyk & Samochowiec, 2004). According to the DSM-5, EDs are characterized by enduring gastrointestinal symptoms and maladaptive eating-related behaviors that lead to disordered nutrient intake and absorption, ultimately impairing psychological, physical, and social health (Biskupek-Wanot et al., 2020).

The DSM-5 distinguishes six primary diagnostic categories: anorexia nervosa (AN), bulimia nervosa (BN), binge eating disorder (BED), avoidant/restrictive food intake disorder (ARFID), rumination disorder, and pica. It also recognizes other specified feeding or eating disorders (OSFED) and unspecified feeding or eating disorders (UFED).

Rome & Strandjord, (2016), which include, among others, purging disorder and night eating syndrome (Jabłońska et al., 2019). In clinical practice, additional emerging patterns, such as orthorexia nervosa and muscle dysmorphia (bigorexia), are also observed (Mróz & Korek, 2020).

Within the context of ballet dancers, two disorders are of particular significance—anorexia nervosa and bulimia nervosa—and the following discussion will focus primarily on these conditions.

The development of EDs is multifactorial, with psychological, social, cultural, biological, and familial determinants all playing a role (Jabłońska et al., 2019).

Psychological determinants include personality traits such as perfectionism, low self-esteem, excessive ambition, sensitivity to criticism, and insecurity (Biskupek-Wanot et al., 2020). Individuals with EDs frequently exhibit high levels of intelligence while simultaneously displaying a lack of trust in themselves and others.

Sociocultural influences play a pivotal role. Media and the Internet promote thinness as a standard of beauty and success, which in predisposed individuals fosters body dissatisfaction (Jabłońska et al., 2019). Particularly harmful are pro-anorexia (“pro-ana”) online forums, where affected individuals exchange “tips” on concealing symptoms and encourage one another in unhealthy pursuits of weight loss (Peter & Brosius, 2021).

Biological contributors include both genetic predispositions and neurobiological abnormalities. Mutations in the ESRRA and HDAC4 genes have been implicated in increasing the risk of EDs (Cui et al., 2013). Dysregulations in neurotransmitter systems—dopamine, serotonin, and norepinephrine—as well as gut microbiota disturbances that may influence emotion regulation and satiety have also been highlighted (Jabłońska et al., 2019).

Family dynamics are of considerable importance. Healthy family functioning reduces the risk of EDs, whereas dysfunctions such as lack of emotional support, appearance-related criticism, and excessive pressure significantly elevate the likelihood of their development (Kierus et al., 2012).

The treatment of EDs requires an interdisciplinary approach. Core management includes the cooperation of a psychiatrist, psychotherapist, and dietitian, and when necessary, specialists in other fields. Prior to initiating therapy, an assessment of somatic status is essential, including laboratory and imaging studies (Biskupek-Wanot et al., 2020). Indications for hospitalization comprise severe somatic symptoms, suicide risk, profound malnutrition, or the ineffectiveness of outpatient treatment (Rome & Strandjord, 2016).

Nutritional therapy focuses on the gradual restoration of body weight, correction of nutrient deficiencies, and adequate hydration (Biskupek-Wanot et al., 2020). In justified cases, pharmacological treatment is employed, most commonly antidepressants and medications supporting the function of compromised organ systems (Hilbert et al., 2017). Complementary interventions include family-based therapy and patient education on stress management and healthy eating practices (Długosz et al., 2020).

Anorexia nervosa (AN) is a severe psychiatric disorder most commonly affecting adolescents and young women. It is estimated that approximately 1% of women and 0.5% of men in developed countries suffer from this condition (Zipfel et al., 2015). Anorexia nervosa is characterized by the pursuit of significantly reduced body weight through dietary restriction, fasting, or excessive physical activity (Pytlińska, 2010). Two subtypes are distinguished: the restrictive type and the binge-eating/purging type, which may also coexist (Rome & Strandjord, 2016). Importantly, AN is associated with the highest mortality rate among all eating disorders, ranging from 3.2% to 6.6%, particularly in cases with comorbid substance use, endocrine disturbances, and severe somatic deficits (Eddy et al., 2015; Franko et al., 2013).

According to DSM-V criteria, the diagnosis of AN includes restriction of energy intake leading to undernutrition, intense fear of gaining weight, and body image disturbances (Rome & Strandjord, 2016). In the ICD-10 classification, emphasis is placed on body weight reduction of $\geq 15\%$ or $\text{BMI} \leq 17.5 \text{ kg/m}^2$, accompanied by endocrine abnormalities (Zipfel et al., 2015). Screening tools such as the SCOFF questionnaire may be helpful in identifying individuals at risk (Sim et al., 2010).

The occurrence of anorexia nervosa is influenced by biological, psychological, environmental, and familial factors. Women are ten times more likely to develop the disorder than men (Treasure et al., 2020). A positive family history increases the risk, suggesting genetic predispositions (Peterson & Fuller, 2019). Dysregulation of neurotransmitters such as serotonin, dopamine, and norepinephrine has been associated with obsessive-compulsive and anxiety-related behaviors (Jabłońska et al., 2019). Psychologically, traits such as perfectionism, cognitive rigidity, and a distorted body image are typical among individuals with AN (Treasure et al., 2020). Sociocultural factors include media pressure, the influence of pro-ana online forums, and the specific demands of professions requiring a lean physique, such as ballet or modeling (Peterson & Fuller, 2019). Family dynamics also play a significant role; excessive parental control, particularly within the mother-daughter relationship, has been shown to increase vulnerability to the disorder (Kierus et al., 2012).

Individuals with AN often avoid shared meals, obsessively count calories, engage in excessive exercise, and resort to weight-loss behaviors such as self-induced vomiting or the misuse of laxatives. Social withdrawal and denial of illness are also common features (Jabłońska et al., 2019).

Anorexia nervosa results in a wide range of medical and psychological complications, including endocrine disorders (amenorrhea, infertility, hypoglycemia), cardiovascular dysfunctions (bradycardia, arrhythmias, hypotension), and gastrointestinal problems (constipation, bloating, perforations). Additional complications include osteoporosis, muscle wasting, dermatological manifestations (lanugo, xerosis), and psychiatric comorbidities such as depression (Skoczeń et al., 2014; Strumia, 2009).

Bulimia nervosa (BN) is characterized by recurrent episodes of uncontrolled binge eating followed by compensatory behaviors such as self-induced vomiting, misuse of laxatives, or excessive exercise (Biskupek-Wanot et al., 2020). The disorder affects approximately 3% of young women (Rome & Strandjord, 2016). Two subtypes are distinguished: the purging and the non-purging types (Jabłońska et al., 2019).

According to DSM-V, diagnostic criteria include recurrent binge-eating episodes accompanied by a loss of control, compensatory behaviors occurring at least once per week for three months, and excessive emphasis on body weight and shape in self-evaluation (Rome & Strandjord, 2016). ICD-10 highlights preoccupation with eating, a compulsive drive to eat, and the presence of compensatory behaviors (Jabłońska et al., 2019).

Major contributing factors include familial and psychiatric burdens, such as anxiety and bipolar disorders (Castillo & Weisler, 2017). Biological predispositions involve a higher prevalence in women, neurotransmitter imbalances, and alterations in leptin and ghrelin synthesis (Castillo & Weisler, 2017; Maciąg & Maciąg, 2018; Monteleone et al., 2018). Sociocultural influences, including cultural pressure, negative social experiences, and phenomena such as fat talk, are significant risk factors (Treasure et al., 2020). Pro-mia online forums further exacerbate risk by facilitating the exchange of compensatory “techniques” (Jabłońska et al., 2019).

Individuals with BN consume large amounts of high-calorie food within a short period, typically in isolation, followed by compensatory methods to avoid weight gain. Body weight often remains within the normal range, which complicates early detection and diagnosis (Osińska et al., 2021).

Common complications include dehydration, electrolyte imbalances (particularly hypokalemia), dental enamel erosion, esophageal mucosal damage, and salivary gland inflammation. Further consequences may involve renal, gastrointestinal, and cardiovascular disorders. BN is also frequently associated with psychiatric comorbidities, including depression and anxiety disorders (Osińska et al. 2021; Franczak-Young & Jezierska-Kazberuk, 2011).

Eating disorders, particularly anorexia nervosa and bulimia nervosa, represent severe illnesses with a complex etiology encompassing biological, psychological, familial, and cultural factors.

Ballet dancers are at especially high risk due to strict aesthetic requirements and pressures within the artistic environment. In the study of Arcelus et al. the overall prevalence of eating disorders was 12.0% (16.4% for ballet dancers), 2.0% (4% for ballet dancers) for anorexia, 4.4% (2% for ballet dancers) for bulimia and 9.5% (14.9% for ballet dancers) for eating disorders (Arcelus et al. 2014). Both disorders are associated with serious somatic and psychological complications, and effective treatment requires an interdisciplinary approach combined with family support. In Poland, there are only a few publications on ballet dancers and eating disorders. Available studies often involve ballet school price lists, small clinical samples, or are part of academic dissertations and reports; large, representative, nationwide epidemiologies of eating disorders solely in the dancer population are rare.

The aim of this study was to analyze the predisposition to eating disorders among ballet dancers using validated diagnostic tools (EAT-26 and EDE-Q).

Materials and Methods

The study included 25 adult (20.7 ± 2.3 years) female ballet dancers who met the following criteria: female gender, age ≥ 18 years, and a minimum of 5 years of ballet training experience and declaration of professional activity – current participation in ballet training and performances. Participants were recruited via social media platforms. After providing informed consent, they proceeded to complete an online survey.

The questionnaire consisted of three parts:

- Author's section – covered sociodemographic data, anthropometric parameters, training intensity, lifestyle, and dietary habits.
- EAT-26 – created by Garnert et al. (1982) a widely used screening tool in population-based studies (Penniment & Egan, 2012; Anshel, 2004; Łucka et al., 2019; Szabo & Allwood, 2004; Czech-Szczapa (n.d.), 2012; Kaźmierczak et al. 2017). A score of ≥ 20 points indicates an increased risk of eating disorders.
- EDE-Q – a self-report questionnaire comprising 22 items rated on a 0–6 scale, assessing four subscales: restraint, eating concern, shape concern, and weight concern, as well as a global score (Jennings & Phillips, 2017; Mond et al. 2006).

Statistical analysis was conducted using TIBCO Statistica 14.0, means and standard deviations for quantitative variables and percentages for qualitative variables. Results were compared against population norms (Jennings & Phillips, 2017; Mond et al. 2006).

Results

1. Participant Characteristics

The study included 25 young female ballet dancers, all of Polish nationality. The majority (88%) resided in cities with populations exceeding 50,000, while 12% came from rural areas. The mean age was 20.72 ± 2.7 years (range: 18–28), and the average ballet training experience was 11 ± 4.3 years.

A total of 56% of participants reported ballet achievements, including solo performances, international stage appearances, foreign scholarships, and awards in national or school competitions. Additionally, 80% were employed, reporting moderate to high physical activity at work, primarily standing or mixed-type occupations.

2. Height, Body Mass, BMI and Physical Activity

The mean body mass was 52.7 ± 6.2 kg (range: 35–62 kg), and mean height 167.3 ± 6.5 cm (range: 158–183 cm). The mean BMI was 18.8 ± 2.8 kg/m², with 40% of participants underweight (BMI <18.5 kg/m²), and 60% within the normal range (18.5–24.9 kg/m²). BMI values ranged from 13.5 to 23.7 kg/m².

Participants engaged in an average of 5 ± 1.2 ballet training sessions per week, with a mean duration of 3.5 ± 0.6 hours per session. Additional physical activities such as yoga, pilates, running, gym workouts, contemporary dance, and others were reported by 56% of participants (Table 1).

Table 1. Anthropometric characteristics and training activity of study group

Parameter	Mean $\pm$ SD	Range
Weight (kg)	52.7 ± 7.4	35–62
Height (cm)	167.3 ± 6.7	158–183
BMI (kg/m ²)	18.8 ± 3.0	13.5–23.7
BMI classification: underweight	10 (40%)	
BMI classification: normal	15 (60%)	
Training frequency (sessions/week)	5 ± 1.2	3–7
Training duration (hours/session)	3.5 ± 0.7	2.5–4.5
Participation in additional physical activities	14 (56%)	

3. Dietary Habits and Lifestyle

The majority of participants (60%) rated their diet as “healthy,” 16% as “unhealthy,” and 34% were unable to specify. Most consumed 3–4 meals daily (64%), 5 meals (20%), 2 meals (12%), and more than 5 meals (8%). Only 24% reported balanced meals, and 18% ate regularly. 12% consumed peri-training meals, with 20% answering “rather yes.”

Snacking behavior was regular in 28%, sporadic in 60%. Preferred snacks included sweets, pastries, fruits, vegetables, nuts, hummus, and granola. Fast-food consumption was once per week in 8%, 1–2 times per month in 52%, several times per year in 32%, and avoided by 8%. Sweets were consumed several times per week by 52%, once per week by 28%, and 1–2 times per month by 20%. Salty snacks were eaten several times per week by 36%, once per week by 36%, 1–2 times per month by 20%, several times per year by 4%, and never by one participant.

Hydration was ≤ 2 L/day in 76%, with water, tea, coffee, fruit juices, and isotonic drinks preferred. 32% reported dietary supplementation, including vitamins D, E, A, C, B12, B6, minerals (magnesium, calcium), collagen, and probiotics. Routine medical examinations at least once per year were performed by 64%. Sleep duration was 5–6 hours (20%), 7–8 hours (52%), and >8 hours (28%) (Table 2).

Table 2. Characteristics of dietary habits of the surveyed ballet dancers (n = 25)

Variable	Category / Frequency	Number of Participants (n)	Percentage (%)
Self-assessment of diet	Healthy	15	60
	Unhealthy	4	16
	Undefined	6	24
Number of meals per day	2	3	12
	3–4	16	64
	5	5	20
	>5	2	8
Meal balance	Yes	6	24
Meal regularity	Yes	4	18
Pre/post-training meals	Yes	3	12
	Rather yes	5	20
Snacking	Regularly	7	28
	Occasionally	15	60
Consumption of sweets	Several times per week	13	52
	Once a week	7	28
	1–2 times per month	5	20
Consumption of salty snacks	Several times per week	9	36
	Once a week	9	36
	1–2 times per month	5	20
	Several times per year	1	4
	Never	1	4
Fast-food consumption	Once a week	2	8
	1–2 times per month	13	52
	Several times per year	8	32
	Never	2	8
Hydration (daily water intake)	≤2 L	19	76
	>2 L	6	24
Dietary supplementation	Yes	8	32
	No	17	68

4. EAT-26 Results

Analysis of EAT-26 revealed that 13 of 25 participants (52%) scored ≥ 20 points, indicating predisposition to eating disorders. The highest scores were in the Dieting subscale (92.3% of predisposed participants), while the Bulimia and Food Preoccupation subscale did not reach maximum values, although 9 participants scored second highest.

5. EDE-Q Results

The highest EDE-Q subscale scores were observed for Shape Concern (3.57) and Weight Concern (3.29), while the lowest was in Eating Concern (1.52). The global score was 2.66. Subscale distributions are summarized in Table 3.

Table 3. Distribution of EDE-Q subscale scores and mean BMI

EDE-Q Subscale	Score range	% of participants	Mean BMI (kg/m ²)
Over-control of eating habits and physical activity	≤1	28%	18.1
	1–2	8%	18.0
	2–3	40%	18.6
	3–4	16%	20.9
	>4	8%	17.1
Concern about eating	≤1	40%	18.4
	1–2	24%	19.5
	2–3	8%	17.1
	3–4	24%	19.0
	>4	4%	21.7
Shape concern	≤1	8%	19.2
	1–2	20%	18.1
	2–3	8%	18.3
	3–4	16%	17.8
	>4	48%	19.5
Weight concern	≤1	12%	18.8
	1–2	16%	18.6
	2–3	20%	18.4
	3–4	4%	20.2
	>4	48%	19.0
Global score	≤1	12%	18.4
	1–2	28%	18.3
	2–3	8%	15.6
	3–4	28%	19.4
	>4	24%	20.1

6. Compensatory Behaviors

Compensatory behaviors aimed at controlling body weight or shape were observed in the study group. Detailed results are presented in Table 4.

Table 4. Compensatory behaviors reported to reduce body weight/maintain appropriate body shape (EDE-Q questionnaire)

Compensatory behavior	Number of participants (n, %)
Use of laxatives	5 (20%)
Self-induced vomiting	3 (12%)
Excessive training intensity/duration	14 (48%)

7. Comparison of own study results with norms

Table 5. Comparison of own study results with norms according to Mond et al. (2006).

Age group	Subscale: Restraint	Subscale: Eating concern	Subscale: Shape concern	Subscale: Weight concern	Global score
18–22 y	N: 1.29 / W: 2.29	N: 0.87 / W: 1.65	N: 2.29 / W: 3.75	N: 1.89 / W: 3.52	N: 1.59 / W: 2.81
23–27 y	N: 1.34 / W: 1.50	N: 0.81 / W: 0.85	N: 2.24 / W: 2.78	N: 1.84 / W: 2.15	N: 1.56 / W: 1.75
28–32 y	N: 1.28 / W: 2.80	N: 0.78 / W: 1.60	N: 2.37 / W: 4.13	N: 1.90 / W: 4.20	N: 1.58 / W: 3.18

N – population norms according to Mond et al.; W – own study results

Norms by Mond et al. (2006) were applied according to age. Analysis revealed that women aged 18–22 years exhibited the highest predisposition, with particular emphasis on shape concern and weight concern. Elevated scores were also observed in the 28–32 age group; however, only one participant belonged to this group, limiting the generalizability of these findings. Overall, shape concern and weight concern were the most prominent subscales, with mean scores exceeding 3.

Discussion

Based on the results obtained, several observations can be made. According to the Body Mass Index (BMI) standards approved by the World Health Organization (WHO), 40% of the surveyed ballet dancers were underweight, having a BMI below 18.5 kg/m². Notably, one participant weighed 36 kg at a height of 163 cm, resulting in an extremely low BMI of 13.5. Similar findings have been reported in other studies, where 50% of ballet dancers had a BMI below 18.5 kg/m² (Stokić et al., 2005; Toro et al. 2009; Santo André et al., 2022; Wayon et al., 2014). All participants demonstrated a high level of physical activity, assessed subjectively based on the number of weekly training sessions (5 ±1,2 sessions/week) and their duration (3,5 ±0,7 hours/session). Vatansever et al. (2023) conducted a study on the injury profile of professional ballet dancers. They found that the average training time per day was 5 hours, and approximately 60% of participants trained more than two hours per day. Furthermore, approximately 80% of the ballet dancers trained more than once per day (Vatansever et al., 2023). Analysis of the first part of the questionnaire indicated that the majority of respondents did not exhibit healthy dietary habits: meals were consumed irregularly, were not properly balanced across food groups, snacking was common, and there was relatively frequent consumption of energy-dense, nutrient-poor snacks and fast food. However, most dancers maintained adequate hydration, consuming approximately 1–2 liters of water per day. Furthermore, many participants reported regular medical check-ups and adequate sleep duration. This section of the survey would benefit from individual dietary interviews, which could provide a more precise assessment of eating patterns and lifestyle. In study reveals disturbing eating habits among ballerinas, such as irregular meals, skipping meals, following restrictive diets, and consuming foods considered “bad” or “fatty” (Santo André et al. 2022). In the de

Medeiros Eufrásio et al. (2021) study found that ballerinas often exhibit unhealthy eating habits, such as irregular meals, frequent snacking, and consuming foods with high energy density and low nutritional value (de Medeiros Eufrásio et al., 2021).

The EAT-26 questionnaire results showed that 13 participants (52%) scored 20 points or more, indicating a predisposition to eating disorders. The highest scores were observed in the “dieting” subscale, with 12 participants demonstrating traits consistent with bulimic tendencies, including dissatisfaction with body shape and weight. Additionally, nine participants had the second-highest scores in the “bulimia and food preoccupation” subscale, suggesting a higher tendency toward developing binge eating behaviors. These results are consistent with previous studies reporting that ballet dancers score higher in the EAT-26 dieting subscale compared to other populations (Diogo et al., 2016; Toro et al., 2009). The EAT-26 is widely used in research on eating disorders among ballet dancers. For example, Diogo et al. reported a high proportion of dancers with scores ≥ 20 , indicating increased risk of developing eating disorders, with approximately 35% of participants reaching this threshold (Diogo et al., 2016). Similarly, Kaufman et al. (2005) noted a high risk of pathological eating behaviors based on EAT-26 results.

These findings highlight the significant prevalence of eating disorder risk factors among ballet dancers, emphasizing the need for preventive interventions and monitoring within this population. Comparison with EDE-Q Norms and Risk Analysis.

The EDE-Q results were compared to the normative data for young women established by Mond et al. (2006) and are presented in Table 5. In the present study, participants with scores indicative of potential clinical concern were identified in every subscale and in the global score. Specifically, 2 participants (8%) scored in the clinical range for restraint, 1 participant (4%) for eating concern, 12 participants (48%) for shape concern, and 12 participants (48%) for weight concern. Evaluating the global score, 6 participants (24%) may exhibit clinical-level problems. Notably, a substantial number of dancers scored ≥ 3 across all subscales, suggesting an elevated risk of developing eating disorders. Norms by Mond et al. (2006) were applied according to age. Analysis revealed that women aged 18–22 years exhibited the highest predisposition, with particular emphasis on shape concern and weight concern. Elevated scores were also observed in the 28–32 age group; however, only one participant belonged to this group, limiting the generalizability of these findings. Overall, shape concern and weight concern were the most prominent subscales, with mean scores exceeding 3, consistent with previous research indicating that ballet dancers demonstrate heightened concern regarding body shape and weight (Toro et al., 2009).

Interestingly, only in the restraint subscale at a clinically significant level (>4) did a dancer exhibit a BMI of 17.1, indicating underweight status and a potential predisposition to anorexia nervosa. The mean BMI for other participants with elevated subscale scores remained within the normal range (Stokić et al., 2005).

Taken together with available literature, these findings confirm that ballet dancers constitute a group at particular risk for developing eating disorders. Studies indicate a higher prevalence of eating disorders among dancers compared to the general population. Arcelus et al. (2014) conducted a systematic review and meta-analysis reporting an overall prevalence of 12% among dancers, rising to 16.4% among ballet dancers (Arcelus et al., 2014).

Furthermore, in the present study, 52% of participants (13 out of 25) scored ≥ 20 on the EAT-26 questionnaire, indicating predisposition to eating disorders, confirming the high frequency of these disorders in this occupational group. These results are consistent with other studies highlighting increased risk of eating disorders among ballet dancers (de Medeiros Eufrásio et al., 2021; Santo André et al., 2022).

Age-stratified analysis in this study also demonstrated that dancers aged 18–22 years had the highest risk, aligning with previous reports that identify this age group as particularly vulnerable (de Medeiros Eufrásio, et al., 2021; Santo André et al., 2022; Anderson, 2024).

These findings emphasize the need for early identification and intervention in ballet dancers at risk for eating disorders to ensure adequate support and health-focused preventive measures.

Conclusions

Ballet dancers exhibit a high predisposition to developing eating disorders (EDs). The main areas of concern are excessive focus on body shape and weight and the presence of compensatory behaviors. In the study group, 52% of participants scored at or above the cutoff in the EAT-26, and 24% in the EDE-Q. Underweight status, observed in 40% of participants, represents an additional risk factor. These findings underscore the need for targeted prevention programs and psychological and nutritional education directed at dancers and their professional environment.

Limitations and Future Implications

The study was characterized by a limited sample size and online recruitment. Experienced ballet dancers who actively prepare for and participate in performances do not constitute a very large group. Scientific publications regarding the risk of eating disorders in this group are also quite rare. Anthropometric data were self-reported, which may reduce accuracy. Future research should include in-person measurements, expand the sample to other age groups and male dancers, and incorporate additional psychometric instruments (e.g., CISS, SCOFF) to allow for a more comprehensive assessment.

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Cite this article as: Ryterska, K., & Kulczyńska, P. (2025). Predisposition to Eating Disorders among Ballet Dancers: An Analysis Using the EAT-26 and EDE-Q Questionnaires. *Central European Journal of Sport Sciences and Medicine*, 4(52), 67–78. <https://doi.org/10.18276/cej.2025.4-06>

EFFECTS OF COMBINED PRECONDITIONING STRATEGIES ON ATHLETIC PERFORMANCE: A RANDOMIZED CROSSOVER TRIAL

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^AStudy design; ^BData collection; ^CStatistical analysis; ^DManuscript Preparation

Abstract This study investigated the effects of ischemic preconditioning (IPC), post-activation performance enhancement (PAPE), and their combination (IPC+PAPE) on anaerobic performance in trained male athletes. In a randomized crossover design, participants performed a Wingate test following four distinct warm-up protocols. Statistical analysis revealed that only the PAPE protocol significantly improved maximum and relative maximum power compared to the control group ($p < 0.05$). In contrast, IPC alone did not affect substantially any power parameter, and the combined IPC+PAPE protocol demonstrated no synergistic effect over PAPE alone. These findings confirm that PAPE is an effective short-term strategy for enhancing explosive anaerobic performance. From a practical standpoint, this study suggests that while coaches can effectively utilize PAPE protocols to acutely boost power output, combining them with IPC may not provide additional benefits for Wingate performance, thereby questioning their time efficiency in a warm-up setting.

Key words: anaerobic performance, ischemic preconditioning, postactivation potentiation, warm-up

Introduction

Various warm-up strategies are employed prior to training sessions and competitions to enhance athletic performance (Civan et al., 2023; Zarei et al., 2018). In recent years, these strategies, including ischemic preconditioning (IPC) and post-activation performance enhancement (PAPE) protocols, have attracted significant interest from sports scientists (Akgül et al., 2024; Souza et al., 2024).

IPC is typically defined as repeated cycles of temporarily reducing local blood flow, followed by reperfusion, either before (De Groot et al., 2010) or after (Arriel et al., 2018) exercise. Common IPC protocols involve application of pressure within a broad range (e.g., from 10 mmHg above systolic blood pressure to over 300 mmHg) or individualized targeting using the individual's arterial occlusion pressure (Slysz & Burr, 2021). IPC has been extensively researched across various sporting disciplines, exercise modalities, and intensity levels (Marocolo et al., 2018). Over the past 22 years, evidence has demonstrated its capacity to acutely enhance isometric force

production (approximately 20%), leading to a surge in research investigating these effects. However, persistent heterogeneity in results and protocols remains a significant challenge (O'Brien & Jacobs, 2021). Nevertheless, recent meta-analyses suggest that IPC's influence extends beyond isometric strength to encompass aerobic and anaerobic performance parameters (Chen et al., 2024). Potential mechanisms proposed include hyperemia (a 5-6-fold increase in muscle blood flow) during reperfusion (Libonati et al., 2001), decreased ATP consumption, increased phosphocreatine production, and enhanced oxygen uptake during the reperfusion phase (Andreas et al., 2011). PAPE, in contrast, is defined as an acute enhancement of athletic performance (including maximum strength, power, and speed) following prior loading during warm-up (Kasicki et al., 2024). While some researchers have proposed mechanisms underlying the post-activation potentiation (PAP) effect observed in the literature, the theoretical link to PAPE remains, with the exact mechanisms supporting PAPE not yet fully elucidated. Some researchers note that the temporal profile of myosin light chain phosphorylation, a key proposed mechanism for PAPE, rarely overlaps with the temporal profile of strength gains. Furthermore, unlike PAP, alterations in muscle temperature, intracellular water content, and muscle activation could contribute, at least in part, to the observed strength enhancement, potentially explaining the phenomenon termed PAPE (Blazeovich & Babault, 2019). Several pre-load strategies are employed to elicit PAPE. Heavy resistance exercises (80% or greater of one repetition maximum (1RM)) are commonly used as pre-load strategies (Sanchez-Sanchez et al., 2018). In this context, a recent systematic review and meta-analysis indicates that resistance exercises applied during warm-up have a more pronounced effect on athletes' jump and sprint performance compared to plyometric or complex exercises (Liu et al., 2024). Previous studies have consistently supported the efficacy of resistance exercises using maximal or near-maximal contractions during warm-up (Prieske et al., 2020; Vargas-Molina et al., 2021).

Studies examining the application of IPC and PAPE within warm-up protocols, and contrasting them with other warm-up methods, exist. However, studies directly comparing these two methods are limited. Furthermore, no studies have been found combining these two approaches within a single warm-up protocol. Given their potential applicability and influence on performance improvements, this study aims to investigate the effects of pre-exercise interventions involving different conditions (IPC, PAPE, and IPC+PAPE) on anaerobic performance.

Material and Methods

Participants

The study involved 16 healthy male volunteers with at least three years of strength training experience. The mean age of the participants was 22.56 ± 2.09 years, mean training experience was 5.88 ± 1.46 years, mean height was 174.56 ± 5.23 cm, mean weight was 70.48 ± 9.15 kg, mean BMI was 23.08 ± 2.35 kg/m², mean body fat percentage was $16.52 \pm 5.48\%$, mean body muscle mass was 33.2 ± 3.83 kg, mean one repetition maximum (1RM) was 125.47 ± 16.28 kg, and mean 1RM/kg was $1.78 \pm 0.13\%$. Descriptive characteristics of the participants are presented in Table 1. The study adhered to the principles of the Helsinki Declaration and was approved by the Karabük University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (date: December 26, 2023, no: 2023/1601).

Table 1. Baseline physical characteristics of participants. (n = 16)

Variables	Mean $\pm$ SD
Age (years)	22.56 $\pm$ 2.09
Training experience (years)	5.88 $\pm$ 1.46
Height (cm)	174.56 $\pm$ 5.23
Body weight (kg)	70.48 $\pm$ 9.15
BMI (kg/m ²)	23.08 $\pm$ 2.35
Body fat percentage (%)	16.52 $\pm$ 5.48
Body muscle mass (kg)	33.2 $\pm$ 3.83
1 RM (kg)	125.47 $\pm$ 16.28
1RM/Body weight (%)	1.78 $\pm$ 0.13

BMI = body mass index. RM = repetition maximum. Kg = kilogram. SD = standard deviation.

Measurements

Height and Body Composition Measurements

Participant height was measured using a stadiometer with a precision of 0.01 mm. Body weight and body mass index were determined using an InBody 270 (Biospace, California, USA) device.

Warm-up Protocol

Participants performed 5 minutes of continuous running at a constant speed of 6.5 km/h on a treadmill, followed by 2 minutes of dynamic stretching. Static stretching, jumping, and sprinting were discouraged prior to the warm-up (Sarı et al., 2022).

1 Repetition Maximum Test

The exercise was performed using a Smith Machine (Fitness Center, Hasan Doğan Faculty of Sports Sciences, Karabük University, Turkey). Following the warm-up protocol, participants performed 8–10 repetitions of the back squat (BS) without weight on the machine. Subsequently, they performed 3–5 repetitions with a weight approximating 60–80% of their estimated 1RM. A 2-minute rest period followed, during which they performed 2–3 repetitions at approximately 90–95% of their estimated 1RM. A 4-minute rest period followed. Finally, a 1RM attempt was made, with the 1RM value determined over 4–5 attempts (ACSM, 2018). Throughout the testing, the exercise form adhered to the same protocol as that for the PAPE protocol.

Experimental Procedures

The study was conducted at the Performance Laboratory and Fitness Center of the Hasan Doğan Faculty of Sports Sciences, Karabük University. Participants attended the facility for a total of six days, with all testing sessions separated by intervals of 48 to 72 hours. Participants were instructed to avoid strenuous physical activity in the days leading up to the study and to monitor their carbohydrate intake. On day one, participants received study information, and height, weight, and body fat percentage (determined using the InBody 270 device) were recorded. After collecting the participants' characteristics, a familiarization session was conducted to acclimate participants to the warm-up protocol and subsequent tests. After a 48-hour interval, a standard warm-up protocol was followed,

and the 1RM was determined and recorded. A second 48-hour interval separated the subsequent testing days, during which different conditions (control, IPC, PAPE, IPC+PAPE) were applied at various time points. To avoid any lingering effects of IPC, 72-hour intervals were used between days 3, 4, 5, and 6. To mitigate the impact of time on the results, the study employed a randomized crossover design, with participants equally divided into four groups. Participants were instructed to refrain from eating for 1.5 hours before any intervention. Informed consent was obtained from all participants. Participants were allowed to consume water (500ml) during testing, and verbal encouragement was provided to athletes during the Wingate Test. Figure 1 presents the study design.

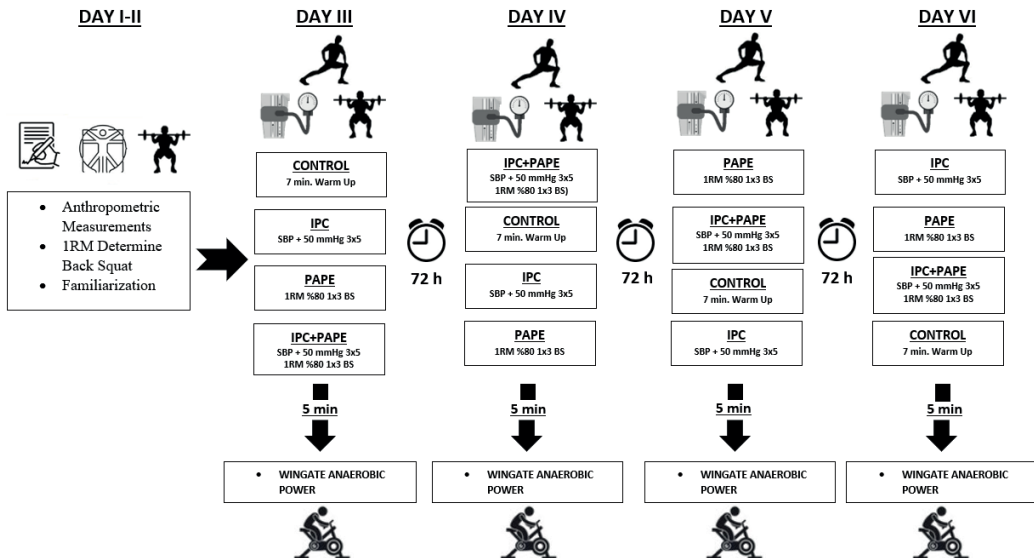


Figure 1. Experimental Procedures

PAPE protocol

Following the warm-up session, a single set of three repetitions of the back squat (BS) exercise was performed using a Smith machine, at 80% of the determined maximum, as is standard practice in other studies (Prieske et al., 2018; Petisco et al., 2019). The exercise was performed with feet shoulder-width apart and in a controlled manner. Participants were instructed to maintain foot contact with the ground and to descend until the knee angle reached 90 degrees. The completion of the squat was indicated by contact between the participant's hamstring and a resistance band placed on the floor, marking the 90-degree knee angle zone (Tseng et al., 2021).

IPC Protocol

Participants performed occlusion and reperfusion phases while seated, with knees at 90 degrees, using a cuff (Reiser, Germany) (Marocolo et al., 2017). All interventions commenced with blood pressure assessment. Occlusion was initiated by applying a pressure 50 mmHg above systolic blood pressure. Participant blood pressure

and applied pressures for each protocol are detailed in Table 2. The intervention began with the right leg, and the cuff was positioned as close to the groin as possible. The procedure lasted 30 minutes, comprising 3 cycles of 5 minutes occlusion followed by 5 minutes of reperfusion. Peripheral pulse monitoring was achieved at the ankle artery region during the occlusion phase (Gürses, 2015).

Table 2. Participants' blood pressure and applied pressure values, according to the implemented protocols (n = 16)

Variables	Mean $\pm$ SD
IPC SBP (mmHg)	123.06 $\pm$ 5.27
IPC DBP (mmHg)	69.78 $\pm$ 7.16
IPC+PAPE SBP (mmHg)	123.41 $\pm$ 7.23
IPC+PAPE DBP (mmHg)	73.91 $\pm$ 9.42
IPC pressure (mmHg)	173.06 $\pm$ 5.27
IPC+PAPE pressure (mmHg)	173.41 $\pm$ 7.23

IPC = Ischemic preconditioning. PAPE = Post-activation performance enhancement. SBP = systolic blood pressure. DBP = diastolic blood pressure. SD = standard deviation.

IPC+PAPE Protocol

Following the occlusion and reperfusion cycles of the IPC protocol, participants immediately continued with the warm-up protocol without interruption. The warm-up was then followed by the BS exercise, completing the PAPE protocol.

Wingate Test Protocol

Following all conditions, a 5-minute rest period (Seitz & Haff, 2016) was allowed before the Wingate test (Monark 894 E, Sweden) was administered. A resistance corresponding to 7.5% of the participant's body weight was applied for the 30-second maximal effort. Participants remained seated throughout the test. Power output data were sampled at 10 Hz throughout the test. The highest power value recorded within a 1-second interval was defined as peak power. Average power output was determined as the average power output throughout the 30-second test duration. The lowest power value recorded within a 1-second interval was defined as minimum power. All values were recorded in Watts and also evaluated in W/kg to determine relative power output.

Blood Pressure Measurement

A manual sphygmomanometer was used to determine systolic and diastolic blood pressure of the participants. After a 5-minute rest period in a room-temperature environment, participants' left arms were used for blood pressure measurement. Each measurement was taken twice, with a one-minute interval between readings, and the average value was expressed in mmHg. If the results differed by more than 5 mmHg, a third measurement was taken, and the average of the two closest values was recorded.

Statistical Analysis

Data analysis was performed using IBM SPSS 27 (IBM Corp., Armonk, New York, USA) and Microsoft Excel 2019 (Microsoft Corp., Seattle, WA, USA). A Shapiro-Wilk test was used to confirm normality. Wingate test measures were evaluated using a one-way repeated measures analysis of variance (ANOVA). The sphericity assumption was assessed using Mauchly's test. Where sphericity was violated (Epsilon < 0.75), Greenhouse–Geisser corrections were

applied; where Epsilon > 0.75, Huynh–Feldt corrections were applied. Significance was set at $p < 0.05$ for all analyses. Effect size was evaluated using eta-squared (η^2), categorized as small (≤ 0.05), medium (0.06–0.13), or large (≥ 0.14).

Results

This section analyzes the responses of athletes subjected to different warm-up protocols on the Wingate test. Table 3 presents the anaerobic power values for the control group and the various intervention groups.

Table 3. Anaerobic power values for the control, IPC, PAPE, and IPC+PAPE protocols ($n = 16$)

Variables	Control	IPC	PAPE	IPC+PAPE	F	p	η2
	Mean ±SD						
Maximum Power (W)	779.69 ±141.57	782.88 ±118.12	792.65 ±159.8	783.06 ±159.56	5.56	0.04*	0.27
Maximum Power (W/kg)	11.17 ±2.14	11.18 ±1.5	11.29 ±1.95	11.19 ±1.98	5.23	0.05*	0.26
Avarage Power (W)	569.6 ±80.6	566.4 ±67.31	583.12 ±83.45	550.93 ±85.31	2.39	0.10	0.14
Avarage Power (W/kg)	8.25 ±0.99	8.23 ±0.69	8.49 ±1.02	7.99 ±1.01	2.54	0.08	0.15
Minimum Power (W)	330.26 ±64.46	326.97 ±54.5	321.88 ±75.75	320.35 ±55.14	0.21	0.82	0.01
Minimum Power (W/kg)	4.82 ±0.74	4.74 ±0.61	4.68 ±1.11	4.66 ±0.74	0.24	0.78	0.02
Power Drop (W)	480.03 ±117.28	449.66 ±106.36	482.36 ±122.96	451.63 ±17.39	2.05	0.12	0.12
Power Drop (W/kg)	6.96 ±1.63	6.55 ±1.54	6.98 ±1.66	6.55 ±1.91	1.97	0.14	0.12

IPC = Ischemic preconditioning. PAPE = Post-activation performance enhancement. SD = standard deviation. W = Watt. Kg = kilogram. W/kg = relative strength. * = $p < 0.05$.

Analysis of the differences in maximum power (W) and maximum power (W/kg) across conditions revealed that the control protocol exhibited no significant difference compared to the IPC protocol. However, a statistically significant difference was found when comparing the control protocol to the PAPE protocol. No significant difference was observed between the control protocol and the IPC+PAPE protocol. The IPC protocol, when compared to the control, showed no significant difference, but did demonstrate a statistically significant difference compared to the PAPE protocol. No significant difference was found between the IPC protocol and the IPC+PAPE protocol. PAPE demonstrated statistically significant differences when compared to both the control and IPC protocols. Importantly, a statistically significant difference was also observed between the PAPE and IPC+PAPE protocols. The IPC+PAPE protocol did not show a significant difference compared to the control or IPC protocols, but did exhibit a statistically significant difference compared to the PAPE protocol ($p < 0.05$) (Table 4).

Table 4. Pairwise comparisons of maximum power (W) with Bonferroni correction

Variables	Protocol	Mean $\pm$ SD	Protocol	Mean $\pm$ SD	p
Maximum Power (W)	CON	779.69 $\pm$ 141.57	IPC	782.88 $\pm$ 118.12	1.00
			PAPE	792.65 $\pm$ 159.8	0.05*
			IPC+PAPE	783.06 $\pm$ 159.56	1.00
	IPC	782.88 $\pm$ 118.12	CON	779.69 $\pm$ 141.57	1.00
			PAPE	792.65 $\pm$ 159.8	0.05*
			IPC+PAPE	783.06 $\pm$ 159.56	1.00
	PAPE	792.65 $\pm$ 159.8	CON	779.69 $\pm$ 141.57	0.05*
			IPC	782.88 $\pm$ 118.12	0.05*
			IPC+PAPE	783.06 $\pm$ 159.56	0.05*
	IPC+PAPE	783.06 $\pm$ 159.56	CON	779.69 $\pm$ 141.57	1.00
			IPC	782.88 $\pm$ 118.12	1.00
			PAPE	792.65 $\pm$ 159.8	0.05*

Con = Control. IPC = Ischemic preconditioning. PAPE = Post-activation performance enhancement. SD = standard deviation. W = Watt. Kg = kilogram. * = $p < 0.05$.

Analysis of relative maximum power (W/kg) revealed no significant difference between the control protocol and the IPC protocol. However, a statistically significant difference was observed when comparing the control protocol to the PAPE protocol. No significant difference was found between the control protocol and the IPC+PAPE protocol. The IPC protocol, when compared to the control protocol, demonstrated no significant difference, and no significant difference was found when compared to the PAPE or IPC+PAPE protocols. The PAPE protocol, on the other hand, showed a statistically significant difference compared to the control protocol, but no significant differences were observed when compared to the IPC or IPC+PAPE protocols. Finally, the IPC+PAPE protocol showed no significant differences when compared to the control or IPC protocols, nor when compared to the PAPE protocol ($p > 0.05$) (Table 5).

Table 5. Pairwise comparisons of relative maximum power (W/kg) with Bonferroni correction

Variables	Protocol	Mean $\pm$ SD	Protocol	Mean $\pm$ SD	p
Maximum Power (W/kg)	CON	11.17 $\pm$ 2.14	IPC	11.18 $\pm$ 1.5	1.00
			PAPE	11.29 $\pm$ 1.95	0.05*
			IPC+PAPE	11.19 $\pm$ 1.98	1.00
	IPC	11.18 $\pm$ 1.5	CON	11.17 $\pm$ 2.14	1.00
			PAPE	11.29 $\pm$ 1.95	0.06
			IPC+PAPE	11.19 $\pm$ 1.98	1.00
	PAPE	11.29 $\pm$ 1.95	CON	11.17 $\pm$ 2.14	0.05*
			IPC	11.18 $\pm$ 1.5	0.06
			IPC+PAPE	11.19 $\pm$ 1.98	0.06
	IPC+PAPE	11.19 $\pm$ 1.98	CON	11.17 $\pm$ 2.14	1.00
			IPC	11.18 $\pm$ 1.5	1.00
			PAPE	11.29 $\pm$ 1.95	0.06

Con = Control. IPC = Ischemic preconditioning. PAPE = Post-activation performance enhancement. SD = standard deviation. W = Watt. Kg = kilogram. * = $p < 0.05$.

Discussion

The most significant finding of this study is that the PAPE protocol demonstrated a statistically significant improvement in maximum power (W) and relative maximum power (W/kg) compared to the control and other protocols. Conversely, no statistically significant differences were observed in the average power, minimum power, or power decline parameters. This finding aligns substantially with the results of similar studies in the existing literature, although variations exist based on the subject pool, protocol duration, and methodologies employed.

These findings regarding the PAPE protocol support the mechanisms proposed by Hamada et al., (Hamada et al., 2000). focusing on increased motor unit activation and myosin light chain phosphorylation as contributing factors to enhanced power output. Tillin et al. highlight the pronounced effect of PAPE, particularly in short-duration, high-intensity activities, linking this effect to increased calcium sensitivity resulting from myosin phosphorylation (Tillin et al., 2012). Similarly, Mitchell and Sale observed improvements in vertical jump performance following a 5RM squat exercise, attributing these improvements to both mechanical and neuromuscular adaptations (Mitchell & Sale, 2011). This corroborates the maximum power enhancement observed in our study using the PAPE protocol. Furthermore, Seitz and Haff., suggest that AIPA is more effective in trained athletes than in untrained individuals, potentially explaining the heightened responsiveness to the PAPE protocol exhibited by the trained participants in this study (Seitz & Haff, 2016).

Relative maximum power (W/kg), representing power normalized to individual body weight, is a critical performance indicator, particularly for athletes. Our study observed an average relative maximum power output of 11.29 ± 1.95 W/kg with the PAPE protocol, demonstrating a significant improvement compared to the control group. This finding aligns with Chiu et al., (2003) observation that PAPE exhibits a more pronounced effect in trained athletes. Existing literature consistently indicates that PAPE is more effective in individuals with a substantial training history, and that body-weight-normalized values often reveal these effects more clearly (Seitz & Haff, 2016). Furthermore, Hodgson et al. (2005), noted a short-term performance-enhancing effect of AIPA on the neuromuscular system, particularly evident in dynamic activities. Our findings suggest that AIPA is an effective method to enhance athletes' anaerobic performance.

Average power (W) and relative average power (W/kg) are crucial indicators of anaerobic performance sustainability. In this study, no statistically significant differences were found in these parameters across the various protocols. However, a moderate effect size ($\eta^2 = 0.14$) was observed between the PAPE and control groups. Existing literature suggests that PAPE is particularly effective in activities requiring explosive power over short durations, but its effect on sustained anaerobic performance is limited (Hodgson et al., 2005). The lack of significant effects on average power in our study aligns with this literature, suggesting a limited impact of PAPE on prolonged exertion requiring sustained power output.

No significant effect of the IPC protocol was observed on maximum power and relative maximum power in our study. However, the literature surrounding IPC's effects on performance remains somewhat controversial, with some studies reporting positive findings and others showing limited or no effect. For example, Bailey et al. (2012) indicated that IPC can improve endurance running performance by reducing lactate accumulation. Yet, the effect of IPC on anaerobic activities appears more limited. Similarly, Crisafulli et al. (2011) reported that IPC can delay muscle fatigue, potentially enhancing performance in short-duration, high-intensity exercise. However, our study did not find a statistically significant effect of IPC on this type of activity. The literature emphasizes that the effectiveness of IPC is contingent on protocol duration, pressure levels, and timing of application (Marocolo et al., 2016). In our study, the

IPC protocol, using a pressure of 173.06 ± 5.27 mmHg, showed more limited results compared to studies employing different pressure levels. While Gürses et al. (2017) observed significant improvements in anaerobic performance in footballers using an IPC protocol, the lack of a similar effect in our study highlights the variable impact of this protocol based on individual differences and exercise type. Furthermore, Incognito et al. (2016) suggested that the variability in responses to IPC (with some participants showing performance improvement, others not) indicates the importance of cautious interpretation due to potential phenotypic differences in responses to this protocol.

The combined application of IPC and PAPE (IPC+PAPE) did not demonstrate the expected synergistic effect in our study. Findings indicate that the IPC+PAPE combination did not enhance maximum power or relative maximum power compared to AIPA alone. This result aligns with Bouffard et al. (2021) work emphasizing the limited influence of IPC on neuromuscular adaptations. While Carvalho and Barroso suggest IPC can improve sustained power performance, they also indicate a lack of substantial evidence supporting the effectiveness of combined protocols with PAPE (Carvalho & Barroso, 2019). Similarly, Griffin et al. (2018) highlighted potential positive effects of IPC on critical power performance but did not definitively demonstrate a further enhancement when combined with PAPE.

The combined application of IPC and PAPE (IPC+PAPE) did not demonstrate the expected synergistic effect in our study, as the findings indicated that this combination did not enhance maximum power beyond that achieved with PAPE alone. Several potential mechanisms could explain this lack of a synergistic benefit. First, a physiological ceiling effect may be at play; the PAPE protocol, involving high-intensity contractions, may have already elevated motor unit recruitment and calcium sensitivity to a near-maximal level, leaving little room for IPC to provide an additional ergogenic effect (Seitz & Haff, 2016). Second, the combination of two distinct physiological stressors—*ischemic and mechanical*—could have induced greater accumulated fatigue than potentiation. While each protocol is designed to enhance performance, their combined application within a short timeframe might have tipped the balance towards fatigue, thereby masking any potential additive benefits (Incognito et al., 2016).

Furthermore, the timing and duration of the protocols are critical. The optimal potentiation windows for IPC and PAPE may not align perfectly. It is plausible that the 5-minute rest period implemented in our study was not sufficient or ideally timed to capitalize on the peak effects of both interventions simultaneously (Carvalho & Barroso, 2019). Finally, the distinct underlying mechanisms of IPC (e.g., enhanced blood flow, metabolic efficiency) and PAPE (e.g., neural activation, myosin light chain phosphorylation) may interact in a complex or even antagonistic manner, where the effects of one protocol could potentially neutralize or interfere with the other. Future research should therefore investigate the combined effect of IPC and PAPE with varying recovery periods, protocol intensities, and subject characteristics to better understand how to optimize these strategies for anaerobic performance.

A key limitation of this study is the relatively small sample size ($n = 16$), which may have limited the statistical power to detect small to moderate effects and could increase the risk of a Type II error.

In conclusion, this study demonstrates that the PAPE protocol is effective in enhancing short-term anaerobic power performance. No significant effect of the IPC protocol was observed on maximum or average power parameters. The combination of IPC and PAPE did not yield the expected synergistic effect, suggesting the need for optimization of protocol durations and intensities. Future research should investigate the combined effect of IPC and PAPE with varying recovery periods, protocol intensities, and subjects with different training levels. Such studies could provide a clearer understanding of the impact of both IPC and PAPE on anaerobic performance.

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Cite this article as: Yıldız, K. C., & Akgül, M. Ş. (2025). Effects of Combined Preconditioning Strategies on Athletic Performance: A Randomized Crossover Trial. *Central European Journal of Sport Sciences and Medicine*, 4(52), 79–89. <https://doi.org/10.18276/cej.2025.4-07>

