



The impact of modern digital technologies in physical education on the level of physical activity of general secondary school pupils

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Abstract. The aim of the study was to reveal the theoretical foundations of integrating electronic educational platforms and mobile services into school physical education classes in order to outline their potential for increasing the physical activity of schoolchildren. The methodology was based on a combination of theoretical analysis, a regulatory and legal approach, and conceptual modelling. It was found that the main tools of digital technologies are exergames, fitness trackers, online lessons, gamified programmes, social networks, and activity monitoring platforms. Exergames, wearable trackers, and gamification provide sufficient intensity of exercise, provide objective data for self-monitoring and goal setting, and stimulate daily physical activity among pupils. Online physical education formats partially compensate for the reduction in physical activity during distance learning if they have a well-thought-out pedagogical design. Digital media in the concept of health promotion are used to prevent physical inactivity and bring pupils closer to the recommended levels of physical activity. Within the framework of technology-enhanced pedagogy, digital tools individualise the load, improve the assimilation of motor actions and expand the space for activity outside school. It has been established that the integration of digital technologies results in an increase in moderate/high activity time, improved physical fitness, motivation, self-regulation, and a positive attitude towards physical culture. Effectiveness and risks depend on teacher competence, material resources, organisational support, as well as screen time control, digital inequality, and data confidentiality. A conceptual model of “input – process – outcomes” is proposed, where the “input” consists of types of digital technologies, regulatory guidelines and conditions for implementation, the “process” consists of motivational, organisational and monitoring mechanisms of influence, and the “output” is changes in physical activity and attitudes towards physical culture. The practical significance lies in the fact that the results can be used by physical education teachers and methodologists to plan lessons aimed at increasing physical activity and motivation among pupils

Keywords: exergames; wearable trackers; gamified platforms; online sports training; pupil motivation; physical activity

Introduction

Physical activity among children and adolescents in the 21st century is considered one of the key determinants of health, and school as an environment where the basic conditions for the formation of motor behaviour are created.

Despite this, most schoolchildren do not meet the minimum recommendations for daily physical activity, which is exacerbated by trends in urbanisation, increasing sedentary lifestyles and screen time. In such conditions, the

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question arises of how schools, and physical education classes in particular, can use digital technologies not only as a means of communication, but also as a tool for increasing the actual level of physical activity among pupils.

In the scientific field, the digitisation of physical education is considered a separate area of research. In a study by S. Guijarro-Romero *et al.* (2023), an intermittent training module based on wearing fitness bracelets and a set of behavioural strategies (step goals, counselling, reminders) was tested. The authors found that pupils' perceived support for autonomy, satisfaction of basic psychological needs, and autonomous motivation for physical activity increased, as did their habitual physical activity. This means that integrating wearable devices into physical education lessons can not only increase the amount of movement, but also influence the motivational mechanisms that are essential for long-term activity maintenance. Similarly, the work of S. Guijarro-Romero *et al.* (2025) focused on the same type of intermittent module with bracelets, but assessed its impact on the weekly number of steps: an eight-week programme with progressive targets, counselling and daily monitoring led to a statistically significant increase in steps among adolescents aged 12-16. This work provides direct quantitative evidence that a well-designed programme of wearable trackers integrated into physical education lessons can significantly bring pupils' actual levels of daily activity closer to the recommended standards.

Virtual physical education during COVID-19, built within the framework of "diversity-equality-inclusion" in the study by E.M. D'Agostino *et al.* (2021), showed that remote physical education formats can either exacerbate or mitigate existing inequalities in access to physical activity, depending on how online tools are designed. The authors highlight key design features of platforms (convenience, accessibility, monitoring and evaluation capabilities) that teachers consider crucial for ensuring equitable access to quality online physical education for pupils, thereby setting benchmarks for the design of future digital solutions. In their study, O. Østerlie *et al.* (2022) conceptualised the field of "digital technology in physical education", emphasising that digital tools (flipped learning, gamification, exergames) have already demonstrated their ability to enhance student motivation, learning outcomes and performance. At the same time, the authors point out the lack of knowledge about how teachers implement these technologies in different pedagogical approaches and at the level of specific lesson tasks, calling for more in-depth research into the didactic component of digital physical education, rather than just the technical side. Digital tools, as found in the work of F. Jastrow *et al.* (2022), mostly enhance student motivation and improve motor skills, but at the same time reveal serious barriers – a lack of resources and insufficient preparation of teachers to work with media. The authors also emphasised that most studies focus on "learning with media", while the aspect of "learning about media" (data protection, critical attitude to images, etc.) remains almost unexplored, which creates a gap for further pedagogical models of digital physical education.

In a systematic review by D.I. Tohänean *et al.* (2025) analysed 13 studies on the integration of artificial intelligence and information and communication technologies

into physical education at different levels of education, identified the main types of their application and demonstrated their potential for personalising learning, providing real-time feedback, and increasing motivation and inclusiveness. At the same time, the authors note that the transformative potential of these tools is limited by insufficient infrastructure, a lack of professional training for teachers, and methodological shortcomings in existing studies, which requires targeted pedagogical design of digital solutions in school physical education.

In Ukrainian scientific discourse, the use of digital technologies in physical education explores the possibilities of mobile applications and comprehensive digital solutions for school physical education. Fitness applications and interactive platforms (Nike Training Club, Google Fit, Workouts for Kids), as shown by H.M. Alekseeva *et al.* (2025), can compensate for the loss of classroom activity by maintaining motivation, engagement, and the level of physical activity of middle-aged schoolchildren. Research by V.V. Geitenko *et al.* (2025) on the use of digital technologies in physical education classes shows that mobile apps for tracking activity, fitness bracelets, video platforms (YouTube, Nike Training Club), virtual/augmented reality, and online diaries can significantly increase pupils' interest in classes, individualise training tasks, and provide more accurate monitoring of physical fitness. Both studies show that mobile applications, fitness devices, and other digital platforms can increase pupils' interest in classes and contribute to the individualisation of physical activity. At the same time, this potential can only be realised if teachers have the necessary competence in information and communication technologies and schools have the appropriate technical equipment.

A summary of foreign studies shows that the use of digital technologies in physical education contributes to increased motivation, engagement and physical activity levels among schoolchildren, while Ukrainian publications mainly focus on individual tools and approaches without offering a comprehensive system for their pedagogically sound application. There was a lack of comprehensive works that would systematise groups of digital technologies and present a conceptual model for their integration into lessons and extracurricular physical education activities for pupils in general secondary education institutions.

Thus, the aim of the study was to provide a theoretical justification for the use of electronic tools and online solutions in the process of physical education of pupils in general secondary education institutions as a means of increasing their level of physical activity. To achieve this aim, the following objectives were set: to analyse regulatory documents that define the requirements for the level of physical activity of pupils in the process of using digital technologies in physical education in general secondary education institutions, to systematise the main groups of digital tools for school physical education, taking into account empirical data on their impact on the physical activity of pupils, and to develop a theoretical conceptual model for the integration of digital technologies into the process of physical education and health activities of pupils in general secondary education institutions as a means of increasing their physical involvement.

Materials and Methods

The study was theoretical and analytical in nature and used a comprehensive approach combining theoretical, analytical, comparative-normative and structural-modelling analysis. This made it possible to systematically study the possibilities, effectiveness, risks and directions of using digital technologies in school physical education, taking into account their impact on pupils' physical activity. Using methods of normative-legal and comparative-normative analysis, a normative act was developed that approves the State Standard of Ukraine (Resolution of the Cabinet of Ministers of Ukraine No. 898, 2020) and its official presentation and explanation on the website of the Ministry of Education and Science of Ukraine (MES) Ministry of Education and Science of Ukraine (n.d.), which regulates the educational field of "Physical Education" in general secondary education institutions in Ukraine. International benchmarks are presented in official standardised documents of the World Health Organization (2010; 2020). The choice of documents is due to the fact that Ukrainian documents establish mandatory requirements for the content and results of physical education in schools, while international recommendations set scientifically based target guidelines for the level of physical activity, which was necessary for the formation of a regulatory framework against which the potential for integrating digital technologies into school physical education was assessed.

To develop a classification of digital technologies, methods of classification and systematisation of empirical research results were used, which describe the use of digital tools in physical education of pupils in general secondary education institutions – exergames (active video games) (Röglin *et al.*, 2024; Zhao *et al.*, 2024; Merino-Campos & Del-Castillo, 2025), wearable technologies (Creaser *et al.*, 2022; Chen *et al.*, 2025), online physical education and mixed formats (Montiel-Ruiz *et al.*, 2022; Knoke *et al.*, 2024), gamified programmes and social networks (Montiel-Ruiz *et al.*, 2022), digital platforms for monitoring and analysing physical activity (Creaser *et al.*, 2022; Knoke *et al.*, 2024; Chen *et al.*, 2025), which are most representative of approaches to the digitalisation of physical education and reflect various mechanisms of influence on the level of physical activity of pupils. The selection criteria were a focus on school age (pupils in general secondary education), the presence of a clearly described digital component in the physical education programme (exergames, wearable trackers, online lessons, gamified services, monitoring platforms), recording of physical activity indicators or related behaviour, as well as the possibility of replicating these solutions in a regular school setting. This was done in order to create a generalised classification framework that allows for comparison of the potential of different groups of digital solutions and serves as a basis for further analysis of their effectiveness.

To verify the theoretical conclusions about the potential of digital technologies as a means of increasing the level of physical activity, physical fitness and motivation of pupils, the types of digital technologies were analysed using content analysis and analytical generalisation methods: exergames (ExerCube), exergames (school exergaming programme), gamified programme + cards/sensors (active way to school), Edmodo social network + gamification of

physical education courses, wearable activity trackers (wearables), and exergame-based training. These types were selected as representative examples of the main groups of digital technologies identified in the classification, for which quantitative changes in the level of physical activity, physical fitness and motivation of pupils have been documented in school settings. This approach made it possible to empirically substantiate the theoretical provisions of the study and to specify which types of digital technologies and in which formats of class organisation provide the most noticeable positive changes in pupils' physical activity.

To identify risks and limitations associated with the use of digital technologies in school physical education, such as increased screen time, digital inequality, and data privacy issues, methods of critical analysis and the comparative-normative approach were applied. This allowed the conditions for pedagogically appropriate and safe integration of digital tools into the educational process to be outlined. Based on the results of theoretical and empirical synthesis, methods of structural-logical and conceptual modelling were used to construct the "input-process-outcomes" model of digital technology use in the physical education of general secondary education pupils. This ensured the integration of disparate research findings into a coherent conceptual framework suitable for practical application by physical education teachers and by developers of educational programmes.

Results and Discussion

Regulatory guidelines and classification of digital technologies in physical education

The regulatory and legal basis for the physical education of pupils in institutions of general secondary education in Ukraine is the State Standard of Basic Secondary Education, approved by Resolution of the Cabinet of Ministers of Ukraine No. 898 (2020). The document defines the aims of basic education, which include the formation of a culture of a healthy lifestyle and the creation of conditions for the harmonious physical and mental development of the pupil. Within its structure, the educational field "Physical Culture and Sport" is distinguished, the content of which is aimed at developing physical qualities, mastering basic motor skills and abilities, and forming the capacity for independent physical activity and health-related exercise (Ministry of Education and Science of Ukraine, n.d.). On the basis of the Standard, model educational programmes are developed that determine the content of learning material, the indicative distribution of hours, and the expected learning outcomes in the field of "Physical Culture and Sport" for different age groups. The allocated number of hours is intended to ensure the minimally necessary conditions for achieving the school's health-preserving aims and for bringing pupils closer to levels of physical activity recommended by international organisations.

In this context, digital technologies are viewed not as an end in themselves but as tools for implementing the requirements of the State Standard: they increase the attractiveness of physical education lessons, expand opportunities for individualising physical load and monitoring physical activity, and facilitate the organisation of feedback. The integration of digital tools into the content and teaching methods of lessons may be considered one of the ways

to develop pupils' health-preserving and digital competences in line with the priorities of the New Ukrainian School. However, the State Standard of Basic Secondary Education of Ukraine focuses primarily on describing the content of the field "Physical Culture and Sport" and the expected learning outcomes, rather than on clearly quantified indicators of pupils' daily volumes of physical activity (Resolution of the Cabinet of Ministers of Ukraine No. 898, 2020; Ministry of Education and Science of Ukraine, n.d.). On the basis of the Standard and the model educational programmes, school timetables and the minimum required number of physical education hours are established, creating basic conditions for achieving the school's health-preserving goals, but this alone does not guarantee attainment of the recommended daily level of physical activity.

International benchmarks for planning and assessing the physical activity of children and adolescents are provided by the recommendations of the World Health Organization (2010): children and adolescents aged 5-17 years should engage daily in at least 60 minutes of moderate-to-vigorous physical activity, predominantly aerobic in nature, including vigorous-intensity activities and exercises to strengthen muscles and bones at least three times per week, as well as limiting sedentary behaviour (World Health Organization, 2010; 2020). A substantial proportion of children and adolescents in different countries, including during the Coronavirus Disease (COVID)-19 pandemic and periods of distance learning, do not reach the levels of physical activity recommended by the WHO (Knoke *et al.*, 2024; Martín-Rodríguez *et al.*, 2025). For institutions of general secondary education, this implies the need to organise physical education lessons and extracurricular physical and sports activities in ways that support the attainment

of these standards, in particular through the purposeful use of modern digital technologies of the twenty-first century (mobile applications, wearable trackers, exergames, online platforms), which can increase the overall volume and intensity of pupils' physical activity and reduce the gap between actual indicators and international recommendations. A comparison of Ukrainian requirements with international benchmarks shows that the Ukrainian Standard defines the content-related and organisational framework of physical education, whereas WHO documents establish quantitative target benchmarks for physical activity; taken together, these can be regarded as complementary regulatory bases for evaluating and improving school practice through the use of digital technologies.

Contemporary approaches to the physical education of pupils increasingly emphasise that digital solutions should be considered not as an "addition" to the traditional lesson but as an integral part of the teacher's pedagogical toolkit, capable of supporting both educational and health-preserving aims. In the scientific literature, there is no single established definition of this concept, and different authors include within it both basic information and communication technology (ICT) tools (video materials, multimedia presentations, online platforms) and specialised interactive systems with elements of gamification and monitoring. The term "digital technologies" in physical education is used broadly and encompasses tools ranging from simple video resources to complex interactive systems with motion sensors, elements of artificial intelligence, and augmented reality (Martín-Rodríguez *et al.*, 2025; Ketelhut *et al.*, 2025). The groups of digital tools relevant for pupils in general secondary education institutions were summarised in Table 1.

Table 1. Classification of digital technologies in the physical education of general secondary education pupils

Group of digital technologies	Characteristics	Implementation
Exergames (active video games)	Interactive gaming systems in which successful task performance directly depends on the user's motor activity. They provide a game-based format with a sufficient intensity of physical load.	Specialised solutions (ExerCube) and commercial active video games used in school-based interventions.
Wearable technologies (wearable devices)	Sensor-based devices for measuring indicators of physical activity (steps, duration and intensity of exercise, heart rate), used for monitoring and self-control.	Fitness bands, smartwatches, and chest-strap heart rate monitors integrated into school programmes aimed at increasing physical activity.
Online physical education and blended formats	The use of video lessons, streamed workouts, virtual classes, and educational platforms to organise physical education lessons in distance and blended formats, as well as to support traditional lessons.	Distance and blended physical education programmes developed during the COVID-19 pandemic, as well as platforms supporting physical education lessons.
Gamified applications and social networks	Digital services in which physical activity is integrated into a system of game mechanics (points, levels, leaderboards, badges) and supported through social interaction (chats, online communities, challenges).	Gamified interventions to stimulate active travel and participation in physical activity, and gamified physical education courses based on social networks.
Digital platforms for monitoring and analysing physical activity	Web-based and mobile applications for recording the volume and structure of physical activity, analysing its dynamics, setting goals, and generating reports for pupils, parents, and school administration; they are integrated with wearable devices.	School-based and commercial platforms that collect data from trackers and visualise physical activity indicators for the purposes of the educational process and health promotion.

Source: compiled by the authors based on F.J. Montiel-Ruiz *et al.* (2022), S. Ketelhut *et al.* (2022), A.V. Creaser *et al.* (2022), C. Knoke *et al.* (2024), L. Röglin *et al.* (2024), M. Zhao *et al.* (2024), X. Chen *et al.* (2025), C. Merino-Campos & H. Del-Castillo (2025)

Digital technologies in the physical education of pupils in general secondary education institutions encompass both tools for the direct organisation of motor activity (exergames, wearable devices, online lessons) and means of motivation, social interaction and monitoring of its outcomes (gamified applications, digital platforms for

analysing physical activity). This makes it possible to use them both during physical education lessons and in extracurricular sport and health-related activities, thereby expanding the space for pupils' physical activity. The impact of digital technologies on the physical activity of pupils in general secondary education institutions is appropriately

explained within several interrelated theoretical approaches. Within the health-preserving and health promotion approach, digital media in physical education are viewed as tools for health promotion that should contribute to bringing pupils closer to recommended levels of physical activity, improving indicators of physical fitness and fostering awareness of the relationship between motor activity and health (Mackenbrock & Kleinert, 2023; Martín-Rodríguez & Madrigal-Cerezo, 2025). In this context, digital interventions are integrated into school programmes for the prevention of hypodynamia. Within the technology-enhanced pedagogy approach, digital technologies are interpreted as an element of a holistic pedagogical system that changes the structure and logic of the teaching and learning process in physical education. Digital tools are used to increase pupils' engagement, improve the acquisition of motor skills, individualise loads and provide differentiated feedback, which in the long term contributes to the formation of sustainable habits of physical activity (Ketelhut *et al.*, 2025).

The motivational perspective, primarily within the framework of self-determination theory, emphasises that digital media can satisfy pupils' basic psychological needs for autonomy, competence and social relatedness, thereby strengthening intrinsic motivation for motor activity (Lambe *et al.*, 2022). Tracking one's own progress through trackers and mobile applications enhances the sense of competence; gamified tasks and challenges create situations of success; online communities, rankings and team competitions support a sense of belonging to a group (Mackenbrock & Kleinert, 2023). The alignment of the health promotion, technology-enhanced and motivational approaches makes it possible to view digital technologies in physical education as a multi-level influencing factor: from directly increasing the volume and intensity of motor activity to transforming the structure of the lesson and strengthening intrinsic motivation for engaging in physical education (Lambe *et al.*, 2022; Martín-Rodríguez & Madrigal-Cerezo, 2025).

The results of the study revealed that exergames, as a digital tool, provide a sufficient intensity of physical load, improve endurance, strength and coordination, and also create a positive emotional gaming experience that changes attitudes towards motor activity. This is consistent with the work of Y.Z. Birinci *et al.* (2023), in which exergames are considered an educational tool in physical education capable of influencing not only physical but also cognitive, social and affective domains of pupils' development. The authors demonstrated that active video games can support the learning of motor skills, promote cooperation and social interaction, and increase motivation and satisfaction with lessons. Exergames thus represent a comprehensive pedagogical resource that simultaneously addresses physical, motivational and socio-affective outcomes in school physical education.

The study by E.A. Talero-Jaramillo *et al.* (2024) shows that ICT in school physical education is used in several functional areas: as a means of presenting content, organising and assessing pupils' activities, as well as a tool for shaping motivation and engagement in lessons. The results obtained in the present study are consistent with this multidimensional view: the term "digital technologies" encompasses a spectrum of tools ranging from basic ICT (videos, presentations, online platforms) to specialised interactive systems (exergames, wearable devices, monitoring

platforms), and the identified groups of digital tools perform different but interrelated functions -direct organisation of motor activity, monitoring and self-control, and support for motivation and social interaction. The classification of digital technologies proposed in our study reflects this multifunctionality of ICT and specifies it in the context of school physical education.

The results of the study showed that the combination of the State Standard and the WHO's quantitative recommendations forms a regulatory framework for the target level of physical activity for pupils. In these conditions, digital technologies are seen as a means of compensating for the limited number of hours formally allocated to physical education and bringing actual physical activity closer to international benchmarks. A similar logic is demonstrated in a systematic review by N. Mulato *et al.* (2024), which emphasises that optimising physical education in the digital age requires the targeted integration of technologies into the learning process to increase pupil motivation and participation, rather than simply their formal presence. The authors stress that digital tools must be linked to curriculum updates, the introduction of blended learning and the management of the educational process in order to have a real impact on outcomes, including levels of physical activity. Digital technologies should be designed as a means of achieving regulatory goals, rather than as a self-sufficient "digital" component of the lesson.

A review by J. Sargent & A. Calderón (2022) showed that digital technologies in physical education are analysed through the prism of teaching and learning. The authors emphasised that most studies describe an increase in motivation or engagement, but rarely link technological interventions to clearly defined programmatic or regulatory goals. The current results partly correspond to and at the same time specify this conclusion: digital solutions are not considered as an "addition" to the lesson, but as part of the pedagogical toolkit designed to implement the requirements of the State Standard and WHO recommendations. The classification of tools is linked to their potential to provide sufficient volume and intensity of physical activity, support health-saving goals, and develop pupils' digital and information literacy.

The results of the study indicated that digital technologies (wearable trackers, gamified programmes, online communities) are considered tools for satisfying pupils' basic psychological needs and forming a sustainable motivation for physical activity, which is consistent with the provisions of self-determination theory. M. Standage *et al.* (2025) demonstrate that the gap between the WHO-recommended levels of physical activity and actual indicators is largely related to the quality of pupils' motivation in physical education, and not only to the formal parameters of educational programmes. Educational environments that support autonomy, competence and relatedness promote high-quality intrinsic motivation, greater engagement and better well-being among pupils, which is consistent with the results of the present study. The mere existence of regulatory requirements (State Standard, WHO recommendations) and digital tools does not guarantee an increase in physical activity if the technologies are not used in a way that supports self-regulation, a sense of competence and social inclusion among pupils. In this sense, digital

technologies are not only a tool for implementing formal standards, but also a component of a motivational environment capable of ensuring real progress towards physical activity targets. Thus, the combination of the State Standard and WHO recommendations sets a framework within which digital technologies can be used in a targeted manner to increase the actual level of physical activity among pupils. At the same time, their effectiveness depends on the extent to which these solutions are integrated into the pedagogical model of the lesson and support motivation, self-regulation, health-saving and digital competence, rather than being implemented formally.

Empirical interventions, risks of digitalisation and a conceptual model of use in physical education

Modern digital technologies of the 21st century in the physical education of secondary school pupils appear as a

multidimensional phenomenon that combines various types of tools (exergames, wearable devices, online platforms, gamified services, monitoring systems) and performs a wide range of pedagogical functions, from informing and demonstrating to motivating, monitoring and supporting independent physical education and health activities. At the same time, the mere presence of a digital tool does not automatically increase physical activity: the didactic scenario for its use, the degree of integration of the goal, the content and methods of physical education lessons, compliance with regulatory requirements, and the ability to support pupils' motivational needs are of decisive importance. Moving from theoretical considerations to specific examples allows to see more clearly the real impact of digital technologies on the physical activity of schoolchildren. Table 2 shows the use of digital technologies and their impact on the level of physical activity of pupils.

Table 2. Examples of school interventions using digital technologies in physical education

Type of digital technology	Characteristics	Main effects
Exergames (ExerCube)	Randomised controlled study (primary school, pupils aged approximately 10 years): 58 pupils, three months, standard physical education lessons plus 20 minutes of exergaming twice a week.	A significant improvement in physical fitness indicators (endurance, strength, coordination) was observed in the intervention group compared with the control group → exergames can provide sufficient exercise intensity and increase the level of physical activity during lessons.
Exergames (school-based exergaming programme)	Randomised controlled study (Years 5-6): 58 pupils, three months, school-based exergaming intervention.	An increase in physical self-concept (self-assessment of strength, endurance, and agility); the positive emotional experience of gaming improves attitudes towards movement → indirectly supports higher levels of physical activity.
Gamified programme with cards/sensors (active travel to school)	Seven-week intervention (16 schools – exergaming intervention; 2 schools – control group), "outdoor game" (walking/cycling, points awarded for sensor check-ins).	An increase in the proportion of children achieving the recommended level of physical activity and a higher frequency of active travel to school → digital activity tracking combined with game mechanics changes daily behaviour, not only participation in physical education lessons.
Edmodo social network + gamification of the physical education course	Ten teachers and 56 pupils (secondary school), gamified Physical Education (PE) course delivered via Edmodo.	Pupils received points/badges for physical activity and took part in challenges; both pupils and teachers positively evaluated the platform, and a high impact on the promotion of physical activity outside lessons was noted → demonstrates how a social network can support home-based and extracurricular physical activity.
Wearable activity trackers (wearables)	Cross-sectional survey of 1,087 school staff, describing practices of using activity trackers.	Used during physical education lessons, throughout the school day, in "movement breaks", for step challenges, and for teaching children how to interpret their own data. The majority of staff were willing to continue using trackers to increase physical activity.
Exergame-based training sessions	Randomised controlled study (primary school): 68 children, eight weeks; experimental group – exergame-based training three times a week, control group – usual physical activity.	After eight weeks in the experimental group, there was a significant improvement in 800 m running time (cardiorespiratory endurance) and in muscular endurance indicators (sit-ups) compared with the control group.

Source: compiled by the authors based on F.J. Montiel-Ruiz *et al.* (2022), S. Ketelhut *et al.* (2022), A.V. Creaser *et al.* (2022), B. Lambi *et al.* (2022), L. Röglin *et al.* (2024), C.F. Lin *et al.* (2025)

Online physical education highlights the dual nature of the digital educational environment's impact on pupils' levels of physical activity. A summary of the results obtained in the context of the COVID-19 pandemic shows that the transition to remote formats was accompanied by a decrease in the overall level of physical activity and a deterioration in the physical fitness of schoolchildren, particularly when theoretical or formal online classes predominated (Knoke *et al.*, 2024). Structured online physical education programmes using video lessons, interactive tasks and activity monitoring tools have been shown to reduce the negative effects of lockdowns and partially preserve or improve certain components of physical fitness (Merino-Campos & Del-Castillo, 2025). The potential of such platforms (such as

Edmodo, Zoom, Google Meet) is realised under conditions of adequate technical support, a clear pedagogical lesson plan, and consideration of the ethical aspects of online interaction, while common limitations remain unequal access to the internet and devices for pupils, difficulties in monitoring actual levels of physical activity in the home environment, and additional workload for teachers (Gao *et al.*, 2025).

In the context of Ukrainian physical education for pupils in general secondary education, the issue of digitalisation is considered primarily in the broader context of educational innovation and the use of information and communication technologies. Multimedia tools, interactive forms of work, online resources, and electronic educational platforms can increase pupils' motivation to engage

in physical education, promote the individualisation of learning, and expand opportunities for independent physical activity (Yazlovetska, 2022; Kuzmenko, 2022). However, specific models of online physical education, with a structured description of the use of platforms such as Zoom, Google Meet or Edmodo in the context of systematic school physical education programmes, are generally not detailed. This indicates a gap between the general recognition of the usefulness of digital tools in physical culture and the lack of theoretically described and empirically verified Ukrainian practices of online physical education. This provides grounds for viewing online formats in school physical education as a promising yet still insufficiently conceptualised area. On the one hand, the digital environment creates additional opportunities to support continuity in physical education and to extend the space of physical activity beyond the sports hall; on the other hand, the effectiveness of such solutions directly depends on how clearly they are embedded in the pedagogical model of the lesson, aligned with normative requirements and oriented towards achieving target levels of pupils' physical activity.

A key condition for the effective use of digital technologies in physical education is the appropriate level of digital and methodological competence of the teacher. The introduction of innovative tools requires the teacher to be ready to design digital lessons, select adequate resources, differentiate the workload and ensure safe work in online and offline environments (Martín-Rodríguez & Madrigal-Cerezo, 2025). A significant methodological requirement is to maintain a sufficient motor component of the lesson: digital tools should stimulate and organise physical activity, not replace it. This is advisable for online physical education and mixed formats, where there is a risk of reducing the lesson to watching videos or taking tests (Merino-Campos & Del-Castillo, 2025; Gao *et al.*, 2025). Exergames, wearable trackers, and gamified platforms are effective when their use is linked to clear targets for the volume and intensity of physical activity and integrated into the structure of the lesson or extracurricular activities as a systematic rather than episodic element (Creaser *et al.*, 2022; Röglin *et al.*, 2024). Accordingly, digital technologies should be designed as a tool for achieving these goals, rather than as a distraction from them.

Alongside the advantages of using digital technologies in physical education, a number of risks and limitations also emerge. One of the most obvious is the threat of increased screen time, which runs counter to the objective of reducing sedentary behaviour: without a carefully designed balance between "screen-based" and movement components, a lesson may turn into yet another seated activity (Lambe *et al.*, 2022; Knoke *et al.*, 2024). A significant problem is unequal access to devices and high-quality internet connectivity, particularly in the context of distance learning and the use of online physical education. Digital inequality can exacerbate educational disparities by limiting participation in programmes based on exergames, trackers or gamified platforms (Lambe *et al.*, 2022; Knoke *et al.*, 2024). A separate group of risks relates to the reliability and interpretation of data from wearable devices: formal task completion, manipulation of trackers or misinterpretation of indicators may occur, which reduces the educational potential of such tools (Creaser *et al.*, 2022; Montiel-Ruiz *et al.*, 2022). In

addition, issues of privacy and the protection of pupils' personal data arise, especially when commercial platforms and cloud services are used. Finally, there is a risk of formalism, whereby a digital tool is introduced primarily to demonstrate "innovation" without any real change in lesson content or teaching methods. In such cases, the impact on actual levels of physical activity remains minimal, and digitalisation takes the form of superficial modernisation not supported by deeper didactic change (Martín-Rodríguez & Madrigal-Cerezo, 2025).

On the basis of synthesising research findings, digital technologies in the physical education of pupils in general secondary education institutions can appropriately be considered within a conceptual "input-process-outcomes" model, which integrates the approaches of health promotion (orientation towards creating a supportive educational environment, expanding learners' opportunities and involving them in decision-making) and technology-enhanced pedagogy (the use of digital tools for personalised learning, active participation, feedback and monitoring). Within this model, digital tools are not an end in themselves but are viewed as resources that activate specific mechanisms for changing pupils' movement behaviour. The "input" block comprises three interrelated groups of components: the main groups of digital tools (exergames, wearable trackers, gamified platforms, online physical education and blended formats), regulatory and normative reference points (the State Standard and WHO recommendations on physical activity for children and adolescents), and pedagogical conditions of implementation (teachers' digital and methodological competence, material and technical resources, and organisational support from the educational institution). In the logic of health promotion, this combination forms a "physical-activity-supportive environment", while in the logic of technology-enhanced pedagogy it constitutes the infrastructure for implementing active, personalised and data-informed learning. It is precisely the configuration of these "input" elements that determines which "process" mechanisms can be activated and how effectively they operate: for example, the availability of wearable trackers without an analytical platform and pedagogical support limits opportunities for self-monitoring and reflection, while access to exergames without school support and appropriate spatial organisation does not ensure a systematic increase in physical activity.

The "process" of integration reflects the mechanisms through which "input" resources are transformed into behavioural changes. Exergames and gamified platforms, drawing on the principles of technology-enhanced pedagogy, increase both intrinsic and extrinsic motivation through game mechanics (levels, points, badges, leaderboards, challenges) and social comparison. This aligns with health promotion ideas regarding active participation and peer support among pupils. Wearable trackers and analytical platforms facilitate self-monitoring, the setting of individual goals, and immediate feedback, creating the conditions for developing self-regulation skills in physical activity. Online PE, digital media, and social networks expand the space for physical activity beyond the lesson: they support the regularity of exercise in remote and blended formats, structure extracurricular challenges, and foster networked communities oriented towards an active

lifestyle. Furthermore, video and interactive content support the teaching of movement techniques and the acquisition of theoretical knowledge, which enhances the quality of exercise execution and the mindfulness of motor behaviour. The effectiveness of these mechanisms depends on the degree of their organic integration into the structure of lessons and extracurricular activities, their alignment with educational programmes, and the teacher's ability to implement technology-supported pedagogical design.

At the “outcome” level, the model distinguishes between direct, indirect, and long-term effects. The activation of the described “process” mechanisms leads directly to an increase in time spent in moderate-to-vigorous physical activity, improved physical fitness indicators, and increased participation in physical and sporting events. Indirectly, through the experience of success, social support, the ability to track one's own progress, and the receipt of positive reinforcement, a positive attitude towards physical education is formed, physical self-concept is enhanced, self-regulation skills for physical activity are developed, and pupils' health-preserving competence is strengthened. In the long term, in line with the logic of health promotion, such integration of digital technologies contributes to a more stable alignment with international recommendations regarding physical activity levels and the formation of the foundations for an active lifestyle throughout the life cycle (Fig. 1).

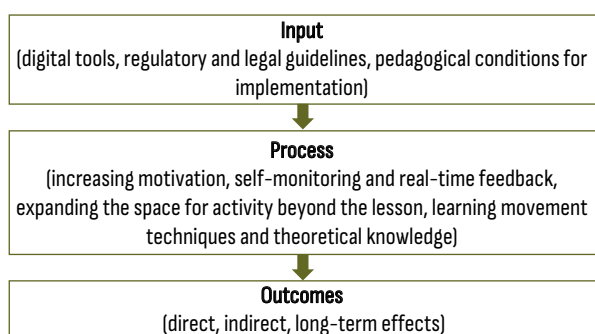


Figure 1. Conceptual model of the integration of digital technologies into the physical education of general secondary education pupils (“input – process – outcomes”) within the framework of the health promotion and technology-enhanced pedagogy approaches

Source: compiled by the authors based on World Health Organization (2020), F.J. Montiel-Ruiz *et al.* (2022), C. Knoke *et al.* (2024), C. Merino-Campos & H. Del-Castillo (2025), A. Martín-Rodríguez & R. Madrigal-Cerezo (2025)

The proposed model can be applied not only to physical education lessons but also to the school sport system as a whole, including the work of sports clubs, the preparation of teams for competitions, and the organisation of school and interschool tournaments. Thus, digital technologies in the physical education of general secondary education pupils demonstrate a significant but heterogeneous potential to influence levels of physical activity. Exergames combine a high level of physical load with an engaging game-based format, positively affecting physical fitness and self-perception; wearable trackers and related platforms provide monitoring, self-control, and goal setting; and gamified programmes and social services help shift the focus from

the lesson itself to everyday movement behaviour. Online formats of physical education support continuity of learning in conditions of distance education; however, their effectiveness in maintaining adequate levels of physical activity depends on the quality of pedagogical design. Of decisive importance is the alignment of digital solutions with the aims of the field of Physical Culture and Sport, their consistency with the recommendations of the WHO, teacher competence, and the resources of the educational institution. Thus, digital technologies should be regarded as tools for the purposeful enhancement of pupils' physical activity both during lessons and in extracurricular sports and health-related activities.

The results of the study indicate that the proposed classification of digital technologies (exergames, wearable trackers, digital monitoring platforms) and the “input-process-outcomes” model, in which monitoring mechanisms, individualisation of load, and feedback play a key role, reflect the logic of their practical application in physical education. In the study by Q. Zhong *et al.* (2025), it is shown that “digital-intelligent technologies” form a closed cycle in physical education: intelligent lesson design, real-time visualisation of the process, and data-driven assessment and adjustment. This correlates with the findings of the present study, which demonstrate that digital monitoring platforms and wearable devices that collect activity data enable the tracking of dynamics, goal setting, and adjustment of physical load. In both cases, digital tools are viewed not as an “addition to the lesson” but as the core of a new, more controllable and personalised model of physical education. This confirms the appropriateness of the systematic use of digital technologies as a structure-forming element of modern school physical education in the twenty-first century.

In the study by V. Tagimaucia *et al.* (2024), online physical education is examined through the lens of teachers' experiences who were forced to switch to online formats during COVID-19 lockdowns. The authors showed that insufficient teacher preparation, a lack of online pedagogical skills, and limited infrastructure constitute key barriers to high-quality distance teaching of physical education. Without targeted development of teachers' digital and methodological competence, as well as adequate material and technical support, the potential of online formats is only partially realised. The results obtained in the present study are consistent with these conclusions: digital solutions in physical education prove effective only when the teacher designs the lesson in such a way that screen-based components organise real motor activity rather than replace it, and when the risks of increased screen time, digital inequality, and the formal use of platforms as a mere “demonstration of innovativeness” are addressed. The transition to online formats in itself does not guarantee the achievement of target levels of pupils' physical activity unless it is accompanied by systematic teacher support and well-considered pedagogical design of lessons.

The results of the study established that gamified programmes and social networks (challenges, points, leaderboards, badges, online communities) stimulate everyday movement behaviour (travel to school, extracurricular activity) and support motivation, which is consistent with the work of V. Arufe-Giráldez *et al.* (2022). The authors summarised the experience of gamification in school physical

education, showing that the use of game elements (narrative, levels, rewards) enhances pupils' engagement, interest, and satisfaction with physical education lessons, while the effect of gamification depends on the quality of pedagogical design. Both studies indicate that gamification is not "automatically" effective; however, when competently embedded into the structure of lessons and extracurricular activities, it significantly strengthens the motivational component and pupils' readiness to be physically active.

In the systematic review by C. Wang *et al.* (2023), blended learning in physical education is analysed as a promising but methodologically complex approach. The authors synthesise tools, theoretical frameworks, and assessment methods and show that combining online and offline components can increase pupil engagement, flexibility, and continuity of learning, but is not automatically effective. Key conditions for the effectiveness of blended formats include clear instructional design, a sufficient level of teachers' digital skills, and support for pupils' self-regulation. The findings of the present study resonate with these conclusions: online and blended formats in Ukrainian school physical education are viewed as a promising yet still insufficiently conceptualised direction, the effectiveness of which depends on the quality of integration into the pedagogical model of the lesson and alignment with the requirements of the State Standard and the recommendations of the WHO regarding 60 minutes of moderate-to-vigorous physical activity per day. Blended learning in physical education is effective only when supported by thoughtful pedagogical design and orientation towards the goals of the State Standard and WHO recommendations. Thus, digital technologies in the physical education of general secondary education pupils have a substantial but heterogeneous potential to increase levels of physical activity and motivation – from exergames and wearable trackers to gamified programmes and online formats. Their real effect is determined not so much by the fact of digitalisation itself as by the quality of pedagogical design, compliance with regulatory documents in the field of physical education, their use as tools for the purposeful enhancement of pupils' motor engagement, teacher competence, and the mitigation of risks related to excessive screen time, digital inequality, and formalism.

Conclusions

The results of the study revealed that formally allocated physical education hours create only minimal conditions for health preservation and, without additional tools, particularly digital ones, do not provide the recommended 60 minutes of activity per day. A classification of digital tools for school physical education has been developed, covering active video games, wearable devices, online platforms, gamified services, and systems for collecting and analysing

data on physical activity. Exergames in the form of educational interventions provide sufficient intensity of exercise and contribute to the growth of endurance, strength and coordination indicators in younger schoolchildren. Regular use of active video games is associated with improved physical self-concept and a more positive attitude towards physical education among pupils. Gamified programmes and social networks stimulate not only activity in the classroom, but also daily physical behaviour, including active commuting to school and extracurricular activities. Online and blended formats of physical education can prevent a sharp decline in physical activity during distance learning, but only if they are well designed pedagogically and adequately supported by technology. In Ukraine, online physical education is still largely fragmented and requires further theoretical justification and standardisation of practices.

The effectiveness and safety of using digital technologies in physical education depend on the teacher's high digital and methodological competence and avoiding the risks of excessive screen time, digital inequality and data privacy violations. A conceptual model of "input-process-outcomes" has been proposed, in which the "input" stage combines a reasoned choice of digital tools, compliance with national and international regulatory documents, and resource support for the educational institution, while the "process" of integration is implemented through gamification, self-control, operational feedback, social interaction, and individualisation of workload. The systematic use of such technologies increases the proportion of pupils who achieve target levels of physical activity and better physical fitness results, so digital tools should be seen as a means of purposefully shaping an active lifestyle rather than a formal marker of innovation. The limitations of the study are its theoretical and review nature and the lack of empirical data, which complicates the direct extrapolation of conclusions to the Ukrainian context. Prospects for further research should be directed towards conducting an empirical assessment of the effectiveness of digital solutions in the physical education of the general secondary school pupils, developing methodological recommendations and programmes for teacher training, as well as analysing the ethical and legal aspects of the use of digital data, particularly in Ukraine.

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Conflict of Interest

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Вплив застосування сучасних цифрових технологій у фізичному вихованні на рівень фізичної активності учнів середньої школи

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Анотація. Метою дослідження було розкрити теоретичні засади інтеграції електронних освітніх платформ і мобільних сервісів у шкільні заняття з фізичної культури для окреслення їх можливості щодо посилення рухової залученості школярів. Методологія базувалась на поєднанні теоретичного аналізу, нормативно-правового підходу та концептуального моделювання. Виявлено, що основними інструментами цифрових технологій є exergames, фітнес-трекери, онлайн-уроки, гейміфіковані програми, соцмережі та платформи моніторингу активності. Exergames, носимі трекери та гейміфікація забезпечують достатню інтенсивність навантаження, дають об'єктивні дані для самоконтролю й постановки цілей та стимулюють щоденну рухову активність учнів. Онлайн-формати фізичного виховання частково компенсують зниження рухливості під час дистанційного навчання, якщо мають продуманий педагогічний дизайн. Цифрові медіа в концепції health promotion використовуються для профілактики гіподинамії та наближення учнів до рекомендованих рівнів рухової активності. У межах technology-enhanced pedagogy цифрові засоби індивідуалізують навантаження, покращують засвоєння рухових дій і розширюють простір активності поза школою. Встановлено, що результатами інтеграції цифрових технологій є зростання часу помірної/високої активності, покращення фізичної підготовленості, мотивації, саморегуляції та позитивного ставлення до фізичної культури. Ефективність і ризики залежать від компетентності вчителя, матеріальної бази, організаційної підтримки, а також від контролю екранного часу, цифрової нерівності й конфіденційності даних. Запропоновано концептуальну модель «вхід – процес – результати», де на «вході» – типи цифрових технологій, нормативні орієнтири й умови реалізації, у «процесі» – мотиваційні, організаційні та моніторингові механізми впливу, а в «результатах» – зміни фізичної активності та ставлення до фізичної культури. Практична значущість полягає в тому, що результати доцільно застосовувати вчителям фізичної культури та методистам для планування занять, спрямованих на підвищення фізичної активності й мотивації учнів

Ключові слова: exergames; носимі трекери; гейміфіковані платформи; онлайн-навчання спорту; мотивація школярів; рухова активність