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**The impact of the Eduball method on selected parameters
of creativity and motor fitness in early age school children**

Doctoral Dissertation

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*To my husband, without whose support
and absolute belief in me this dissertation
would never have come to life*

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LIST OF ABBREVIATIONS

AF (pol. aktywność fizyczna) – physical activity

CG – control group

EG – experimental group

M – mean

MVPA – moderate-to-vigorous physical activity

PA – physical activity

PE – physical education

SD – standard deviation

SHR – 10 × 5-meter Shuttle Run

TCT-DP – Test for Creative Thinking–Drawing Production

TCAM – Thinking Creatively in Action and Movement test

WF (pol. wychowanie fizyczne) – physical education

ABSTRACT

Introduction. Creativity has become an essential competence in contemporary society, recognized as a key skill for success in today's rapidly changing and competitive world. Although the promotion of creativity is increasingly emphasized in education, physical education (PE) is still predominantly associated with the development of motor skills and physical fitness, while its potential to foster creativity is often overlooked. Empirical evidence, however, indicates that PE provides a natural context for creative expression through problem-solving, improvisation, and divergent movement tasks. The Eduball method, an innovative interdisciplinary approach that incorporates educational balls to combine physical activity (PA) with cognitive tasks, offers a promising avenue for supporting both cognitive and motor creativity alongside traditional fitness outcomes. This project aimed to assess the impact of the Eduball method on selected parameters of creativity and motor fitness during PE classes in early school-aged children.

Material and Methods. The study followed a pre-test–post-test experimental design. Participants were pupils aged 8–9 years, recruited from three primary schools (grade 2) and attending a standard school curriculum. The pre-test (Publication 1) involved 195 pupils (47% girls) and included assessments of anthropometric data (body height and weight), motor fitness, self-reported PA, cognitive creativity, and motor creativity. Motor fitness was assessed using selected Eurofit battery tests: a 20-meter Shuttle Run to evaluate cardiorespiratory endurance, and a 10 × 5-meter Shuttle Run (SHR) to assess speed and agility. The Piórkowski apparatus test measured eye-hand coordination, reaction time, and precision of movements. The level of moderate-to-vigorous physical activity MVPA was determined using the Physical Activity Screening Measure. Cognitive creativity was assessed using the Test for Creative Thinking–Drawing Production (TCT-DP). Motor creativity (fluency, originality, imagination) was evaluated using the Torrance's 'Thinking Creatively in Action and Movement' (TCAM) test. Following this assessment, entire classes of participants were randomly divided into three groups: two experimental groups (EG1 and EG2) and one control group (CG). The eight-week intervention program using the Eduball method was conducted during PE classes in two experimental groups: EG1 participated in the Eduball intervention program once per week, alongside two traditional PE classes; EG2 engaged in the Eduball program twice a week, with one traditional PE class. Meanwhile, CG followed the standard curriculum, receiving only traditional three PE classes without Eduball intervention. The data of participants of experimental groups who attended less than 60% of intervention program were excluded and not considered in the analysis of the post-test results. The post-test (Publication 2) involved 173 pupils (48% girls) and included the same assessments.

Results. The findings of pre-test indicated significant gender differences in motor fitness, whereas no differences were observed between boys and girls in PA, cognitive creativity, or motor creativity. Furthermore, no associations were identified between PA, motor fitness, and either form of creativity within either gender group (Publication 1). Importantly, at the pre-test there were no significant differences between experimental and control groups in any measured parameter. However, statistically significant differences were

observed in the post-test for the TCT-DP scores, motor imagination (TCAM), and eye-hand coordination in Piórkowski apparatus test, all favoring EG2. Within-group comparisons showed significant improvements in all motor fitness parameters, as well as in TCAM fluency and imagination across all groups. However, no significant change in TCT-DP or TCAM originality was observed in the experimental groups. The control group showed a significant decline in these two parameters (Publication 2).

Conclusions. The findings of this study demonstrate that while gender differences exist in motor fitness among 8- to 9-year-old children, no differences were observed in PA, cognitive creativity, or motor creativity between boys and girls. Moreover, no associations were identified between PA, motor fitness, and creativity parameters, indicating that fostering creativity in children requires purposefully designed pedagogical environments and strategies rather than reliance on natural links with fitness or activity levels.

The results further highlight the potential of the Eduball method as an effective pedagogical tool in PE. The intervention showed a positive, dose-dependent impact on creativity, particularly in enhancing cognitive creativity, motor imagination, preserving motor originality, and improving eye-hand coordination with higher implementation frequency. Although Eduball did not lead to significant gains in all motor creativity components, it successfully prevented the decline observed in traditional PE settings. These outcomes emphasize the importance of integrating creativity-oriented approaches into PE curricula, ensuring that children's natural inclination for both movement and creativity is supported and developed.

Taken together, the evidence suggests that PE, when enriched with innovative methods such as Eduball, provides a valuable context for fostering children's creative potential alongside their motor development, with equal effectiveness for both genders.

STRESZCZENIE

Wprowadzenie. Kreatywność stała się kluczową kompetencją we współczesnym społeczeństwie, uznawaną za niezbędną umiejętność w szybko zmieniającym się i konkurencyjnym świecie. Choć w edukacji coraz częściej podkreśla się potrzebę wspierania kreatywności, wychowanie fizyczne (WF) wciąż jest przede wszystkim kojarzone z rozwijaniem sprawności motorycznej i kondycji, a jego potencjał do kształtowania kreatywności bywa pomijany. Dowody empiryczne wskazują jednak, że WF stwarza naturalny kontekst do twórczej ekspresji poprzez rozwiązywanie problemów, improwizację i zadania ruchowe o charakterze dywergencyjnym. Metoda Eduball – innowacyjne podejście interdyscyplinarne, w którym wykorzystuje się piłki edukacyjne do łączenia aktywności fizycznej (AF) z zadaniami poznawczymi – stanowi obiecującą drogę wspierania zarówno kreatywności poznawczej, jak i motorycznej, obok tradycyjnych efektów w zakresie sprawności. Celem projektu była ocena wpływu metody Eduball na wybrane parametry kreatywności i sprawności motorycznej podczas lekcji WF u dzieci w wieku wczesnoszkolnym.

Materiał i metody. Zastosowano schemat badania eksperymentalnego z pomiarem przed i po interwencji (pre–post). Uczestnikami byli uczniowie w wieku 8–9 lat, zrekrutowani z trzech szkół podstawowych (klasa 2) realizujących standardową podstawę programową. Pomiar wstępny (publikacja 1) objął 195 uczniów (47% dziewcząt) i uwzględniał ocenę danych antropometrycznych (wysokość i masa ciała), sprawności motorycznej, deklarowanej AF, kreatywności poznawczej oraz kreatywności motorycznej. Sprawność motoryczną oceniano wybranymi testami baterii Eurofit: 20-metrowym biegiem wahadłowym do oceny wydolności krążeniowo-oddechowej oraz biegiem wahadłowym 10 × 5 m do oceny szybkości i zwinności. Test na aparacie Piórkowskiego mierzył koordynację wzrokowo-ruchową, czas reakcji i precyzję ruchów. Poziom umiarkowanej do intensywnej aktywności fizycznej określono za pomocą Physical Activity Screening Measure. Kreatywność poznawczą oceniano Rysunkowym Testem Twórczego Myślenia (Test for Creative Thinking – Drawing Production – TCT-DP). Kreatywność motoryczną (płynność, oryginalność, wyobraźnię) oceniano testem Torrance’a „Twórcze myślenie w działaniu i ruchu” (Thinking Creatively in Action and Movement – TCAM). Po tym pomiarze całe klasy losowo podzielono na trzy grupy: dwie eksperymentalne (EG1 i EG2) oraz jedną kontrolną (CG). Ośmiotygodniowy program interwencji Eduball realizowano na lekcjach WF w obu grupach eksperymentalnych: EG1 uczestniczyła w zajęciach Eduball raz w tygodniu, obok dwóch tradycyjnych lekcji WF; EG2 – dwa razy w tygodniu, z jedną tradycyjną lekcją WF. Grupa CG realizowała standardowy program, otrzymując wyłącznie trzy tradycyjne lekcje WF bez interwencji Eduball. Dane uczestników grup eksperymentalnych, którzy uczestniczyli w mniej niż 60% zajęć interwencyjnych, wykluczono i nie uwzględniano w analizie wyników pomiaru końcowego. Pomiar końcowy (publikacja 2) objął 173 uczniów (48% dziewcząt) i zawierał te same pomiary.

Wyniki. Wyniki pomiaru wstępnego wykazały istotne różnice międzypłciowe w sprawności motorycznej, natomiast nie odnotowano różnic między chłopcami i dziewczętami w zakresie AF, kreatywności poznawczej ani kreatywności motorycznej. Ponadto nie stwierdzono związków między AF, sprawnością motoryczną a którymkolwiek typem kre-

atywności w żadnej z grup płci (publikacja 1). Co istotne, w pomiarze wstępnym nie było różnic między grupami eksperymentalnymi i kontrolną w żadnym z mierzonych parametrów. W pomiarze końcowym odnotowano jednak istotne statystycznie różnice na korzyść EG2 w wynikach TCT-DP, w zakresie wyobraźni motorycznej (TCAM) oraz w koordynacji wzrokowo-ruchowej w teście aparatem Piórkowskiego. Porównania wewnątrzgrupowe wykazały istotną poprawę we wszystkich parametrach sprawności motorycznej, a także w płynności i wyobraźni (TCAM) we wszystkich grupach. Nie odnotowano natomiast istotnej zmiany w TCT-DP ani w oryginalności (TCAM) w grupach eksperymentalnych, podczas gdy w grupie kontrolnej zaobserwowano istotny spadek tych dwóch parametrów (publikacja 2).

Wnioski. Wyniki badania pokazują, że choć u dzieci w wieku 8–9 lat występują różnice międzypłciowe w sprawności motorycznej, nie stwierdzono różnic między chłopcami i dziewczętami w zakresie AF, kreatywności poznawczej ani kreatywności motorycznej. Ponadto nie zaobserwowano związków między AF, sprawnością motoryczną a parametrami kreatywności, co wskazuje, że rozwijanie kreatywności u dzieci wymaga celowo zaprojektowanych środowisk i strategii pedagogicznych, a nie polegania na naturalnych związkach z poziomem sprawności czy aktywności.

Dalsze wyniki podkreślają potencjał metody Eduball jako skutecznego narzędzia pedagogicznego w WF. Interwencja wykazała pozytywny, zależny od dawki (częstości), wpływ na kreatywność – w szczególności na wzrost kreatywności poznawczej, wyobraźni ruchowej, utrzymanie oryginalności motorycznej oraz poprawę koordynacji wzrokowo-ruchowej – przy wyższej częstotliwości wdrożenia. Choć Eduball nie doprowadził do istotnych przyrostów we wszystkich komponentach kreatywności motorycznej, skutecznie zapobiegł spadkom obserwowanym w tradycyjnych warunkach WF. Wyniki te podkreślają znaczenie włączania podejść ukierunkowanych na kreatywność do programów WF, tak aby wspierać i rozwijać naturalną skłonność dzieci zarówno do ruchu, jak i do kreatywności.

Podsumowując, dane sugerują, że WF wzbogacone o innowacyjne metody, takie jak Eduball, stanowi cenny kontekst dla rozwijania potencjału kreatywności dzieci równoległe z ich rozwojem motorycznym – i to z równą skutecznością dla obu płci.

1. INTRODUCTION

Childhood represents a crucial stage in human life that largely determines future prospects for personal growth, the ability to realize one's own potential, and has a profound influence on self-fulfillment in adulthood (Hampson 2008). Consequently, it is essential to provide an environment in early childhood that ensures the most favorable conditions for a child's development, taking into consideration all contributing factors.

Movement plays a critical fundamental role throughout childhood development. Children, naturally inclined to be active and curious, explore and learn about the world through movement in the whole range of types and forms (Sevimli-Celik 2018). It serves as the first means of perceiving their surroundings—almost as a primary language through which an infant expresses intention and desire. From birth, the brain prioritizes movement as one of its primary functions, following vital physiological processes such as breathing, circulation, and digestion. Each movement performed by a child contributes to the formation of new neural connections, thereby enhancing their physical and motor capacities (Aspire Education 2022). The diversity of movements that a child acquires supports the development of essential motor skills required for interacting with their immediate environment, while also fostering an active, healthy body that positively influences quality of life in later years (Sevimli-Celik 2018).

On a physiological level, higher levels of physical activity (PA) are associated with improved body composition, greater bone mineral density, enhanced insulin sensitivity (Donnelly et al. 2017), and overall energy balance, which contribute to healthy growth, optimal weight, and healthy development of the cardiovascular and musculoskeletal systems, working as the prevention of risk factors. Sedentary behaviors, on contrary, are recognized as the ones leading to all range of health-related malfunctions of the psychosomatic body cardiovascular diseases such as hypertension, dyslipidemia, and diabetes (Koyama et al. 2020; Li et al. 2024; Loprinzi et al. 2012).

Beyond promoting physical health and preventing diseases, regular participation in PA is also connected to enhanced brain functioning and cognitive performance, as well as improved academic outcomes (Hillman et al. 2008; Khan and Hillman 2014). Several theoretical mechanisms have been proposed to explain how exercise may benefit cognitive processes. These include: 1) increased cerebral blood and oxygen flow (Jorgensen et al. 2000); 2) higher levels of norepinephrine and endorphins (Fleshner 2000; Winter et al. 2007), which reduce stress and improve mood (Yeung 1996); and 3) elevated concentrations of growth factors that facilitate the formation of new neurons and strengthen synaptic plasticity (Schinder and Poo 2000; Van Praag et al. 1999), specifically in a young developing brain of a child.

The role of PA in supporting children's health is of exceptional importance as we continue to deepen our understanding of how physical, social, and cultural environments influence population health. Numerous studies have confirmed the association between PA, cognition, brain structure and function, and academic performance (Bidzan-Bluma and Lipowska 2018; Chaddock et al. 2011; Khan and Hillman 2014). Donnelly et al. (2017) reported that large-scale cohort studies have provided consistent evidence supporting the link between PA and cognitive functioning, indicating that higher volumes or more intensive types of activity are related to cognitive improvement. Similarly, acute PA studies

have also demonstrated positive correlations between PA engagement and cognition (Donnelly et al. 2017).

In a rapidly changing world driven by technological advancement, social transformation, and global competitiveness, creativity has emerged as a vital and highly sought-after skill. It is now recognized as one of the essential competencies for the modern workforce. According to the Future of Jobs Report 2025 published by the World Economic Forum (2025), creativity ranks among the top five professional skills most valued by employers. This underscores the necessity of developing an adaptive, innovative, and cooperative workforce, in which creative potential plays a central role in achieving success.

Previous research has conceptualized creativity as a multidimensional construct, acknowledging its manifestation not only in art but also in science, engineering, commerce, and business innovation (Higuera et al. 2021; Mann and Chan 2011; Sawyer 2006). Consequently, it is understandable that creativity, long acknowledged as an educational priority, has gained renewed and increasing attention in recent years (Aquiye-Mansilla et al. 2025; Vincent-Lancrin et al. 2019) as a vital factor in preparing young people for adulthood and its growing demands.

Recent studies have increasingly explored methods and strategies for fostering creativity among children in educational contexts (Aquiye-Mansilla et al. 2025; Gu et al. 2022; Maslin et al. 2023; Paz-Baruch et al. 2025; Turaboyeva 2024). However, relatively few have examined creativity development within the context of physical education (PE) and its potential in this regard (Konstantinidou 2023; Neville and Makopoulou 2021; Richard et al. 2018; Thomaidou et al. 2021). The promotion of creativity should form a fundamental component of children's education and holistic development.

Most existing approaches to developing children's creativity focus primarily on academic subjects (Aquiye-Mansilla et al. 2025; Renzulli 2017), whereas PE has often been undervalued in this respect. This limited perspective stems from the widespread belief that PE serves only to enhance motor abilities and physical fitness. This misconception is rooted in the fact that modern PE programs are typically reproductive in nature, emphasizing repetitive motor skill practice and physical conditioning over creative exploration (Constantinides and Antoniadis 2022; Hincă 2020; Sympas et al. 2017).

It is important to recognize that children in early school years undergo a phase of accelerated motor development, during which both fundamental motor skills (e.g., running, jumping, throwing) and supporting motor abilities (such as strength, speed, agility, coordination, and balance) become increasingly refined (Haywood and Getchell 2021; Payne and Isaacs 2020). At this stage, children exhibit noticeable gains in movement efficiency, enabling them to combine and apply motor patterns in progressively complex ways, especially in play-based situations. Aerobic capacity and speed show pronounced improvements in this period, reflecting both biological maturation and greater involvement in organized PA (Lloyd et al. 2016). Meanwhile, fine motor skills also develop steadily, resulting in improved dexterity and eye-hand coordination. Altogether, these developmental changes enhance children's coordination, balance, and general motor proficiency, which are essential for effective participation in structured games and PE activities (Haywood and Getchell 2021).

From a gender perspective, physical growth and the development of motor abilities such as speed, endurance, and strength occur in both boys and girls, though at different rates and magnitudes. While the development of muscle strength tends to progress more slowly than that of speed and endurance, certain gender-specific tendencies are evident. Girls generally demonstrate greater flexibility and coordination than boys at the primary school age (Bos and Ulmer 2003; Roth et al. 2018). However, Popovici et al. (2017) found

that boys outperform girls in lower- and upper-limb strength and abdominal muscle power, whereas girls excel in balance-related tasks. Similarly, boys tend to achieve significantly higher endurance running performance compared to girls (Roth et al. 2018). These findings suggest that although general developmental trajectories are shared, distinct gender-related patterns exist in specific motor domains.

In terms of cognitive development, studies indicate that early school-aged children exhibit only minimal gender differences (Ardila et al. 2011; Gur et al. 2012; Wai et al. 2018). Ardila et al. (2011) observed significant distinctions in just three domains—language, spatial, and sensory-perceptual abilities—with boys outperforming girls; however, these accounted for only a small proportion of the overall variance. Likewise, Gur et al. (2012) found that girls displayed higher accuracy and speed in verbal memory, social cognition, and face recognition tasks, while boys performed better in attention, spatial, and working memory tests, as well as in sensorimotor and locomotor speed. Importantly, Gur et al. (2012) emphasized that such differences become more pronounced only after mid-adolescence. Overall, available evidence suggests that during early school years, gender-related differences in cognition are minor and not likely to significantly affect learning potential.

Considering this inherent tendency toward rapid motor and cognitive growth, PE programs should be deliberately structured to support and stimulate these developmental processes. Well-designed PE programs can provide an effective platform for enhancing both motor proficiency and cognitive engagement by integrating movement, perception, and problem-solving experiences.

Evidence accumulated over the past decade—particularly from European studies—demonstrates that PE possesses considerable capacity for cultivating creativity. Heilmann and Korte (2010) conducted a content analysis of European curricula and found that PE ranked among the top three school subjects featuring the highest frequency of creativity-related terms, reflecting its long-recognized potential for nurturing creativity within educational settings. PE activities naturally encourage creative expression through collaborative plays and games, where students can alter rules, invent alternative movement patterns, and demonstrate divergent approaches to sports tasks. Such features make PE an especially suitable context for developing creative ability through movement (Konstantinidou et al. 2011).

Movement is a fundamental necessity and natural stimulus for children from birth (Sevimli-Celik 2018), while play constitutes one of the most engaging and essential aspects of their development (Mehta et al 2020; Whitebread et al. 2012). Research suggests that creativity is less likely to emerge in conditions characterized by boredom or negative emotions; conversely, it flourishes in environments marked by positive mood and engagement (Baas et al. 2008; St-Louis and Vallerand 2015). PE teachers, by leveraging the distinctive characteristics of their subject, can establish such positive and stimulating settings. In these contexts, creativity can be effectively supported and expressed through movement, allowing its development to occur naturally and enjoyably rather than as an imposed task.

Creativity is traditionally defined as the capacity to produce outcomes that are both novel (original) and appropriate to a given task or context (Sternberg and Lubart 1999). Another widely accepted definition describes it as the ability to generate ideas or products that are simultaneously original and useful (Sternberg 2022). Other theoretical perspectives, however, conceptualize creativity not as an individual attribute or product but as a dynamic, embodied, and socio-culturally situated phenomenon emerging through interaction between individuals and their environments (Richard et al. 2021b). In the present study, creativity is examined within the school context, focusing specifically on little-c creativity—

the everyday form of creativity that can be fostered through educational experiences and differs from the eminent, domain-transforming creativity associated with professional expertise or genius (Kaufman and Beghetto 2009). Within the 4C framework (Kaufman and Beghetto 2009), little-c creativity lies between mini-c (personally novel insights) and pro-c (professional-level achievements). It encompasses everyday creative behaviors such as pretend play, questioning, and problem-solving, all of which are critical for children's learning, well-being, and overall development (Kaufman and Glăveanu 2019).

Motor creativity, or creativity expressed through movement, was initially defined by Wyrick (1968) as the ability to produce unique and varied motor responses to a stimulus, though the author noted the difficulty of its objective evaluation. Later models, including Torrance's Thinking Creativity in Action and Movement (TCAM) (Torrance 1981), expanded this definition by adding fluency—the number of generated responses—as an additional criterion. Thus, while creativity may be viewed from product-, process-, or systems-oriented perspectives (Green et al. 2023), the present study adopts a predominantly product-based approach, emphasizing observable outcomes of children's cognitive and motor creativity.

Understanding motor creativity is particularly significant within school-based PE. Studies exploring instructional methods for enhancing motor creativity in PE lessons have demonstrated their positive effects (Richard et al. 2018; 2021a; Thomaidou et al. 2021). However, it has been noted that traditional PE programs, which focus primarily on physical fitness and repetitive skill execution, are not conducive to developing motor creativity. Such programs typically employ reproductive, teacher-centered teaching styles emphasizing repetition and precision rather than creative exploration (Konstantinidou 2023). In practice, these approaches rely on linear, standardized instruction aimed at performance mastery instead of innovation. By contrast, motor creativity is best stimulated through activities that promote nonlinear learning mechanisms. Techniques such as constraint manipulation (e.g., performing an action with one limb), functional variability (e.g., "show another way to do this"), problem-solving (e.g., "find a way to..."), improvisation (e.g., "do whatever you want"), fantasy play (e.g., "pretend you are an animal"), and creation (e.g., "invent a completely new movement") have been shown to significantly encourage creative motor expression (Richard et al. 2018). In linear instruction, overly rigid task constraints often limit children's exploration of new movement possibilities (Marinšek and Lukman 2021; Richard et al. 2018; Scibinetti et al. 2011). The inability of traditional PE to effectively stimulate creativity highlights a broader issue in PE pedagogy, where the prevailing focus on standardization tends to suppress opportunities for innovation and individual expression. Consequently, nurturing motor creativity in PE requires specifically designed pedagogical strategies.

One of the most innovative approaches in this area is the Eduball method—a distinctive educational approach that merges PA with academic learning. This method combines movement with subject-based instruction through structured lesson plans, interdisciplinary strategies, and defined didactic principles. By integrating movement and play, it enhances children's cognitive abilities and makes learning more engaging and effective (Ribeiro et al. 2024). Developed in 2001 by Polish researchers Rokita and Rzepa, the method applies an interdisciplinary model of PE that combines physical and mental cognitive engagement. It employs special didactic tools—educational balls (Eduballs)—used in PE lessons with adapted tasks designed to stimulate cognitive functions through movement (Rokita et al. 2017b).

The Eduball set includes 100 balls in five colors (red, blue, green, yellow, and orange), each marked with letters, numbers, or mathematical symbols (Rokita and Rzepa 2002;

2005). Through interactive PE activities with Eduballs, children learn about colors, letters, numbers, and basic mathematical operations while simultaneously improving fine and gross motor skills, including catching, passing, dribbling, throwing, and bouncing (Ribeiro et al. 2024; Rokita et al. 2017b). These games are based on natural forms of movement and support children's holistic development. The combination of letters, numbers, and symbols, together with color coding, allows for wide application across multiple school subjects during PE lessons (Rokita et al. 2017a; 2017b). Since their introduction, numerous pedagogical studies have investigated the outcomes of movement-based learning with Eduballs (Cichy et al. 2015; 2020; 2022; Rokita et al. 2007; Wawrzyniak et al. 2015; 2021; 2022). Findings indicate that educational ball activities positively affect coordination, spatial awareness, and locomotor abilities among primary school students (Cichy et al. 2015; Wawrzyniak et al. 2015).

The most distinctive characteristic of the Eduball method, however, lies in its impact on academic performance. Research has revealed significant improvements in language competence (both native and foreign), reading and writing proficiency, and mathematical skills among children participating in Eduball-based programs (Cichy et al. 2020; 2022; Rokita et al. 2007; Wawrzyniak et al. 2022). Additionally, increased graphomotor efficiency has been observed in primary school pupils (Wawrzyniak et al. 2021). The relationship between cognitive ability and academic performance is well established (Peng and Kievit 2020; Tikhomirova et al. 2020), with evidence showing that this link is particularly strong in early school years (Tikhomirova et al. 2020). Moreover, Runco (2007) demonstrated that basic cognitive processes—such as attention, perception, memory, and information processing—are directly related to creative problem-solving.

Accordingly, the conceptual framework of the Eduball method suggests that it offers meaningful opportunities to promote creativity within the PE setting. This potential may arise not only indirectly—through its positive influence on academic achievement and cognitive functioning, both closely associated with creativity—but also directly, through the very nature of Eduball tasks. These tasks are purposefully designed to engage both cognitive and physical domains simultaneously, encourage nonlinear movement exploration, and stimulate problem-oriented thinking. This assumption, supported by prior empirical findings (Cichy et al. 2020; 2022; Rokita et al. 2007; 2017b; Wawrzyniak et al. 2021, Rzepa and Wójcik 2007a), formed the basis for the hypothesis that the Eduball method could serve as an effective tool for enhancing both cognitive and motor creativity in PE lessons.

To evaluate this hypothesis, a study, based on an experimental design, was conducted to examine the impact of the Eduball method on the development of cognitive and motor creativity among early school-aged pupils in PE settings.

2. AIMS AND HYPOTHESIS

The main goal of the research was to evaluate the impact of the Edubal method on cognitive creativity, motor creativity and motor fitness during physical education classes in 8-to 9-year-old children.

Specific aims:

1. To examine gender differences in cognitive creativity, motor creativity, and motor fitness among children aged 8–9 years.
2. To investigate correlations between physical activity, motor fitness, and creativity parameters in children aged 8–9 years.
3. To assess the effects of an 8-week Eduball intervention program on cognitive creativity, motor creativity, and motor fitness in children aged 8–9 years.
4. To determine whether the effectiveness of the Eduball method depends on its frequency of implementation, with particular emphasis on its impact on cognitive creativity, motor creativity, and motor fitness.

Hypothesis:

1. There are no differences in cognitive creativity or motor creativity between boys and girls aged 8–9 years.
2. There are strong correlations between physical activity, motor fitness, and creativity parameters in children aged 8–9 years.
3. The Eduball method has a positive effect on cognitive and motor creativity in children aged 8–9 years.
4. The impact of the Eduball method on motor fitness in children aged 8–9 years is comparable to that of traditional PE classes.
5. The effectiveness of the Eduball method on cognitive creativity, motor creativity, and motor fitness depends on the frequency of implementation.

3. LIST OF PUBLICATIONS

The submitted doctoral dissertation consists of a series of two monothematic articles presented under the common title: *The impact of the Eduball method on selected parameters of creativity and motor fitness in early school-aged children.*

1. Khorkova M., Bojkowski Ł., Korcz A., Łopatka M., Adamczak D., Krzysztosek J., Bronikowski M. (2024) The relationship of creativity and motor creativity with physical activity and motor fitness in a gender perspective among 8–9-year-old children. *Children*, 11(12), 1501. <https://doi.org/10.3390/children11121501>
MEiN score: 40; Impact Factor: 2.0.
2. Khorkova M., Bojkowski Ł., Korcz A., Łopatka M., Adamczak D., Krzysztosek J., Bronikowski M. (2025) Impact of the Eduball method on cognitive creativity, motor creativity, and motor fitness during physical education classes in 8- to 9-year-old children. *Frontiers in Public Health*, 13, 1660650. <https://doi.org/10.3389/fpubh.2025.1660650>
MEiN score: 100; Impact Factor: 3.4.

Total MEiN score: 140; Total Impact Factor: 5.4.

4. MATERIAL AND METHODS

4.1. Research Participants

The study included 195 second-grade primary school children (47% girls), aged 8–9 years, all of whom attended a standard curriculum in three urban primary schools in Poznań, Poland. Sample size estimation was performed using G*Power 3.1 with an expected effect size of 0.25, a significance level of $\alpha = 0.05$, and statistical power set at 0.90, yielding a required minimum of 162 participants. Prior to enrollment, written informed consent was obtained from parents or legal guardians, and verbal assent was secured from all children. Exclusion criteria were: 1) age outside the 8–9 years range, 2) presence of congenital diseases, and 3) intellectual developmental disorders or diagnosed learning disabilities.

Publication 1 presented the results of the pre-test, conducted between January and February 2024. The sample comprised 195 pupils (92 girls and 103 boys) aged 8–9 years ($M = 8.01$, $SD = 0.29$). Descriptive characteristics of pre-test participants are presented in Table 1 of Publication 1.

Publication 2 reported the total results of the experiment, including the pre-test, intervention program, and post-test, conducted from January to May 2024. Following the pre-test, entire classes of participants were randomly assigned to three groups: two experimental groups (EG1 and EG2) and one control group (CG). The intervention program began in March and lasted for eight weeks. The total sample size for the experiment declined to 173 children (83 girls and 90 boys) aged 8–9 years ($M = 8.03$, $SD = 0.29$) due to several reasons: some pupils changed schools, some sustained injuries, and some were absent during post-test measurements. In addition, data from participants in the experimental groups who attended fewer than 60% of the intervention sessions were excluded from the analysis. Consequently, the final sample sizes were limited to 61 pupils in EG1, 39 pupils in EG2, and 73 pupils in CG. Descriptive characteristics of pre-test participants are presented in Table 1 of Publication 2.

4.2. Research tools

4.2.1. Creativity Assessment

The Test for Creative Thinking-Drawing Production (TCT-DP) was used to assess pupils' creativity following Urban's protocol (Urban 2005). The participants were asked to complete a drawing that begins with a square frame and six figural fragments placed on a test sheet following the Jellen and Urban method (Jellen and Urban 1989; Matczak et al. 2000). Additionally, the subjects were asked to provide a title for the drawing. It has been previously reported that eventual experience in drawing is unrelated to TCT-DP score (Urban 2005). All pupils performed this test on their own. The instructions emphasized freedom of expression, and the participants were not informed about the time limit (although the maximum allowed time was 15 minutes, which was considered in the scoring) (Jellen and Urban 1989; Matczak et al. 2000; Urban 2005). The assessment of the TCT-DP consisted

of fourteen criteria, which include the following: 1) continuations, 2) completions, 3) new elements, 4) connections made with a line, 5) connections that contribute to a theme, 6) boundary breaking that is fragment-dependent, 7) boundary breaking that is fragment-independent, 8) perspective, 9) humor and affectivity, 10) unconventionality with, manipulation of the test material, 11) unconventionality with, abstract elements, 12) unconventionality in the use of symbols, 13) unconventionality with unconventional usage of the given fragments, and 14) speed (Urban 2005). A qualified psychologist assessed the creativity scores with the final TCT-DP result calculated as the total sum of points obtained across all the criteria.

The test has two versions (A and B) differing only in the positioning of the elements relative to the test item. In version B, the initial arrangement is rotated 180 degrees. In this study version A was used for the pre-test, while version B was used for the post-test. Using both versions is particularly important when participants take the test more than once, as in this pre-test and post-test design. Administering different versions accordingly to test manual minimizes practice effects and prevents apparent improvements due to familiarity with the test stimuli, thereby ensuring that observed changes reflect genuine increases in creativity.

The reliability and validity of the TCT-DP have been confirmed in numerous studies (Matczak et al. 2000; Jellen and Urban 1986; Urban 2005). In Polish standardization studies internal consistency was assessed using Cronbach's alpha, with coefficient ranging from 0.62 (army cadet school students) to 0.80 (preschool children) (Matczak et al. 2000).

4.2.2. Motor Creativity Assessment

Torrance's TCAM test was used to assess pupils' motor creativity (Torrance 1981). The test administration and scoring guide were translated from English to Polish using back-to-back translation method with appropriate adaptations. The test included four activities. In the first activity, the child was asked to cover the designated distance of three meters in as many different ways as possible. The second activity required the participant to imagine themselves in six fiction situations and perform appropriate actions accordingly. For the third activity the participant was asked to demonstrate or describe as many different ways as possible to place a paper cup into wastebasket located two-meter away. In the fourth activity the subject was asked to list or demonstrate different possible uses for a paper cup (Torrance 1981). The first, third and fourth activities were scored in two categories, motor fluency and originality, while second activity assessed imagination. Motor fluency is determined as the ability to create different, alternative movement patterns and was scored by the total number of ways and combinations of movements the child invented. Motor originality is determined by the ability to produce novel, unique, and unusual ways of movement and was scored by comparing the child's responses with a reference list based on the statistical infrequency of the responses, after which points were awarded accordingly. Imagination is defined by the ability to imagine, empathize, fantasize, and assume unaccustomed roles and was assessed on a five-point rating scale (from 1 = no movement to 5 = excellent imitation) for each fiction situation. All scoring was conducted in accordance with the original manual (Torrance 1981). Overall testing time ranged between 10- and 30-min per child. The reliability coefficients for the individual activities are 0.71 for the first activity, 0.79 for the second activity, 0.67 for the third activity, and 0.58 for the fourth activity. The overall reliability coefficient for the Torrance TCAM test is 0.84 (Torrance 1981).

4.2.3. Motor Fitness Assessment

Participants' motor fitness level was assessed using selected tests from the Eurofit battery (Council of Europe 1993). These included a 20-meter endurance Shuttle Run to evaluate cardiorespiratory endurance, and a 10 × 5-meter Shuttle Run (SHR) to assess running speed and agility. In addition, the Piórkowski test was used to evaluate eye-hand coordination, reaction speed and movements precision.

In the 20-meter Shuttle Run test, participants were asked to stand behind the starting line facing the second line, which was 20 m away. When a special sound signal was heard, they started running. Participants continued running between the two lines turning when the recorded signal sounded. They needed to run at a pace that ensured they reached the end of a 20-meter section when they heard the signal to change direction. Their task was to maintain the pace set by the sound signal for as long as possible. The test ended when a participant could no longer keep up with the signals or feels too tired to continue. The score was determined as a number of levels completed, based on the number of 20-meter shuttles reached before the participant was unable to keep up with the recorded sound signal. The final score was the last level completed (Council of Europe 1993).

The 10 × 5 m SHR test involved participants running back and forth over a 5-meter distance, changing direction 10 times, to measure speed and agility. The score was based on the time it took for the participant to complete this task (Council of Europe 1993).

The Piórkowski test was conducted using the Piórkowski apparatus (Psychology laboratory "Driver", Ustrzyki Dolne, Poland). The apparatus has 10 buttons arranged in one row with a LED above each button that lights up to indicate which button to press. Only one LED lights up at a time. The task was for the participant to press each subsequent button indicated by the apparatus using both hands. The right hand was to be used for buttons on the right side, and the left hand for buttons on the left side. The device does not wait for the correct press but sets its own pace, and the participant were required to hit the button correctly as many times as possible. In this study, the parameters included a 60-second period with a stimulus presentation frequency of 30 pulses. The outcome was measured by the number of correct responses. Thorough instructions were always provided before the examination. The test was previously conducted under Polish conditions in studies by Tomczak et al. (2017) and Merkisz et al. (2014) and proved reliable.

4.2.4. Physical Activity Survey

The level of moderate-to-vigorous physical activity MVPA was determined using the Physical Activity Screening Measure (Prochaska et al. 2001). It was administered separately to children, where they were assisted on a "one-to-one" basis by a trained staff member in comfortable conditions for the child. Participants were asked to answer the questions: 1) Over the past 7 days, how many days were you physically active for a total of at least 60 minutes per day? and 2) Over a typical or usual week, how many days are you physically active for a total of at least 60 minutes per day? There were 8 response categories (0 days, 1 day up to 7 days). The MVPA index was calculated using the formula: $MVPA = (Q1 + Q2)/2$ where Q1 is the number of physically active days over the last 7 days; Q2 is the number of physically active days in a typical week. According to Prochaska et al. (2001), the measure is reliable (ICC = 0.77). The item has been proven to have reasonable validity and moderate reliability (Biddle et al. 2011). This measure was also used earlier in Polish studies (Bronikowski et al. 2016; Korcz et al. 2023; 2024; Mazur et al. 2020).

4.3. Study Procedure

The pre-test, which was conducted between January and February 2024, utilized the aforementioned testing methods. All measurements and tests were performed in a school setting (gym and classrooms). First, the creativity test was conducted in a classroom. Then, motor fitness and motor creativity tests were conducted in a school gym. The participants were informed about the test procedure and each test item was accompanied by detailed instructions. Creativity assessments were conducted by trained instructors under the supervision of a qualified psychologist, and motor fitness assessments were conducted by trained research specialists to ensure reliable measurements. Following this assessment, entire classes of participants were randomly divided into three groups: two experimental groups (EG1 and EG2) and one control group (CG). Randomization was conducted at the class level to ensure that all children within a given class received the same intervention. The intervention program commenced in March and was implemented over eight weeks under natural school conditions in two experimental groups. The experimental factor was a specially designed PA program based on the Eduball method implemented into PE classes. EG1 participated in the Eduball intervention program once per week, alongside two traditional PE classes. EG2 engaged in the Eduball program twice a week, with one traditional PE class. Meanwhile, CG followed the standard curriculum, receiving three traditional PE classes without Eduball intervention. All Eduball sessions were conducted by previously trained PE teachers under the direct supervision of the project coordinator, and each session followed standardized, carefully designed scenarios. This approach ensured consistent delivery of the intervention maintained methodological rigor, and minimized variability, thereby guaranteeing the fidelity and integrity of the intervention throughout the study.

A total of 8 Eduball-integrated PE classes were conducted for EG1, while EG2 received 16 such classes. Each 45 minutes class was structured into three parts: an introduction (5 minutes), a main part (35 minutes), and a concluding synopsis (5 minutes). The main goal of each class was to stimulate pupils' creativity through movement-based problem-solving tasks using the Eduball method. These activities encouraged children to: create new movement patterns, generate multiple effective strategies for completing tasks, solve problem-based scenarios that combined movement and cognitive challenges in a nonlinear way. The mathematical numbers placed on the educational balls allowed for creation of tasks that stimulated creative thinking in solving mathematical operations, while the alphabet letters on the Eduball enabled plays and games that fostered creative thinking in word formation, sentence construction, and storytelling. Additionally, the five-color design of the balls enhanced the creation of tasks that promoted children's creativity.

The scenarios for PE classes using Eduball were developed based on an established pool of Eduball examples (Rokita et al. 2017a; Rokita et al. 2018). Furthermore, some sample scenarios were presented in recent open-access Eduball studies (Cichy et al. 2020; Wawrzyniak et al. 2021). These sample scenarios provide a detailed description of common Eduball-based activities, including their objectives and the specific skills they are aimed to develop. (Attachment 3. Exemplary Eduball lesson scenario).

After the eight-weeks intervention program, a post-test was conducted for all groups in May. The data of participants of experimental groups who attended less than 60% of intervention program (fewer than 5 of 8 sessions in EG1 or fewer than 10 of 16 sessions in EG2) were excluded and not considered in the analysis of the experimental results.

4.4. Statistical Analyses

Publication 1

Statistical analysis began with descriptive statistics, including the calculation of the arithmetic means (M) and standard deviation values (SD) to summarize the descriptive characteristics (age, body height, body mass) of boys and girls. The normality of the variables was assessed using the Shapiro–Wilk test; since the distributions deviated from normality, nonparametric methods were applied. Differences in motor fitness, self-reported PA, creativity, and motor creativity between boys and girls were examined using the Mann–Whitney U test. Correlations between motor fitness, PA, and individual creativity indicators were analyzed using Spearman’s rank correlation coefficient. All statistical analyses were performed using Statistica, version 13.3 (TIBCO Software Inc., Palo Alto, CA, USA), with the level of statistical significance set at $p < 0.05$.

Publication 2

Statistical analysis commenced with descriptive statistics, including M and SD to summarize the main characteristics of the experimental and control groups (age, body height, and body mass). The normality of data distribution was assessed using the Shapiro–Wilk test; since the data deviated from normality, nonparametric methods were applied. Differences in creativity and motor fitness variables between the experimental and control groups in the pre- and post-test were analyzed using a one-way ANOVA on ranks (Kruskal–Wallis H test). Pre- and post-test differences in creativity and motor fitness variables within each group were examined using the Wilcoxon signed-rank test, and the results of these comparisons are presented as Median [Mdn (Q1–Q3)].

Effect sizes were calculated for all statistical tests to support the interpretation of the results. For between-group comparisons conducted using the Kruskal–Wallis test, effect sizes were expressed as eta squared for ranks (η^2_h) and interpreted according to the following thresholds: small = 0.01, medium = 0.06, and large = 0.14 (Cohen, 1988; Tomczak and Tomczak 2014; MRC Cognition and Brain Sciences Unit 2009). For within-group comparisons based on the Wilcoxon signed-rank test, effect size r was reported and interpreted using the following thresholds: small = 0.1, medium = 0.3, and large = 0.5 (Cohen, 1988; Tomczak and Tomczak 2014; MRC Cognition and Brain Sciences Unit 2009).

All analyses were performed using Statistica, version 13.3 (TIBCO Software Inc., Palo Alto, CA, USA), with the level of statistical significance set at $p < 0.05$.

4.5. Ethical Approval

The study protocol was approved by the Bioethics Committee of The Karol Marcinkowski University of Medical Sciences in Poznan (decision number 400/23 of 11 May 2023). Parents were informed in detail about the conditions of the study and consented to their children’s participation before the start of the research. All methods were carried out in accordance with relevant guidelines and regulations such as the Declaration of Helsinki (revised 2013).

5. RESULTS

Publication 1

A comparison of the motor fitness, PA, creativity, and motor creativity test scores between boys and girls is presented in Table 2 (Publication 1). In the area of motor fitness, boys demonstrated higher performance than girls in the 10 × 5 m SHR test ($p < 0.001$) and the 20 m Shuttle Run test ($p < 0.05$). In contrast, girls achieved significantly higher scores in the Piórkowski apparatus test ($p < 0.05$). This result indicates that while boys tended to excel in activities requiring agility, speed, and dynamic movement, girls demonstrated better performance in tasks emphasizing eye-hand coordination and precision of movement. No statistically significant differences were found between boys and girls in MVPA levels, cognitive creativity, or any of the motor creativity variables. This suggests that, regardless of gender, participants displayed comparable levels of engagement in PA and similar creative abilities, both cognitive and motor-related.

For the group of boys, the TCT-DP score (a measure of cognitive creativity) showed no significant association with PA or with any of the three motor fitness indicators. Likewise, no significant relationships were found between motor creativity and PA, indicating that the level of daily physical activity was not directly associated with creative or motor-creative potential in this group. A single weak positive correlation ($r = 0.28$) was identified between the Piórkowski apparatus test and the originality subcategory of motor creativity (TCAM). No other statistically significant correlations were observed (Table 3).

In the group of girls, the TCT-DP score was also not significantly related to PA or to the three indicators of motor fitness. Similarly, no correlations were observed between motor creativity and PA. However, a weak but statistically significant correlation ($r = 0.24$) was found between performance in the Piórkowski apparatus test and fluency, one of the subcategories of motor creativity (TCAM). No other significant associations were detected (Table 4, Publication 1).

Publication 2

A comparison of creativity variables between the experimental and control groups at pre- and post-test is presented in Table 2 (Publication 2). At the pre-test, there were no statistically significant differences among the three groups in any of the creativity variables, including the TCT-DP score and the TCAM parameters (fluency, originality, and imagination). These findings confirm that all groups started from a comparable baseline level prior to the intervention.

At the post-test, statistically significant differences appeared in two creativity variables:

- TCT-DP test – significant differences were identified between EG1 and EG2, as well as between CG and EG2, both in favor of EG2 ($p < 0.01$; effect size $\eta^2_h = 0.09$).
- Imagination (TCAM) – a significant difference was also found between EG1 and EG2, again favoring EG2 ($p < 0.01$; effect size $\eta^2_h = 0.05$).

The within-group comparisons (Table 2, Publication 2) showed statistically significant improvements in fluency (TCAM) across all groups ($p < 0.05$; effect size $r = 0.4$). Imagination (TCAM) also improved significantly in all groups, with the largest improvement recorded in EG2 ($p < 0.05$; effect size $r = 0.7$), whereas EG1 and CG demonstrated comparable progress ($p < 0.05$; effect size $r = 0.5$). No statistically significant changes were noted in

TCT-DP or originality (TCAM) within EG1 or EG2. Nevertheless, the effect size for TCT-DP in EG2 ($r = 0.3$) suggests a moderate, practically relevant improvement despite the lack of statistical significance. In contrast, the control group displayed small but statistically significant declines in TCT-DP ($p < 0.05$; effect size $r = 0.2$) and originality (TCAM) ($p < 0.05$; effect size $r = 0.3$).

A comparison of motor fitness variables between the experimental and control groups at pre- and post-test is presented in Table 3 (Publication 2). At the pre-test, no statistically significant differences were observed among the three groups in any of the motor fitness tests, including the 20 m Shuttle Run, 10 × 5 m SHR, and the Piórkowski apparatus. This confirms the equivalence of groups in terms of physical fitness before the intervention.

At the post-test, no significant differences were found between groups in the 20 m Shuttle Run and 10 × 5 m SHR tests. However, a statistically significant difference was observed in the Piórkowski apparatus test, with EG2 achieving higher scores than both EG1 and CG ($p < 0.001$; effect size $\eta^2_h = 0.09$).

The within-group analysis (Table 3, Publication 2) revealed statistically significant improvements in all motor fitness parameters across the three groups, indicating better post-test outcomes. The greatest improvement was observed in the Piórkowski apparatus test for EG2 ($p < 0.05$; effect size $r = 0.6$), while EG1 and CG exhibited moderate, comparable gains ($p < 0.05$; effect size $r = 0.4$).

6. DISCUSSION

The first objective of the study was to examine gender differences in cognitive creativity, motor creativity, and motor fitness among children aged 8–9 years. With regard to motor fitness, the findings confirmed previous research (Bos and Ulmer 2003; Roth et al. 2018) showing statistically significant gender differences in motor performance among children of this age group. Boys achieved better results than girls in running speed and agility (10 × 5 m SHR test) ($p < 0.001$) as well as in cardiorespiratory endurance (20 m Shuttle Run test) ($p < 0.05$). In contrast, girls outperformed boys in eye-hand coordination, movement precision, and reaction speed (Piórkowski apparatus test) ($p < 0.05$). On the other hand, no statistically significant differences were found between boys and girls in PA levels, suggesting that at this age both genders are active at similar levels.

Regarding cognitive and motor creativity, the analysis revealed no statistically significant gender differences in these variables. Results obtained from the TCT-DP test indicated no meaningful difference between boys and girls in cognitive creativity, which aligns with previous studies (Ardila et al. 2011; Gur et al. 2012; Wai et al. 2018) comparing other cognitive abilities between genders at the early school stage. In the study by Ardila et al. (2011), involving 788 children (350 boys, 438 girls) aged 5–16 years from Mexico and Colombia, gender differences in cognitive development were minimal, appeared only in a few tests, and represented a very small portion of the total variance. Similarly, Gur et al. (2012), who assessed youths aged 8–21 years using measures of performance accuracy and response time in executive control, episodic memory, complex cognition, social cognition, and sensorimotor speed, found that the gender effect was present but considerably smaller than the influence of age. They also noted that while some gender differences appeared in the youngest groups, these discrepancies became more pronounced during adolescence (Gur et al. 2012).

In the study, results from the TCAM test showed no significant gender differences across any motor creativity variables among children aged 8–9 years. Comparable findings were previously reported by Zachopoulou and Makri (2005), who examined the motor creativity of 191 children aged 5–8 years (47 % girls) using the Divergent Movement Ability Test. In that research, gender effects were analyzed for two aspects of motor creativity—motor fluency and motor flexibility—and no statistically significant differences were observed between boys and girls (Zachopoulou and Makri 2005). These results indicate that boys and girls at early school age demonstrate similar performance levels in motor creativity.

The second aim of the study was to investigate correlations between physical activity, motor fitness, and creativity parameters in children aged 8–9 years. In line with this objective, the analysis showed that creativity was not associated with PA in either boys or girls. Likewise, no correlation was observed between motor creativity and PA for both genders, indicating that at this age creativity does not appear to be linked to PA levels. Similar findings were reported by Piya-amornphan et al. (2020), who explored the relationship between creativity and PA among 1447 students aged 6–17 years from 34 schools in southern Thailand. Creativity was measured using the Test for Creative Thinking–Drawing Production (TCT-DP), while PA levels were assessed with the Thailand Physical Activity Children Survey–Student Questionnaire (TPACS-SQ). Their results

showed that for children aged 6–9 and 10–13 years, creativity was not associated with PA in either age group; the relationship appeared only among participants aged 14–17 years (Piya-amornphan et al. 2020).

An expanding body of research (Bidzan-Bluma and Lipowska 2018; Chaddock et al. 2011; Chaddock-Heyman et al. 2014; Khan and Hillman 2014) confirms that children’s engagement in PA has beneficial effects on cognitive functioning and academic performance through its positive impact on overall cognition, brain structure, and neural activity (Gennari and Valentini 2024). However, the mechanism underlying creativity development seems to differ. Based on evidence indicating that PA positively affects brain function (Chaddock-Heyman et al. 2014), and considering that adolescents aged 14–17 with higher activity levels demonstrated greater creativity, it may be assumed that PA provides a foundation conducive to creative development, whereas the actual stimulation of creativity depends on additional influencing factors. This could explain why older children, who have had more time and exposure to such factors—including PA as a contributing element—exhibit higher creativity levels. In this sense, PA may serve as an important supportive factor in creativity development rather than a direct determinant. Therefore, the enhancement of creativity likely requires targeted methods and specific pedagogical strategies.

Another plausible explanation for this finding is that PA might indeed exert a direct effect on creativity development, but through an accumulative mechanism that requires prolonged exposure. This perspective could also clarify why no association between PA and creativity is detected in younger children aged 6–13 years, while it becomes observable in older age groups. Further, more comprehensive research is necessary to explore the relationship between creativity and previous developmental experiences.

With respect to motor fitness and creativity variables, the results showed no significant correlations between creativity and measured indicators of motor fitness for either gender. Only weak associations were found between the Piórkowski test and one variable of motor creativity—originality in boys ($r = 0.28$) and fluency in girls ($r = 0.24$). These findings suggest that motor proficiency and creativity as largely independent traits at this age. Marinšek and Lukman (2022), in their study investigating the relationship between motor fitness and motor creativity among children aged 5–6 years using the Test of Gross Motor Development and Bertsch’s Motor Creativity Test, reported comparable outcomes. Their research showed no association between motor skill proficiency and motor creativity, concluding that motor creativity in early childhood is an independent construct not predictable from a child’s motor skill level (Marinšek and Lukman 2022). These findings are also consistent with the earlier results of Scibinetti et al. (2011).

It appears that traditional PE classes, which are predominantly focused on physical training and the repetition of established motor skills, do not foster motor creativity level (Marinšek and Lukman 2022). Such programs typically develop motor abilities and fitness through linear progression—from simple to complex motor tasks—emphasizing movement efficiency. Conversely, motor creativity emerges primarily through activities promoting nonlinear learning processes, where task constraints are broader and exploration of movement possibilities is encouraged. In linear approaches, overly rigid task structures tend to restrict children’s ability to experiment with new movements level (Marinšek and Lukman 2022).

Taken together, these findings suggest that fostering both cognitive and motor creativity in children within PE settings requires intentionally designed teaching methods and pedagogical strategies that move beyond traditional approaches to PE.

The next objectives of the present study were to evaluate the effects of an eight-week Eduball intervention program on cognitive creativity, motor creativity, and motor fitness

in children aged 8–9 years, as well as to determine whether the effectiveness of the Eduball method in relation to these parameters depends on the frequency of its implementation.

The results demonstrated that the Eduball intervention exerted a positive influence, particularly on creativity-related outcomes, although the magnitude of this effect varied depending on the specific variable assessed and the frequency of the intervention.

In relation to cognitive creativity, as measured by the TCT-DP test, the integration of Eduball activities into PE lessons produced beneficial effects in both experimental groups. Specifically, post-test comparisons revealed a statistically significant difference in creativity scores between groups, favoring EG2 (the group with more frequent exposure). Although the within-group improvement in EG2 did not reach statistical significance, the effect size indicated a moderate magnitude of change, suggesting that the result might have achieved significance in a larger sample. In contrast, EG1 maintained stable creativity levels over time, whereas a statistically significant decline was observed in CG.

The reduction in creativity observed in CG may be attributed to the absence of specific conditions that foster creativity. Previous research has documented that during the transition from early to middle childhood (approximately ages 8–10), children tend to shift from a spontaneous, pre-conventional mode of thinking toward more conventional and socially conforming patterns, which may restrict creative expression within formal school environments (Kohlberg and DeVries 1987; Runco 2014; Torrance 1968). In traditional educational contexts, success is often equated with precision and adherence to rules, while originality receives less reinforcement (Beghetto and Kaufman 2014). This emphasis may reduce children's willingness to take intellectual risks or propose novel ideas, even when their creative potential remains intact. As academic demands increase, students often prioritize accuracy over exploratory thought, which can result in lower measured creativity scores (Kim 2011). Consequently, the decline in creativity observed in CG likely reflects the combined influence of developmental changes and the convergent tendencies of conventional schooling.

Additionally, the findings may be interpreted through the “use it or lose it” principle—children who were not exposed to regular creativity-enhancing activities (such as those provided by the Eduball program) demonstrated a measurable decline in creative performance over time. This explanation aligns with earlier research emphasizing the importance of consistent stimulation and practice for maintaining and enhancing creative capacities (Baer 1993; Runco 2007). The overall pattern of results—decline in CG, stability in EG1, and improvement in EG2—suggests that active engagement in creativity-oriented challenges is essential for supporting children's creative development. The dose–response effect further indicates that a minimum level of exposure is required to sustain creative potential, while increased frequency of creative experiences produces more substantial improvements. Consistent with previous findings by Richard et al. (2018) and Bournelli and Mountakis (2008), these results highlight that creativity must be actively cultivated during this sensitive stage of development to prevent its natural decline. The Eduball method, with its movement-based and cognitively stimulating design, appears to be an effective tool for achieving this aim. Taken together, the findings emphasize the significance of systematic creativity development and the added value of more frequent interventions, as demonstrated by the superior results of EG2.

With regard to motor creativity, the TCAM test revealed differentiated effects across its subcomponents. Pupils from both experimental groups (EG1 and EG2) as well as from CG showed similar gains in motor fluency following the intervention. This suggests that at this developmental stage, motor fluency may naturally improve, a finding consistent with the results of Domínguez et al. (2015). The Eduball program, therefore, did not

produce an additional measurable effect on this variable within the eight-week period. In contrast, Richard et al. (2018), in a study evaluating the effects of a nonlinear pedagogy-based PE program on nine-year-old children over three months (10 sessions), observed a statistically significant post-test improvement in motor fluency in the experimental group compared to the control group. Similarly, Ourda et al. (2017) reported significant increases in motor fluency after a semester-long intervention (20 sessions) with children aged 4–5 years, while the control group showed no change. These discrepancies may stem from differences in program design—since the interventions in those studies specifically targeted motor fluency, whereas the Eduball approach aimed to stimulate creativity through broader cognitive–motor challenges. Additionally, variation in intervention duration may account for these inconsistencies. Consequently, enhancing motor fluency through Eduball may require a period longer than eight weeks to achieve statistically significant effects. Furthermore, although fluency is frequently used as a creativity indicator, it has been described as the most ambiguous and least strongly correlated with creative performance compared to dimensions such as originality, and it is therefore not recommended as a sole measure (Runco and Acar 2012). These factors may explain the lack of additional intervention effects on fluency despite improvements across all groups.

In contrast, the motor originality component showed a statistically significant decrease in CG, while remaining stable in both experimental groups. In the study by Asadi et al. (2023), which applied a nonlinear pedagogy approach with seven-year-old children over six weeks (three sessions per week), no change was found in the control group, whereas the experimental group demonstrated a significant increase in motor originality. Domínguez et al. (2015) reported that motor originality tends to increase between ages 6 and 8 but declines between ages 8 and 10. The decline observed in CG in the present study, but not in Asadi et al. (2023), may therefore reflect these age-related developmental shifts. While nonlinear pedagogy in Asadi’s study enhanced the natural developmental increase in originality, the Eduball method in the current research appeared to serve a protective role, preventing the expected age-related decline and maintaining stable levels of motor originality in both experimental groups. Notably, the frequency of Eduball classes did not significantly influence outcomes, indicating that even less frequent sessions may be sufficient to preserve motor originality during this critical developmental period. The similar stability observed in both EG1 and EG2 suggests that one Eduball session per week might be adequate to prevent decline, although longer interventions could be required to achieve measurable gains. Discrepancies across studies may also stem from methodological differences, including variations in assessment tools and scoring criteria—for example, the contrast between Bertsch’s test (Bertsch 1983) used by Asadi et al. (2023) and the TCAM employed in the present study, which differ in task design, scoring norms, and originality criteria.

Motor imagination, another TCAM variable, demonstrated statistically significant improvement in all three groups. However, while the effect sizes for EG1 and CG were identical, EG2 showed a notably higher effect. This aligns with Domínguez et al. (2015), who reported that motor imagination naturally develops between ages 8 and 10. Thus, the general improvement observed across all groups likely reflects a developmental trend, whereas the additional gain in EG2 indicates a potential positive influence of the Eduball method on this variable. A study by Alper and Ulutaş (2022), involving a 12-week creative movement program for 5–6-year-old children (two sessions per week), also reported a statistically significant improvement in motor imagination in the experimental group. Likewise, Ourda et al. (2017) observed a significant post-test increase in motor imagination in 4–5-year-olds after a 20-session intervention.

Previous studies exploring methods for enhancing motor creativity provide limited comparability regarding changes in motor imagination for two main reasons. First, some studies (Marinšek and Lukman 2021; Richard et al. 2018; 2021a) utilized different assessment tools that did not specifically measure motor imagination. Second, even those employing the TCAM (Alper and Ulutas 2022; Ourda et al. 2017; Thomaidou et al. 2021; Wang 2003) primarily focused on preschool-aged children (3–6 years), which restricts direct comparison with the current findings. Therefore, the present study contributes novel insights into the effects of the Eduball method on motor imagination among older children aged 8–9 years. Nevertheless, caution is warranted in interpreting the imagination component of the TCAM, as its conceptual link to creativity remains debated and inconsistent across studies (Lillard et al. 2013; Silverman 2016). Unlike fluency and originality, imagination is assessed only in the TCAM test among the major motor creativity tests, highlighting both its unique value and its methodological limitations. Accordingly, the present results on imagination should be considered as supplementary to other creativity indicators rather than definitive evidence. Nonetheless, the findings confirm the beneficial impact of Eduball-based PE lessons on children’s motor imagination. Moreover, the significantly higher effect size in EG2, along with the post-test difference between EG1 and EG2 favoring EG2, underscores the importance of intervention frequency—indicating that more frequent sessions yielded stronger outcomes.

In relation to motor fitness, results from the 20 m Shuttle Run and 10 × 5 m SHR tests revealed no statistically significant differences among groups in post-test performance. However, all groups showed significant within-group improvements, suggesting that both the Eduball method and traditional PE effectively enhanced children’s physical fitness. These findings are consistent with earlier research by Cichy and Rzepa (2005), Cichy and Rokita (2012), Rokita and Cichy (2014), Rokita et al. (2017), Pham et al. (2023), which demonstrated that Eduball-based PE classes promote motor fitness to a comparable extent as conventional programs. Conversely, results from the Piórkowski test indicated a statistically significant post-test advantage for EG2. This aligns with findings by Cichy et al. (2015), who reported a greater positive effect of Eduball activities on eye-hand coordination compared to traditional PE. Furthermore, the significant post-test difference between EG1 and EG2, again favoring EG2, reinforces the role of intervention frequency, showing that increased exposure leads to more pronounced positive outcomes.

In summary, the study demonstrated that the Eduball method positively influenced children’s creativity and motor development in a dose-dependent manner, with the enhanced program (EG2) showing the most favorable outcomes. Taken together, these findings highlight the potential of the Eduball method as an effective pedagogical tool for fostering children’s creative potential and supporting their holistic development within school PE settings.

Limitation of the study

There are several limitations to this study that should be considered when interpreting its results. First, the relatively narrow age range of participants (8–9 years) limits the generalizability of the findings, particularly since motor development at this stage is highly dynamic (Roth et al. 2018). Second, the sample size in the enhanced intervention group (EG2) may have reduced the statistical power to detect significant effects, especially for cognitive creativity, where a moderate but non-significant effect was observed. Third, the intervention period lasted only eight weeks; whereas some studies suggest that longer exposure may be required to produce significant improvements in motor fluency and originality. Fourth, despite applying a 60% attendance threshold for inclusion, participants’

occasional absences from sessions could have influenced the results. Fifth, all data on children's PA were self-reported, which introduces the possibility of recall or reporting bias. Sixth, creativity assessment was conducted by a single qualified psychologist, and although blinding procedures were followed, the single-rater approach may have affected measurement reliability. Seventh, although the TCAM test is one of the most widely applied measures of motor creativity in children, it has certain conceptual and methodological limitations. In particular, its fluency and imagination components have been criticized for their ambiguity and inconsistent correlation with creativity (Lillard et al. 2013; Runco and Acar 2012; Silverman 2016). Moreover, TCAM is the only commonly used motor creativity test that includes imagination, making cross-study comparisons more difficult and prompting calls for alternative or complementary assessment tools (Méndez-Martínez and Fernández-Río 2019; Richard et al. 2021**b**). Finally, the study did not include a follow-up phase, preventing evaluation of the long-term sustainability of the observed effects.

Innovations of the Project

The principal innovation of this study lies in introducing the Eduball method as a new pedagogical tool for developing children's cognitive and motor creativity within primary school PE. While Eduball has previously been used to integrate academic content with movement and has been shown to support academic performance (including language competence, reading and writing proficiency, mathematical skills, and graphomotor efficiency), its application specifically for enhancing creativity represents a novel and largely unexplored direction. The study demonstrates that systematic and sufficiently frequent use of Eduball can stimulate children's creativity offering a valuable enrichment to traditional PE approaches.

7. CONCLUSIONS

Publication 1

The findings of this study revealed significant gender differences only in motor fitness among children aged 8–9 years, while no differences were observed in PA, cognitive creativity, or motor creativity parameters. These results are consistent with Hypothesis 1, which proposed that cognitive and motor creativity do not differ between boys and girls in this age group. In contrast, no significant correlations were identified between PA, motor fitness, and creativity parameters for either gender. This finding contradicts Hypothesis 2, which predicted positive relationships among these variables. The lack of associations suggests that children’s creativity does not automatically develop due to just mere participation in PA or motor tasks.

Taken together, these findings underscore the importance of deliberate pedagogical efforts to foster creativity in PE setting. Creativity will not emerge solely from participation in PA; rather, it must be purposefully nurtured through structured, varied, and stimulating learning environments. Although creativity can be stimulated through multiple school subjects, PE—with its flexibility, diversity of movement contexts, and broad range of teaching methods—offers particularly strong potential. Given the absence of gender differences in creativity, co-educational settings can be used effectively, provided that appropriate instructional methods are employed.

Recommendations

The results of the conducted research highlight the need for an intentional and innovative pedagogical approach in PE, particularly in the context of developing children’s motor and cognitive creativity. Since creativity does not emerge spontaneously through PA alone, it is essential to create learning environments that enable pupils to explore movement, experiment with different solutions, and freely express individual ideas through physical action. In this regard, it is advisable to implement teaching strategies that incorporate open-ended tasks, problem-solving situations, and exploratory movement activities that foster autonomous and creative engagement. A further recommendation concerns the preparation and continuous development of PE teachers’ didactic skills. To effectively promote creativity in school settings, both future and currently practicing teachers must possess strong pedagogical competencies that enable them to design and facilitate learning experiences conducive to creative development. For this reason, university teacher education programmes should explicitly include creativity-enhancing pedagogies and train future teachers to foster autonomy and innovation among learners. At the same time, professional development opportunities—such as qualification courses and specialized training workshops—should be offered to in-service PE teachers to ensure they can effectively apply these pedagogical approaches in everyday school practice. Such combined efforts will strengthen the role of PE as a meaningful context for the development of broader life competencies. Considering the lack of gender differences in creativity observed among children, it is also recommended to employ co-educational instructional models that ensure equal participation and creative involvement of both boys and girls. Furthermore, creativity should be systematically embedded as a learning objective within the PE curriculum, rather than remaining an incidental outcome of the

teaching process. Finally, further research is needed to explore innovative teaching and learning methods—that may effectively support the development of creativity in PE setting. Such investigations will help identify the most effective strategies, which can subsequently be implemented both in teachers’ training and in school practice.

Publication 2

The conducted study demonstrates that the implementation of the Eduball method in PE classes among second-grade pupils yields beneficial effects on selected creativity parameters. The results clearly support Hypothesis 3, confirming that the Eduball method positively influences both cognitive and motor creativity in children aged 8–9 years.

With regard to physical fitness, the findings confirm Hypothesis 4, showing that the impact of the Eduball method is generally comparable to that of traditional PE classes. An exception was observed in eye-hand coordination, which improved more distinctly in the enhanced intervention group, where pupils received more frequent Eduball-based stimuli. These outcomes also support Hypothesis 5, highlighting that the effectiveness of the Eduball method depends on the frequency of implementation: greater instructional exposure leads to stronger creativity-related gains (cognitive creativity and motor imagination) as well as more pronounced motor improvements (eye-hand coordination).

Overall, the results underscore the value of Eduball as a pedagogical tool capable of sustaining and enhancing creativity while maintaining physical fitness outcomes equivalent to those achieved through traditional PE classes.

Recommendations

Based on the study’s outcomes, the systematic integration of the Eduball method into primary school PE classes is strongly recommended. It may be used both as full Eduball-based PE lessons and as shorter instructional segments within traditional classes, as even partial implementation can help sustain and enhance children’s cognitive and motor creativity. To ensure high-quality implementation, PE teachers should have access to professional training in the Eduball method through qualification courses and specialized workshops. Such training will enable teachers to integrate cognitive and motor tasks effectively, select appropriate activities, and adapt them to pupils’ developmental needs. Likewise, university programmes preparing future PE teachers should include the Eduball method within their curricula, ensuring that graduates enter the profession with the necessary competencies to use this pedagogical tool in practice. Further research is recommended to determine the optimal conditions for Eduball implementation and to explore its effectiveness across broader age ranges and in combination with other innovative teaching approaches.

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ACADEMIC AND PROFESSIONAL CAREER – ADDITIONAL INFORMATION

Scientific publications (not included in the thesis series)

Chapters in academic monographs

Khorkova M., Bojkowski Ł., M. A Review of Research on the Relationship between Physical Activity and Creativity in the Context of School Physical Education. *Wychowanie fizyczne, sport i olimpizm w perspektywie Bronikowski pedagogicznej*, Wydawnictwo Uniwersytetu Łódzkiego, 2023, pp. 77–90. <https://doi.org/10.18778/8331-324-5-06>

MEiN score: 20

Bronikowski M., Krzysztozek J., Adamczak D., Khorkova M., Bronikowska M. Ćwiczenia śródlekcyjne i przedlekcyjne z wykorzystaniem nowoczesnych technologii. Przewodnik dla nauczycieli edukacji wczesnoszkolnej i współpracujących nauczycieli wychowania fizycznego realizujących program MAŁY MISTRZ. Pod redakcją: Ryszarda Jezierskiego, Ireneusza Cichego, Doroty Groffik, Marka Lewandowskiego, Andrzeja Rokity, Adama Szymczaka. Warszawa 2025, s. 96-105.

Articles in scientific journals

Khorkova M. "Eduball" as an innovative interdisciplinary pedagogical method in physical education. Review of the evidence-based research. *Theory and Methods of physical education and sports*. 2023; 3: 63-68. <https://doi.org/10.32652/tmfvs.2023.3.63-68>

MEiN score: 5

Bronikowska M., Mouratidou K., Khorkova M., Bronikowski M. Moral competence, dilemma discussion, and sports: unravelling the significance of framework, competitive level, and sporting experience. *Physical Education of Students*. 2023; 27(6): 303-12. <https://doi.org/10.15561/20755279.2023.0601>

MEiN score: 100, Impact Factor: 0,8

Korc A., Krzysztozek J., Bojkowski Ł., Koszałka-Silska A., Khorkova M., Gomołysek A., Bronikowski M. The effects of the 'active before school' programme on the academic skills of 8–9-year-old children: a physically and cognitively engaging intervention. *Frontiers in Public Health*. 2024; 12. <https://doi.org/10.3389/fpubh.2024.1402901>

MEiN score: 100, Impact Factor 3,0:

Korc A., Bojkowski Ł., Bronikowski M., Łopatka M., Khorkova M., Koszałka-Silska A., Cieśla E., Krzysztozek J. Cluster analysis of physical activity and physical fitness and their associations with components of school skills in children aged 8-9 years. 2025; 15: 5053; <https://doi.org/10.1038/s41598-025-88359-9>

MEiN score: 140, Impact Factor: 3,8

Conference papers and abstracts

Khorkova M. The Eduball Method as an Innovative, High-Potential Method in the Modern Physical Education System. In Materials of 14th International Session for Educators of Higher Institutes of Physical Education: Renewal and Rejuvenation: Introducing Integral Innovations to the Olympic Movement, 133–135. Ancient Olympia, Athens, 2024.

Bibliometric summary of achievements

Date: 17.03.2026; H-index (according to JCR): 2; Number of citations (according to JCR): 7; Total Impact Factor: 13; Total MEiN score: 505

Participation in scientific conferences

VIth Regional Conference for Young Scientists – “Wieczór Naukowca 2023 – Wokół Człowieka”, University of Physical Education in Wrocław, oral presentation titled: “Eduball and creativity – research perspectives”, May 5, 2023.

VIIth Regional Conference for Young Scientists – “Wieczór Naukowca 2024 – Wokół Człowieka”, University of Physical Education in Wrocław, oral presentation titled: “The relationship between physical activity, physical fitness and creativity in early age school children”, June 6, 2024.

VIIIth Regional Conference for Young Scientists – “Wieczór Naukowca 2025 – Wokół Człowieka”, University of Physical Education in Wrocław; oral presentation titled: “Evaluation of the Impact of the Eduball Method on the Development of Creativity in Early School-Aged Children”, awarded Best Presentation in the “Various Topics” session, June 4, 2025.

XXVI Scientific Conference “Motion activity of people of different ages”; oral presentation titled: “Development of creative thinking of primary school students by introducing the Eduball program in physical education classes”, December 1–2, 2022, University of Szczecin, Szczecin.

14th International Session for Educators of Higher Institutes of Physical Education in the International Olympic Academy; oral presentation titled: “The Eduball method as an innovative, high potential method in the modern physical education system”, July 07–13, 2023, Olympia, Greece.

International Scientific Conference “The Child in Preschool and Early School Age in a Changing World. Challenges for Education”; oral presentation titled: “Correlational relationships between motor fitness, motor creativity, and creative thinking in early school-age children”; Faculty of Educational Studies, Adam Mickiewicz University in Poznań, Poland, May 22–23, 2025.

Jubilee Conference of Student Research Societies “Issues of Physical Culture and Health in the Research of Young Scientists,” University of Physical Education in Warsaw; oral presentation titled: “Assessment of the Impact of the Eduball Method on the Development of Creativity in Early School-Age Children,” June 6, 2025.

5th Conference on Physical and Health Education 2025, Charles University, Prague, Czech Republic; oral presentation title: "Plays and Games with Eduballs", September 12, 2025.
International PhD Students Conference "Human in Motion – An Interdisciplinary Approach to Physical Activity and Health"; University of Physical Education in Warsaw; oral presentation titled: "Impact of the Eduball method on selected parameters of motor creativity and motor fitness during physical education classes in 8- to 9-year-old children", November 21, 2025.

Research internship

Research internship under the supervision of Prof. dr hab. Andrzej Rokita at the University of Physical Education in Wrocław (22 May–2 June 2023).

Research internship under the supervision of Dr. Jitka Vareková at the Faculty of Physical Education and Sport, Charles University in Prague (Czech Republic), conducted as part of the "Zawacka" NAWA programme (1 October–30 November 2025).

Additional activities

Participation in the training "Psychological support for children and youth in sports", organized by the World Health Organization in Warsaw, March 13–16, 2023, (certificated training).

Participation in delivering training courses for PE and early primary education teachers under the "Mały Mistrz" ("Little Champion") project, organized by the School Sports Association "Dolny Śląsk": Szamotuły, 13–14 September 2024; Pleszew, 21 September 2024 and 17 September 2025.

ATTACHMENT 1. DECLARATIONS

załącznik 6 do Wniosku o wszczęcie post.
w sprawie nadania stopnia doktora

Mgr Maryna Khorkova
Imię i nazwisko doktoranta/ki

Poznań, 01.12.2025 r.
Miejscowość, data

Oświadczenie autora rozprawy doktorskiej o jej oryginalności, samodzielności jej przygotowania i o nienaruszeniu praw autorskich

Ja, niżej podpisany/a oświadczam, że:

- a) rozprawa doktorska pt. „**The impact of the Eduball method on selected parameters of creativity and motor fitness in early age school children**” jest wynikiem mojej działalności twórczej i powstała bez niedozwolonego udziału osób trzecich;
- b) wszystkie wykorzystane przeze mnie materiały źródłowe i opracowania zostały w niej wymienione, a napisana przez mnie praca nie narusza praw autorskich osób trzecich;
- c) załączona wersja elektroniczna pracy jest tożsama z wydrukiem rozprawy;
- d) praca nie była wcześniej podstawą nadania stopnia innej osobie.

Mam świadomość, że złożenie nieprawdziwego oświadczenia skutkować będzie niedopuszczeniem do dalszych czynności postępowania w sprawie nadania stopnia doktora lub cofnięciem decyzji o nadaniu mi stopnia doktora oraz wszczęciem postępowania dyscyplinarnego/karnego.

Maryna Khorkova
.....
Podpis doktoranta/ki

Mgr Maryna Khorkova
Imię i nazwisko doktoranta/ki

Poznań, 01.12.2025 r.
Miejscowość, data

Dotyczy: postępowania w sprawie nadania stopnia doktora w dziedzinie nauk medycznych i nauk o zdrowiu, w dyscyplinie nauki o kulturze fizycznej w Akademii Wychowania Fizycznego w Poznaniu.

Oświadczenie

Oświadczam, że mój wkład w powstanie przedłożonej rozprawy doktorskiej pt. „**The impact of the Eduball method on selected parameters of creativity and motor fitness in early age school children**” polegał na:

- Sformułowaniu problemu badawczego oraz hipotez; opracowaniu koncepcji, struktury i metodologii badań; zaplanowaniu i przeprowadzeniu procedur badawczych, a także organizacji całego procesu badawczego.
- Pozyskaniu finansowania projektu w ramach programu Narodowego Centrum Nauki (NCN); przygotowaniu pełnej dokumentacji projektowej oraz uzyskaniu zgody Komisji Bioetycznej.
- Rekrutacji uczestników badań (w tym nawiązaniu współpracy ze szkołami, organizacji spotkań informacyjnych z rodzicami i uzyskaniu pisemnych zgód na udział dzieci w badaniu); przeprowadzeniu badań wstępnych (pre-testów), realizacji interwencji dydaktycznej z wykorzystaniem metody Eduball w wybranych klasach oraz badań końcowych (post-testów); koordynacji przebiegu zajęć z nauczycielami wychowania fizycznego oraz bieżącego nadzoru nad wdrażaniem programu w warunkach szkolnych.
- Przetwarzaniu, oczyszczaniu i analizie danych zgodnie z zasadami statystyki (w tym wyborze odpowiednich testów statystycznych oraz interpretacji wyników); raportowaniu rezultatów badań; przeglądzie literatury krajowej i zagranicznej, przygotowaniu pierwszych wersji publikacji naukowych oraz opracowaniu ich ostatecznej wersji po uwzględnieniu uwag współautorów; formatowaniu artykułów zgodnie z wymaganiami czasopism oraz przygotowaniu odpowiedzi na recenzje.
- W ramach rozwijania kompetencji naukowych aktywnie uczestniczyłam w krajowych i międzynarodowych konferencjach naukowych, odbyłam staże badawcze (krajowe i zagraniczne), brałam udział w warsztatach metodycznych oraz szkoleniach specjalistycznych związanych z tematyką rozprawy i metodyką badań naukowych.

Maryna Khorkova
.....
Podpis doktoranta/ki

**Oświadczenie wskazujące zadania, jakie pełnili promotor oraz (jeśli jest) promotor
pomocniczy w procesie doktorskim mgr Maryny Khorkovej**

Jako Promotor mgr Maryny Khorovej moja pomoc w realizacji podjętego problemu badawczego była wieloetapowa i rozpoczęła się jeszcze zanim mgr Khorkova podjęła naukę w Szkole Doktorskiej AWF w Poznaniu. Początkowo pomoc ta związana była z częstymi spotkaniami i dyskusjami nad ewentualnymi ścieżkami naukowego rozwoju, potem coraz bardziej ukierunkowana była na określeniu tematyki badawczej. W tym zakresie pani mgr Khorova wykazywała bardzo duże zaangażowanie przedstawiając kilka pomysłów badawczych, a moją rolą było podpowiedzenie, który z nich, i w jaki sposób, warty jest dalszego bardziej szczegółowego zgleźbienia.

Wspólnie opracowaliśmy Indywidualny Plan Badawczy, który później, po dostaniu się do Szkoły Doktorskiej, był bardzo skrupulatnie realizowany przez Doktorantkę.

W dalszym wspólnym postępowaniu Doktorantka opracowała metodologię badań, moją rolę było krytyczne odniesienie się do wybranych przez nią metod i narzędzi badawczych, i podpowiadanie jak najlepiej zorganizować proces badawczy.

W przygotowaniach do realizacji badań Doktorantka była odpowiedzialna za opracowanie harmonogramu badań, podział zadań w zespole badawczym, zbieranie danych, kodowania, nadzorowanie przebiegu interwencji oraz dalsze procedowanie zebranych danych. W tych etapach badań pomagał Doktorantce nasz cały zespół, w tym również promotor i promotor pomocniczy, choć należy to wyraźnie zaznaczyć, że to Doktorantka była odpowiedzialna za przebieg każdego z tych etapów.

W przygotowaniu artykułów do publikacji udział Doktorantki był zdecydowanie największy, a moja rola jako promotora związana była z merytorycznymi analizami pierwszych wersji artykułów aż do wersji finalnych, które później składane były do redakcji czasopism. Po otrzymaniu recenzji omawialiśmy je wspólnie z Doktorantką (na co zwrócić uwagę i jak zareagować na uwagi recenzentów), ale to Doktorantka pełniła rolę osoby odpowiedzialnej za końcową wersję artykułu.

W między czasie, jako promotor, pomagałem Doktorantce w realizacji zadań z Indywidualnego Planu Badawczego (również oceniając stopień jego wypełnienia), a swoimi podpowiedziami i doświadczeniem, wskazywałem możliwości w zakresie udziałów w konferencjach, wyjazdów stażowych czy doskonalenia językowego (Doktorantka płynnie operuje czterema językami) starałem się pomóc Doktorantce jak najlepiej przygotować się merytorycznie i metodycznie do pracy naukowej w przyszłości.

Prof. dr hab. Michał Bronikowski

KIEROWNIK
Zakładu Dydaktyki Aktywności Fizycznej
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Zakład Psychologii

Akademia Wychowania Fizycznego im. E. Piaseckiego
w Poznaniu

Poznań, 01.12.2025 r.

**Oświadczenie wskazujące zadania, jakie pełnił promotor pomocniczy rozprawy
doktorskiej Pani mgr Maryny Khorkovej pt.
*The impact of the Eduball method on selected parameters of creativity and motor fitness
in early age school children***


Oświadczam, że jako promotor pomocniczy posiadający wykształcenie psychologiczne oraz kompetencje w zakresie doboru narzędzi diagnostycznych i baterii testów służących ocenie funkcjonowania poznawczego człowieka, a także doświadczenie w prowadzeniu badań nad psychospołecznym funkcjonowaniem jednostki, realizowałem zadania związane z przygotowaniem oraz przebiegiem projektu badawczego prowadzonego przez doktorantkę.

Zakres moich obowiązków obejmował:

1. Nadzór merytoryczny nad realizacją badań dotyczących wybranych procesów umysłowych, w tym kreatywności, w grupie dzieci w wieku szkolnym.
2. Współdziałanie w doborze specjalistycznych narzędzi badawczych, których zastosowanie wymaga kwalifikacji psychologicznych, ukończenia szkoleń specjalistycznych lub dyplomu magisterskich studiów psychologicznych.
3. Udział w przeprowadzaniu badań, w tym prowadzenie pomiarów z wykorzystaniem wybranych narzędzi psychometrycznych oraz nadzór nad zgodnością procedur z przyjętymi standardami metodologicznymi.
4. Współpracę w zakresie analizy statystycznej danych uzyskanych w trakcie badań oraz współdziałanie w interpretacji wyników na tle aktualnego stanu wiedzy.
5. Udzielanie doktorantce pomocy merytorycznej i metodycznej, obejmującej formułowanie problemów badawczych, dobór metod, analizę literatury, interpretację wyników oraz przygotowanie tekstów naukowych.
6. Wsparcie językowe i terminologiczne w zakresie pojęć stosowanych w psychologii i naukach społecznych.

Ponadto wnosilem wkład w rozwój naukowy doktorantki poprzez współautorstwo publikacji powstałych w trakcie realizacji projektu, w tym: współpracę przy opracowaniu koncepcji i metodologii procedur badawczych, wsparcie w realizacji badań, udział w analizie danych, redakcję i korektę tekstu oraz akceptację ostatecznej wersji manuskryptu. Jednocześnie podkreśla się wiodący udział doktorantki w całym procesie planowania, przeprowadzania i opisu wyników badań.

Realizując powyższe zadania, sprawowałem wsparcie merytoryczne, metodyczne oraz organizacyjne na wszystkich etapach projektu badawczego, zgodnie z rolą promotora pomocniczego.



Prof. dr hab. Michał Bronikowski
Imię i nazwisko

Poznań, 01.12.2025r.
Miejscowość, data

Dotyczy: postępowania w sprawie nadania Pani mgr Marynie Khorkovej stopnia doktora w dziedzinie nauk medycznych i nauk o zdrowiu, w dyscyplinie nauki o kulturze fizycznej w Akademii Wychowania Fizycznego w Poznaniu.

Oświadczenie

Oświadczam, że mój wkład w powstanie publikacji wchodzącej w skład rozprawy doktorskiej pana/i Maryny Khorkovej zatytułowanej:

„The impact of the Eduball method on selected parameters of creativity and motor fitness in early age school children”

polegał na:

- publikacja 1 – współautorstwo w publikacji: współpraca przy opracowaniu koncepcji i metodologii procedur badawczych; nadzorowanie realizacji badań oraz zajęć interwencyjnych; współpraca w procesie analizy danych; redakcja, korekta oraz zaakceptowanie ostatecznej wersji manuskryptu; nadzór merytoryczny.
- publikacja 2 – współautorstwo w publikacji: współpraca przy opracowaniu koncepcji i metodologii procedur badawczych; nadzorowanie realizacji badań oraz zajęć interwencyjnych; współpraca w procesie analizy danych; redakcja, korekta oraz zaakceptowanie ostatecznej wersji manuskryptu; nadzór merytoryczny.

Michał Bronikowski

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Podpis współautora/ki

Dr Łukasz Bojkowski

Imię i nazwisko

Poznań, 01.12.2025 r.

Miejscowość, data

Dotyczy: postępowania w sprawie nadania Pani mgr Marynie Khorkovej stopnia doktora w dziedzinie nauk medycznych i nauk o zdrowiu, w dyscyplinie nauki o kulturze fizycznej w Akademii Wychowania Fizycznego w Poznaniu.

Oświadczenie

Oświadczam, że mój wkład w powstanie publikacji wchodzącej w skład rozprawy doktorskiej Pani Maryny Khorkovej zatytułowanej:

„The impact of the Eduball method on selected parameters of creativity and motor fitness in early age school children”

polegał na:

- **publikacja 1** – mój udział obejmował współpracę przy opracowaniu koncepcji i metodologii procedur badawczych, wsparcie w realizacji badań, udział w analizie danych, redakcję i korektę tekstu oraz akceptację ostatecznej wersji manuskryptu.
- **publikacja 2** – mój wkład obejmował analogiczny zakres działań: współopracowanie koncepcji i metodologii badań, wsparcie w realizacji badań, udział w analizie danych, prace redakcyjne i korekcyjne oraz akceptację finalnej wersji tekstu.

Dr Agata Korcz
Imię i nazwisko

Poznań, 01.12.2025r.
Miejscowość, data

Dotyczy: postępowania w sprawie nadania Pani mgr Marynie Khorkovej stopnia doktora w dziedzinie nauk medycznych i nauk o zdrowiu, w dyscyplinie nauki o kulturze fizycznej w Akademii Wychowania Fizycznego w Poznaniu.

Oświadczenie

Oświadczam, że mój wkład w powstanie publikacji wchodzącej w skład rozprawy doktorskiej pana/i Maryny Khorkovej zatytułowanej:

„The impact of the Eduball method on selected parameters of creativity and motor fitness in early age school children”

polegał na:

- publikacja 1 – współautorstwo w publikacji: współpraca przy realizacji badań (pre-test, post-test); recenzja oraz korekta manuskryptu.
- publikacja 2 – współautorstwo w publikacji: współpraca przy realizacji badań (pre-test, post-test); recenzja oraz korekta manuskryptu.

Agata Korcz
Podpis współautora/ki

Prof. AWF dr hab. Jana Krzysztozek

Imię i nazwisko

Poznań, 01.12.2025 r.

Miejscowość, data

Dotyczy: postępowania w sprawie nadania Pani mgr Marynie Khorkovej stopnia doktora w dziedzinie nauk medycznych i nauk o zdrowiu, w dyscyplinie nauki o kulturze fizycznej w Akademii Wychowania Fizycznego w Poznaniu.

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.....
Podpis współautora/ki

załącznik 9 do Wymogi dotyczące
przygotowania autoreferatów rozpraw
doktorskich

Dr Marlena Łopatka
Imię i nazwisko

Poznań, 01.12.2025
Miejscowość, data

Dotyczy: postępowania w sprawie nadania Pani mgr Marynie Khorkovej stopnia doktora w dziedzinie nauk medycznych i nauk o zdrowiu, w dyscyplinie nauki o kulturze fizycznej w Akademii Wychowania Fizycznego w Poznaniu.

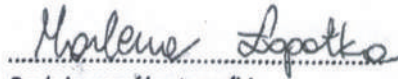
Oświadczenie

Oświadczam, że mój wkład w powstanie publikacji wchodzącej w skład rozprawy doktorskiej pana/i Maryny Khorkovej zatytułowanej:

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Podpis współautora/ki

Mgr Dagny Adamczak
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Poznań, 01.12.2025
Miejscowość, data

Dotyczy: postępowania w sprawie nadania Pani mgr Marynie Khorkovej stopnia doktora w dziedzinie nauk medycznych i nauk o zdrowiu, w dyscyplinie nauki o kulturze fizycznej w Akademii Wychowania Fizycznego w Poznaniu.

Oświadczenie

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Dagny Adamczak
Podpis współautora/ki



Article

The Relationship of Creativity and Motor Creativity with Physical Activity and Motor Fitness in a Gender Perspective Among 8–9-Year-Old Children

Maryna Khorkova ^{1,*} , Łukasz Bojkowski ² , Agata Korcz ¹ , Marlena Łopatka ¹ , Dagny Adamczak ¹ , Jana Krzysztoszek ¹ and Michał Bronikowski ¹

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Abstract: Background: In this study, we aimed to determine the presence of any potential gender differences and relationships in terms of creativity, physical activity (PA), motor fitness, and motor creativity in children aged 8–9 years. Methods: The study included 195 primary school children (92 girls and 103 boys) aged 8–9 years old from grade 2. To determine creativity, the Test for Creative Thinking-Drawing Production was used, while motor creativity was assessed using Torrance’s ‘Thinking Creatively in Action and Movement’ test. Motor fitness was assessed with the selected items from the Eurofit battery and Piórkowski tests. The level of moderate-to-vigorous PA was determined with the Physical Activity Screening Measure. The Mann–Whitney U test was employed for in-between group comparison and Spearman’s correlation to determine relationships between the variables. Results: The results of the research showed the presence of differences in motor fitness between boys and girls, but no differences in PA, creativity, as well as motor creativity between genders. Moreover, it was found there was no association between PA and motor fitness and creativity or motor creativity in either boys or girls at this age. Conclusions: Thus, it can be assumed that to develop creativity through PA in children aged 8–9 years, it might be necessary to create an appropriate environment and strategy that will strengthen, inspire, and promote children’s creativity through movement. Having established that there is no difference in creativity between genders at this age, it was pointed out that it is necessary to look for teaching methods that would effectively awaken this ability in a co-educational setting.

Keywords: early education children; motor creativity; fitness; sex differences; physical education



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1. Introduction

Childhood is a special part of a human’s life, which for the most part determines further opportunities for personal development, the ability to reveal own potential in the future, and has a significant impact on one’s self-realization in adulthood [1]. Therefore, it is extremely important to create an environment in early childhood that promote the most effective conditions for development of a child, taking into account all influencing factors.

Movement is a fundamental aspect of development through the whole childhood. Children, born to be active and to discover, explore the world in different ways of moving [2], using movement as their first means of getting to know the world. One may even call it the first language in which an infant communicates their will. From the moment we are born, the brain gives priority to various forms of movement, and movement becomes one of the main functions in early life, after the basic survival functions of the heartbeat, breathing, and digestion. Every movement made by a child adds to the building of new

important neural pathways in the brain and, thus, helps to develop their physical abilities [3]. The range of movements a child learns helps to develop basic (movement) skills that are necessary for the discovery of their immediate environment. It also helps them develop active and healthy bodies, which will have an impact on their quality of life in later years [2].

At the physical level, it has been shown that higher PA levels are associated with better body composition, higher bone mineral density, higher insulin sensitivity [4], maintenance of energy balance, and, consequently, healthy weight, healthy growth, development of the cardiorespiratory and musculoskeletal system, and avoidance of cardiovascular disease risk factors (e.g., hypertension, dyslipidemia, diabetes) [5,6].

Besides health improvement and disease prevention regular participation in PA is linked to enhancement of brain function and cognition. It also positively influences academic performance [7]. Several hypothesized mechanisms for explaining the process of how exercise can be beneficial for cognition have been proposed. This includes, among others, (1) increased blood and oxygen flow to the brain [8]; (2) increased levels of norepinephrine and endorphins [9,10], leading to a stress reduction and an improvement of mood [11]; and (3) increased growth factor, which helps to create new nerve cells and support synaptic plasticity [12,13].

The role of the physical activity, in general, and motor fitness, in particular on pediatric health, is certainly a topic of a great importance as we move toward a better understanding of the role that the physical, social, and cultural environments have on our population and their health. The association between cognition, brain structure and function, academic performance, and PA has been confirmed in many studies [6,14,15]. In a cross-sectional study by Donnelly et al. [4] it was indicated that the cohort-based studies involving PA have provided positive support for the relationship between PA and cognitive function. The authors pointed that it was the greater amounts or enhanced forms of PA that were associated with the improvements in cognitive functions. Acute PA studies also show a positive relationship between PA and cognition [4]. However, it should be noted the need for more in-depth research on this topic is required to be able to better establish causality and determine underlying processes and potential long-term effects [4].

One of humans' general cognitive skills is creativity, which has recently become an extremely important and in-demand skill in the challenging modern world. Creativity, which is one of the fundamental dispositions in everyday life, appears as a key concept of human innovation [16]. The traditional way of defining creativity is the ability to produce something that is both new/original and task/domain appropriate [17]. More recently, creativity is seen as in a multidimensional perspective that can be performed in art, science, commercial enterprise, and business innovation [18]. Baas et al. [19] define the roots of creative cognition in the arts and sciences and suggest that creativity is not just a cultural or social construct but that it is also psychological and cognitive process [18,20–23]. Despite this, many studies on creativity (including experimental ones) reported inconsistent findings [24–26]. One of the reasons for that could be due to the richness in the diversity of experimental approaches in the field of creativity research and the enormous variety in the ways of measuring and interpreting the creativity performance [24–26].

According to the latest World Economic Forum report, creativity is one of the most important key skills needed in future jobs [27]. Therefore, in order to help children with their self-realization in the future, education ought to focus on the factors that influence the development of their creativity and contribute to their development.

As mentioned above, multiple studies indicate the positive effects of PA on various cognitive functions. It is also known that creativity is based on various cognitive functions such as cognitive flexibility, inhibitory control, working memory updating, fluency, originality, and insights [28]. However, there is limited research regarding the relationship between PA, motor fitness, and creativity in early-aged school children. There is an even smaller number of studies examining the influence of PA and motor fitness level on the development of creativity, let alone with the mediating role of a gender. Such studies could

shed a new light on the most effective strategies for stimulating children's creativity in a gender perspective, though should also consider longitudinal changes.

It is known that early-aged school pupils are subject to extensive physical changes [29]. During the process of physical growth, speed, endurance, and strength increase in both genders; however, the development pattern of muscle strength occurs more slowly than the development of speed and endurance. Apparently, girls have greater flexibility and coordination than boys at primary school age based on individual performance ranges [29,30]. But Popovici et al. [31] showed that it was boys who had better lower and upper limb strength and abdominal muscles, while girls exceeded in body balance. On the other side, boys achieve significantly higher endurance running performance compared to girls [30].

Regarding the cognitive development of children, research confirms that the cognitive abilities of early school-age children show few differences depending on gender [32–34]. In 2011, Ardila et al. [32] carried out research to assess the gender differences in cognition (i.e., verbal, spatial, and arithmetic abilities) in children aged 5 to 16 years. To evaluate cognitive abilities, participants performed the Child Neuropsychological Assessment (CNA) test for seven different cognitive domains (memory, sensory perception, attentional abilities, oral language abilities, metalinguistic awareness, visuospatial, and visuomotor processing). Significant differences in results were observed only in three domains (language, spatial, and sensory-perceptual abilities), and in each of them male participants outperformed female ones. The authors concluded that gender differences could only be found in a small number of the total variance in scores. Therefore, Ardila et al. [32] found only minimal gender differences in cognition during developmental age in children.

In another study, Gur et al. [33] examined a sample of 3500 students aged 8 to 21 who performed the Penn Computerized Battery (Penn CNB) test. The battery consists of 14 single tests and explores many aspects of cognitive functions, such as sensorimotor speed, spatial ability, attention, working, and spatial verbal memory, among others. The results of this study showed that female students, when compared with their male peers, demonstrated higher accuracy and speed on verbal memory, social cognition, and face memory, but they performed worse than males in accuracy and attention speed and spatial and working memory tests. In addition, male students outperformed females in the accuracy and speed of spatial abilities, sensorimotor speed, and locomotor speed tests. Gur et al. [33] emphasized that gender differences become more pronounced after mid-adolescence.

Although the question of whether there are differences in the cognitive abilities of male and female children remains to be studied, the amount of research in this direction is growing [35–38]. On the other hand, there is a gap in the study of creativity in children depending on gender. It is currently unclear whether gender differentiates creativity, specifically in early school age. The lack of attention paid to gender differences in the creative abilities of males and females in early school age means that we do not know precisely how to influence the development of these abilities and miss the opportunity to effectively influence the development of children's creativity at school. The next important question is whether gender differences are established in children's creativity depending on their level of PA and motor fitness. Clarification of these issues could significantly affect the content of the school curriculum in primary school and, in particular, the content of the physical education program.

Therefore, based on the above-mentioned findings and research studies, we have developed a study that aimed at finding out whether there is a gender difference in creativity, PA, motor fitness, and motor creativity in children aged 8–9 years as well as establishing whether there is a relationship between these variables.

2. Materials and Methods

2.1. Participants

The study included 195 primary school children (92 girls and 103 boys) aged 8–9 years old from grade 2. Descriptive characteristics of the sample group are presented in Table 1.

Table 1. Descriptive characteristics.

Variables	Boys	Girls
	M ± SD	M ± SD
Gender	103 (52.82)	92 (47.18)
Age (years)	8.01 ± 0.33	8.01 ± 0.23
Body height (cm)	134.07 ± 6.43	131.61 ± 6.15
Body mass (kg)	31.30 ± 7.35	29.32 ± 5.64

Notes: M—mean; SD—standard deviation; cm—centimeters; kg—kilograms.

All children were recruited from three primary schools and attended a standard school curriculum in the city of Poznan (urban area) in Poland. The research was carried out between January and February 2024. The study was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Local Bioethics Committee of The Karol Marcinkowski University of Medical Sciences in Poznan (decision number 400/23). All parents or guardians provided written informed consent.

2.2. Study Procedure

The study included assessments of anthropometric data (body height and weight), motor fitness level, self-reported PA, creativity, and motor creativity. All measures and tests were performed in the school setting (gym and classroom). First, a creativity test was conducted in a classroom, and then motor fitness and motor creativity tests were performed in a school gym. The participants were informed about the test techniques and each test item was accompanied by detailed instructions presented to the participants by a trained research assistant. The exclusion criteria for this study were cognitive or physical dysfunction in pupils.

2.3. Creativity Assessment

Creativity was determined through the use of the Test for Creative Thinking-Drawing Production (TCT-DP) carried out according to the protocol of Urban [39]. Participants were asked to complete a drawing with six flawed elements placed on a creativity test sheet according to the method of Jellen and Urban [40]; all students performed this test autonomously and by themselves. The examiner noted the end time of the drawing test. Following 15 min from the start of the study, examiners collected sheets from students who had not yet submitted the test. The assessment of the TCT-DP consisted of fourteen criteria, which include the following: (1) continuations, (2) completions, (3) new elements, (4) connections made with a line, (5) connections that contribute to a theme, (6) boundary breaking that is fragment-dependent, (7) boundary breaking that is fragment-independent, (8) perspective, (9) humor and affectivity, (10) unconventionality with manipulation of the test material, (11) unconventionality with abstract elements, (12) unconventionality in the use of symbols, (13) unconventionality with unconventional usage of the given fragments, and (14) speed [39]. These creativity scores were assessed by a qualified psychologist. The final TCT-DP result was formed of the sum of the points obtained in all tested criteria.

The reliability and validity of the TCT-DP has been provided in many studies [39,41,42], and it has been previously reported that eventual experience in drawing is unrelated to the TCT-DP score [39]. In the case of Polish standardization studies, internal consistency was estimated based on the Cronbach's alpha coefficient. The obtained Cronbach alpha coefficients ranged from 0.62 (students of the army cadets' school) to 0.80 (preschool children) [41].

2.4. Motor Creativity Assessment

Motor creativity was evaluated with use of Torrance's 'Thinking Creatively in Action and Movement' (TCAM) test. The administration and the scoring guide of the test were translated back-to-back from English to Polish, and some appropriate adaptations were made by a trained psychologist. The test consists of four activities. The first, third, and

fourth activities help to assess motor fluency and originality, whereas the second activity assesses imagination. Fluency is determined as the ability to create alternative modes of movement. Originality is the ability to produce novel, unique, and unusual ways of movement. Imagination is defined as the ability to imagine, fantasize, and assume unusual roles. In the first activity, the participant was asked to overcome the designated distance of three meters in as many ways as possible. The second activity requires the child to imagine themselves in six fiction situations and perform appropriate actions accordingly. Four of these situations require the child to pretend to be an animal/object (tree, rabbit, fish, snake), and in the last two the child is expected to pretend and perform some actions (driving a car or pushing an elephant off a desired object). In the third activity, the child is asked to describe or demonstrate as many ways as possible of putting a paper cup into a wastebasket, placed within a two-meter distance. For the fourth activity, the participants are asked to list different/show the potential uses for a paper cup. Testing time ranged between 10 and 30 min. Fluency was projected as a sum of the responses recorded on predetermined score sheets. Originality was assessed (calculated) with the use of the tests' original reference list of the most frequent responses and points were awarded accordingly. Imagination was assessed on a five-point rating scale (from 1 = no movement to 5 = excellent imitation). All marking of scores were performed accordingly to the original manual [43]. Reliability coefficients for the separate activities were 0.71 for the first activity, 0.79 for the second activity, 0.67 for the third activity, and 0.58 for the fourth activity. The overall reliability coefficient of Torrence TCAM test was 0.84 [43].

2.5. Assessments of Anthropometric Parameters

Body height and weight were measured without shoes using an anthropological instrument (Wunder Sa. Bi. Srl., Milan, Italy). Height was measured to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg. The measurements were performed once by trained research assistants.

2.6. Motor Fitness

The motor fitness levels of the participants were assessed using the selected tests from Eurofit battery (Council of Europe, Committee for the development of sport, Strasbourg, France) [44]: 10 × 5 m Shuttle Run (SHR)—to determine running speed and agility; 20 m endurance Shuttle Run (Beep test)—to assess cardiorespiratory endurance.

The 10 × 5 m SHR test involves participants running back and forth over a 5-m distance, changing direction 10 times to measure speed and agility [45].

In the 20 m Shuttle Run test, the participants are asked to stand behind the lines facing the second line (the distance between the lines is 20 m), and then on the special sound signal start the running. The speed at the beginning is quite slow. The participants continue to run between the two lines turning when signaled by recorded beeps. After one minute, a sound indicates an increase in speed, and the beep sound increases its frequency as well. This progress continues each minute (level) to the 15 min level. The participant is given a warning if they fail to reach the line (within 2 m) the first time, and after a second warning they are eliminated by the research assistant. The score is given as a number of levels based on the number of 20 m shuttles reached before the participant was unable to keep up with the recorded beep sound. The final score is the last level completed [46].

The Piórkowski test was used to assess eye–hand coordination, precision of movements, and speed reaction. The Piórkowski test was conducted with the use of a Piórkowski apparatus (AP) (Psychology laboratory “Driver”, Ustrzyki Dolne, Poland). This apparatus has 10 buttons arranged in one row. There is an LED above each button that lights up to indicate the button to press. Only 1 LED always lights up. The task is—using both hands—to press each subsequent button indicated by the device. The device does not wait for the correct press but sets its own pace, and the subject must be able to hit the button correctly as many times as possible. In this study, parameters included a 60 s test with a stimulus presentation frequency of 30 pulses. The outcome was the number of correct

responses. A thorough instruction was always provided before the examination. This test has been previously conducted under Polish conditions in the study by Tomczak et al. [47] and Merkisz et al. [48].

2.7. Physical Activity Survey

To determine the level of moderate-to-vigorous physical activity (MVPA), the Physical Activity Screening Measure was used [49]. The scale was administered to children on a “one-to-one” basis by a trained staff member of the research team in comfortable conditions for the child. Pupils were asked the following questions: (1) “Over the past 7 days, how many days were you physically active for a total of at least 60 min per day?” and (2) “Over a typical or usual week, how many days are you physically active for a total of at least 60 min per day?” (0 days, 1 day up to 7 days). The final MVPA index score was calculated with the formula provided by Prochaska et al. [49], $MVPA = (Q1 + Q2)/2$, where Q1 is the number of physically active days over the last 7 days and Q2 is the number of physically active days in a typical week. According to Prochaska et al. [49], the measure is reliable (ICC = 0.77). The item has been proven to have reasonable validity and moderate reliability [50]. This measure has been tested earlier in some Polish studies [51–54].

3. Statistical Analysis

Statistical analyses were performed for physical fitness components, PA, and creativity components. After checking for normality with the use of the Shapiro–Wilk test, the lack of normal distribution was noticed; therefore, to compare differences in motor fitness, self-reported PA, creativity, and motor creativity between boys and girls, the Mann–Whitney U test was employed. The correlation between motor fitness, PA, and individual creativity indicators in boys and girls was determined using Spearman’s correlation. For statistical testing, Statistica 13.3 was used (Statsoft, Kraków, Poland), and statistical significance was set at $p < 0.05$.

4. Results

A comparison of PA, motor fitness, creativity, and motor creativity test results is presented in Table 2. Regarding motor fitness, boys, as opposed to girls, obtained better results in the 10 × 5 m SHR test ($p < 0.001$) and 20 m Shuttle Run test ($p < 0.05$). In the Piórkowski apparatus test, girls achieved higher (better) results than boys ($p < 0.05$). There was no statistically significant difference between boys and girls in MVPA score, nor were there statistically significant differences in creativity or any of the motor creativity variables between genders.

Table 2. A comparison of the motor fitness, PA, creativity, and motor creativity test scores between boys and girls.

Variables	Boys	Girls	p
	M ± SD	M ± SD	
10 × 5 m SHR (s)	24.3 ± 2.69	25.9 ± 2.06	<0.001
20 m Shuttle Run (lvl)	3.3 ± 1.33	2.9 ± 0.96	<0.05
Piórkowski apparatus (no/30 pulses)	23.6 ± 4.61	24.8 ± 3.99	<0.05
MVPA (hrs/week)	4.1 ± 1.58	3.8 ± 1.23	>0.05
TCT-DP (pts)	22.7 ± 9.93	24.2 ± 10.07	>0.05
TCAM Fluency (pts)	24.5 ± 9.24	22.6 ± 9.79	>0.05
TCAM Originality (pts)	26.3 ± 12.58	25.5 ± 13.82	>0.05
TCAM Imagination (pts)	18.7 ± 5.42	18.9 ± 4.61	>0.05

Notes: M—mean; SD—standard deviation; no—number; s—seconds; lvl—level; pts—points; SHR—10 × 5 m shuttle run; MVPA—moderate-to-vigorous PA; TCAM—Torrance’s ‘Thinking Creatively in Action and Movement’ test; TCT-DP—Test for Creative Thinking-Drawing Production.

In boys, the TCT-DP score was not associated with PA (MVPA) and neither with any of the three other indicators of motor fitness. No correlation was noted between motor creativity and PA. Regarding motor fitness and motor creativity, the only correlation, which was mild in power (0.28), was noted between results of the Piórkowski apparatus test and one of the subcategories of creativity, namely originality. No other correlations were noted (Table 3).

Table 3. The correlation between motor fitness, PA, and individual creativity indicators in boys.

Variables	TCT-DP	TCAM Fluency	TCAM Originality	TCAM Imagination
10 × 5 m SHR	−0.17	0.01	0.02	−0.05
20 m Shuttle Run	0.13	−0.03	−0.13	0.06
Piórkowski apparatus	0.04	0.12	0.28 *	0.13
MVPA	0.01	−0.07	0.01	0.08

Notes: SHR—10 × 5 m shuttle run; MVPA—moderate-to-vigorous PA; TCAM—Torrance’s ‘Thinking Creatively in Action and Movement’ test; TCT-DP—Test for Creative Thinking-Drawing Production; * p -value ≤ 0.05 .

In girls, the TCT-DP score also was not associated with PA (MVPA) or with any of the other three indicators of motor fitness. Furthermore, there was no correlation noticed between motor creativity and PA. Regarding motor fitness and motor creativity, a correlation between results of the Piórkowski apparatus test and fluency (one of the TCAM creativity subcategories) was observed, but it was only mild in power (0.24). No other correlations were noted (Table 4).

Table 4. Correlation between motor fitness, PA and individual creativity indicators in girls.

Variables	TCT-DP	TCAM Fluency	TCAM Originality	TCAM Imagination
10 × 5 m SHR	−0.03	0.06	0.15	0.03
20 m Shuttle Run	0.02	0.09	−0.08	0.06
Piórkowski apparatus	0.04	0.24 *	0.17	0.15
MVPA	−0.01	−0.01	0.01	0.02

Notes: SHR—10 × 5 m shuttle run; MVPA—moderate-to-vigorous PA; TCAM—Torrance’s ‘Thinking Creatively in Action and Movement’ test; TCT-DP—Test for Creative Thinking-Drawing Production; * p -value ≤ 0.05 .

5. Discussion

The findings of the study show some gender differences in creativity, motor creativity, PA, and motor fitness in 8–9-year-old children.

Regarding motor fitness, we confirmed the findings of the previous studies [29–31] regarding the existence of differences (with statistical significance) in motor fitness between boys and girls in the 8–9 year old age range. Boys obtained better results in running speed and agility (10 × 5 m SHR test) ($p < 0.001$) as well as cardiorespiratory endurance (20 m Shuttle Run test) ($p < 0.05$) when compared to girls. On the other hand, girls achieved better results than boys in eye–hand coordination, precision of movements, and speed reaction (Piórkowski apparatus test) ($p < 0.05$). Interestingly, no statistically significant difference between genders in PA levels was noticed, indicating that, at least at this age, boys and girls are active to a similar extent.

In terms of creativity and motor creativity in the study, it was found that there was no statistically significant difference between the genders. The results of the TCT-DP showed that there is no statistically significant difference between the two genders in creativity, and this is intersected with the results of previous studies [32–34] comparing the other cognitive skills of boys and girls in early school age. In the study of Ardila et al. [32], a sample of monolingual children from Mexico and Columbia (350 boys, 438 girls, age range 5–16 years) were examined, and it was observed that the gender differences in cognitive development were minimal and appeared only in a small number of tests, which only contributed a low

percentage to the total difference. In turn, in the study of Gur et al. [33], the gender effect on cognitive skills was noted, but it was much smaller than the effect of age. It is worth mentioning that they tested youths ages 8–21 years, and testing included performance accuracy and response times for executive control, episodic memory, complex cognition, social cognition, and sensorimotor speed domains. In that sample, gender differences (in most domains of tested items) were already seen at the youngest age groups, but it was with age that the discrepancy became much more noticeable. The majority of those gender differences were apparent by early adolescence [33].

In our study, the ICAM showed similar results regarding all variables of motor creativity—boys and girls aged 8–9 years did not differ by this indicator either. Earlier, similar findings were obtained by Zachopoulou and Makri [55] in their study that investigated the motor creativity of 191 young children aged 5–8 years. In their study, the subject's motor creativity was assessed using the Divergent Movement Ability Test, where the effect of gender in two factors of motor creativity—motor fluency and motor flexibility—was estimated. No statistically significant differences between the two genders were found [55]. Thus, one can conclude that early-aged young girls and boys have similar levels in terms of motor creativity performance.

According to the correlation between the various variables of our study, the following was established. In both boys and girls, creativity was not associated with PA. There was also no correlation between motor creativity and PA for either gender. It seems that in 8–9-year age range for both gender, creativity does not correlate with PA. Results obtained by Piya-amomphan et al. [56], who investigated the relationship between creativity and PA among 1447 students with different age groups (from 6 to 17 years) in 34 schools from southern Thailand, are in line with our study. The authors, in their study, also used the Test for Creative Thinking-Drawing Production (TCT-DP) to measure creativity. PA was determined with the use of the Thailand Physical Activity Children Survey-the Student Questionnaire (TPACS-SQ). The results of their research showed that in children aged 6–9 years and 10–13 years, creativity was not associated with PA in either of the age categories. The correlation between creativity and PA was observed only in participants aged 14–17 years [56], indicating the possible longitudinal developmental factor.

A growing body of research [6,14,15,57] demonstrates that children's participation in PA has a positive effect on cognitive function and academic achievements in school through positive effects on general brain structure and functioning and, thus, on cognition [58]. But it seems that the mechanism for creative development is different. Based on established data, which show that PA has a positive effect on brain functions [57] and that youth aged 14–17 with a higher level of activity had a higher level of creativity, it can be assumed that PA gives children a predisposition to develop creativity, but the stimulation of creative development occurs due to additional influencing factors. Perhaps, this is why older children, who had more time opportunities for additional influence on the development of creativity, including higher PA as an extra factor, had a higher level of creativity at the end. In this case, it would imply the auxiliary function of PA in the development of creativity, although it may not affect this process directly. Therefore, it can be assumed that the development of creativity requires special methods and development strategies.

Another possible explanation of this thesis might be the assumption that engagement in various movement activities not only has a direct effect on the development of creativity but also has an accumulative effect and requires a longer exposure time. This could also explain why the connection between PA and creativity is not observed in children aged 6–13 years, but it is observed in older children. This question needs further, more in-depth research, which should examine the relationship between creativity and previous experiences.

With regard to motor fitness and creativity, in our study, in both boys and girls, creativity did not correlate with measured indicators of motor fitness. In the case of motor fitness and motor creativity, only a weak correlation was noted between the results of the Piórkowski test and the subfactor of motor creativity, namely originality for boys ($r = 0.28$)

and the Piórkowski test and fluency for girls ($r = 0.24$). The results potentially suggest that motor proficiency and creativity may not be inter-related traits at this early age of school children. Marinšek and Lukman [59], in their study of the relationship between motor creativity and motor fitness, found similar results. The authors used the Test of Gross Motor Development and Bertsch's motor creativity test among 5–6 years old children for the evaluation of motor skill proficiency and motor creativity. No correlations between motor skill proficiency and motor creativity were found in the examined group of children. In their study, the authors concluded that motor creativity is a trait that is independent from motor skill proficiency in early-age children, and one cannot and should not predict motor creativity basing on the knowledge of a child's level of motor skill development in this age category [59]. These results are also in line with previous work from Scibinetti et al. [60].

It seems that physical education classes, based mainly on the reproduction of existing motor skills and physical drills, do not contribute to the development of motor creativity. They affect motor skills and motor fitness, mostly with linear progression (from easier to more complex motor skills), taking into account the efficiency of movements. However, motor creativity mainly arises from activities that facilitate non-linear mechanisms and largely ignore the efficiency of movement. Typically, in linear mechanisms, the constraints of the task are very narrow. They do not allow children to explore new possibilities of movement [59,61,62]. Based on this, it can be assumed that the development of motor creativity requires a specially designed teaching strategy.

Using objective methods of measuring motor fitness and creativity can be considered a strength of our study, but there are some limitations as well. First, the sample's age range was narrowed to children aged 8–9 years, so, generalization, especially given that the motor development process during this period is very dynamic, is limited [29]. Second, all data on children's PA were self-reported, which to some extent depends on recall, and reporting bias is possible. Third, the research design limits us to establishing casual relationships between PA, motor fitness, creativity, and motor creativity; therefore, future studies should use samples of other age categories or a controlled experimental design with modulations of creativity intervention programs. Furthermore, longitudinal studies would be of value in these aspects.

6. Conclusions

The results of this research indicate some significance differences in motor fitness levels between boys and girls aged 8–9 years but a lack of such differences in PA, creativity, and motor creativity levels. Moreover, no correlation between PA, motor fitness, and creativity nor motor creativity were noticed in either of the genders. Thus, it can be pointed out that in order to develop children's creativity through PA, it is necessary to create an appropriate environment and strategy that will strengthen, inspire, and promote children's creativity through movement.

Creativity is one of the most demanded work skills in today's labor market and education should be held responsible for providing such opportunities to school pupils. The development of creativeness can be stimulated via various school subjects—generally the better pedagogically prepared is the teacher, the more educational chances they can provide. However, physical education, with its variety of contexts, sports, and wide range of teaching methods, probably seems to be the best platform. Therefore, knowing there is no difference in creativity between the genders in early-aged school children, we need to search for the new, more effective teaching/learning method, which would effectively awaken that kind of skills in co-educational settings.

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Institutional Review Board Statement: This study was approved by the Local Bioethics Committee of The Karol Marcinkowski University of Medical Sciences in Poznan (decision number 400/23 of 11 May 2023). Parents were informed in detail about the conditions of the study and consented to their children's participation before the start of the research. All methods were carried out in accordance with relevant guidelines and regulations such as the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all parents of children involved in the study.

Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request due to privacy.

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Impact of the Eduball method on cognitive creativity, motor creativity, and motor fitness during physical education classes in 8- to 9-year-old children

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Introduction: Creativity is increasingly recognized as a crucial skill across various fields. Although schools are placing more emphasis on fostering creativity, physical education (PE) often remains overlooked. The Eduball method, which combines physical activity with cognitive challenges using educational balls, presents a promising strategy for enhancing both cognitive and motor creativity in children. This study aimed to assess the effectiveness of an Eduball-based PE program in supporting creativity and motor fitness in early school-aged children.

Methods: The study involved 173 primary school children (48% girls) aged 8–9 years. Cognitive creativity was assessed using the Test for Creative Thinking–Drawing Production (TCT-DP). Motor creativity (fluency, originality, imagination) was evaluated using the “Thinking Creatively in Action and Movement” (TCAM) test. Motor fitness was assessed using selected Eurofit battery tests: a 20-meter Shuttle Run to evaluate cardiorespiratory endurance, and a 10 × 5-meter Shuttle Run (SHR) to assess speed and agility. The Piórkowski apparatus (AP) test measured hand-eye coordination, reaction time, and precision of movements. The eight-week intervention used the Eduball method during PE classes in two experimental groups: Experimental Group 1 (EG1) had one Eduball session per week; Experimental Group 2 (EG2) had two. The control group (CG) participated only in traditional PE classes. Pre- and post-tests were analyzed using one-way ANOVA on ranks and the Wilcoxon signed-rank test.

Results: At the pre-test there were no significant differences between groups in any measured parameter. However, statistically significant differences were observed in the post-test for the TCT-DP scores, motor imagination (TCAM), and eye-hand coordination in AP test, all favoring EG2. Within-group comparisons showed significant improvements in all motor fitness parameters, as well as in TCAM fluency and imagination across all groups. However, no significant change in TCT-DP or TCAM originality was observed in the experimental groups. The control group showed a significant decline in these two parameters.

Conclusion: The Eduball method significantly supported selected aspects of creativity and motor fitness among 8–9-year-old children. These findings highlight the method’s potential as an effective pedagogical tool for fostering creativity development through physical education in school settings.

KEYWORDS

Eduball method, cognitive creativity, motor creativity, motor fitness, early school-aged children

Introduction

In rapidly evolving world, where technological advancements, constant change, and increasing competition across all areas of social life fuel the pace of leaving, creativity has become an essential and highly valued skill. It is now considered a crucial asset for an employee at today's labor market. According to the latest Future of Jobs Report 2025 from the World Economic Forum (1), creativity is among the top five most in-demand professional skills in the workplace. This highlights the importance of having an agile, innovative, and collaborative workforce, where creative abilities play a significant role in achieving success.

Prior research has shown, that creativity has been viewed from a multidimensional perspective, recognizing its expression not only in art but also in science, engineering, commerce, and business innovation (2–4). In this regard, it becomes quite understandable the fact that creativity, while long recognized as an important focus in education, has in recent years gained renewed and increasing attention (5, 6) as a key factor in preparing the younger generation for adult life and its growing competitive demands.

In recent years more and more research has been devoted to investigating methods and strategies for developing children's creativity in educational environment (6–10). Despite this, few studies in this context focus on PE classes and their potential (11–14). Positive impact on children's creativity should become a core of their schooling and sound development.

Most methods designed to develop children's creativity look toward the chances offered by more academic subjects (6, 15), while PE remains underemphasized in this regard. This is due to the prevalent stereotype that PE is solely intended for the development of motor skills and improvement of children's physical fitness. This misconception arises from the fact that modern PE classes are primarily based on their reproductive nature from children's side, emphasizing motor skill acquisition while predominantly focusing on physical fitness and the repetition of existing motor patterns (16–18). It is important to recognize that early school-aged children are in period of rapid motor development, during which both fundamental motor skills (e.g., running, jumping, throwing) and underlying motor abilities (such as strength, speed, agility, coordination and balance) become more refined (19–21). At this stage, children show marked improvements in movement efficiency, allowing them to combine and apply skills in increasingly complex ways, particularly in play contexts. Aerobic capacity and speed demonstrate particularly strong developmental gains in this age range, reflecting both biological maturation and increased engagement in structured activity (22). In addition, fine motor skills progress steadily, leading to greater dexterity and enhanced eye-hand coordination. These developmental changes support better overall coordination and balance, which are critical for successful participation in organized games and physical activity (20, 21). This natural tendency toward rapid motor development should be stimulated accordingly via the design of PE programs.

However, the potential of PE extends far beyond these aspects. This assertion is supported by empirical evidence dating back over a decade, particularly in Europe. Heilmann and Korte's (23) content analysis of European school curricula identified PE among the top three subjects with the highest frequency of creativity-related terms, underscoring its long-recognized potential for fostering creativity in school settings. PE offers activities that naturally allow creative potential to emerge, including team games, where students express creativity by modifying game rules, discovering alternative movements, and demonstrating divergent approaches to sports skills. Such characteristics make PE particularly well-suited to develop creative capacity through movement (24).

Movement is a necessity and natural stimulus for children from birth (25), while play is one of the most engaging and fundamental activities in their development (26, 27). Research shows that creativity is less likely to flourish in a state of boredom or negative emotions. On the contrary, it tends to grow in environments characterized by positive mood and engagement (28, 29). PE teachers, leveraging the unique nature of their subject, can foster such an atmosphere by creating a positive, engaging learning environment. Within such a setting, creativity may be effectively supported and expressed through movement, making its development feel enjoyable and effortless rather than burdensome.

The traditional way of defining creativity is as the ability to produce something both new (original) and appropriate to the task or domain (30). Another widely used definition describes creativity as the capacity to generate ideas or products that are both novel and useful (31). However other perspectives frame creativity not as an individual trait or product, but as a systematic, embodied, and socioculturally situated phenomenon emerging from dynamic interactions between individuals and their environments (32). In this study, we examine creativity within the school context, specifically little-c creativity—the everyday creative potential that can be cultivated through educational experiences and that differs from the eminent, domain-transforming creativity associated with professional expertise or genius (33). Within the 4C framework (33), little-c creativity lies between mini-c (personally novel insights) and pro-c (professional-level achievements). It includes everyday behaviors such as pretend play, problem-solving, or questioning, and is vital for children's learning, wellbeing, and development (34).

Creativity in movement, or motor creativity, has been cautiously defined by Wyrick (35) as the ability to produce both varied and unique motor responses to a stimulus (35), with the important caveat that its objective assessment presents considerable difficulties. While Wyrick emphasized variety and uniqueness, later approaches, such as Torrance's Thinking Creativity in Action and Movement (TCAM) (36)—expended this conceptualization by also incorporating fluency (the number of responses) as a separate criterion. Accordingly, while creativity can be conceptualized in terms of products, processes, or broader systemic perspectives (37), our study adopts a primarily product-oriented approach, focusing on observable children's outcomes of both cognitive and motor creativity.

Understanding motor creativity is particularly relevant in school-based PE. Studies examining the effectiveness of methods for developing motor creativity in PE classes have confirmed their positive impact (11, 12, 38). However, researchers emphasize that traditional PE classes that primarily focus on physical fitness and the repetition of existing motor skills do not effectively promote motor creativity. Traditional PE classes are typically based on reproductive teaching styles, in which teachers direct activities, emphasize repetition, and prioritize mastery of established motor patterns rather than fostering creative exploration (17). In practice, such classes often rely on linear, teacher-centered instruction with standardized exercises, where the main goal is physical fitness and skill automatization rather than problem-solving or innovation. Instead, motor creativity mainly emerges from activities that encourage nonlinear mechanisms of learning. Strategies such as constraint manipulation (e.g., performing a movement using only one limb), functional variability (e.g., “show me another way to do this”), problem-solving (e.g., “find a way to...”), improvisation (e.g., “do whatever you want”), fantasy play (e.g., “pretend you are an animal”), and creation (e.g., “invent a completely new movement”) offer significantly greater potential for developing motor creativity (11). In turn, in linear approaches, task constraints are often too rigid, limiting children’s ability to explore new movement possibilities (11, 39, 40). The lack of effectiveness in stimulating motor creativity within the traditional PE curriculum points to a broader challenge in the PE system, where the prevailing focus on standardized performance often suppresses opportunities for innovation and creative impression. Based on this, it can be assumed that fostering motor creativity in PE classes requires a specifically designed PE method or strategy.

One of the promising and innovative methods in PE is the Eduball method—a unique educational approach that integrates physical activity (PA) with academic learning. The method integrates PA with subject-matter learning through structured lesson plans, interdisciplinary instructional strategies, and defined didactic principles. This method enhances children’s cognitive abilities by combining movement and play, making the learning process more engaging and effective (41). It was developed in 2001 by Polish academic researchers Rokita and Rzepa. The concept is based on an interdisciplinary approach to teaching PE, blending cognitive engagement with movement tasks. This is achieved through the use of special didactic tools—educational balls (Eduballs)—which are incorporated into PE classes with modified tasks that stimulate cognitive skills and functions during movement (42).

The Eduball set consists of 100 balls in five colors (red, blue, green, yellow and orange), each marked with letters, numbers or mathematical symbols (43, 44). Through interactive physical activities with Eduballs, children learn about colors, letters, numbers and fundamental mathematical operations, as well as various language and mathematical rules. At the same time, they develop fine and gross motor skills, along with fundamental movement abilities such as passing, catching, dribbling, throwing, rebounding, and receiving the ball (41). Plays and games with Eduballs are based on natural forms of movement and holistically stimulate children’s development. The numbers, letters, and symbols, along with colors of the educational balls, allow for their broad application in teaching and reinforcing concepts from nearly all school subjects during PE classes (42, 45, 46). Since the introduction of educational balls, numerous pedagogical studies have been conducted to assess the effects of movement-based

learning with Eduballs (47–53). Research has demonstrated that PA involving educational balls have a positive impact on overall body coordination, eye-hand coordination, spatial–temporal orientation, and locomotor skills of primary school students (48, 50).

However, the most distinctive feature of the Eduball method is its influence on pupil’s academic performance. Studies have confirmed a significant impact of the method on children’s language skills (both native and foreign), reading and writing abilities, and mathematical competencies (47, 49, 52, 53). Additionally, positive trends have been observed in the graphomotor efficiency of primary school students (51). The link between cognitive abilities and academic performance has been well established (54, 55), with evidence indicating that this relationship is particularly strong at the primary school level compared to later stages of education (54). Moreover, Runco (56) demonstrated that basic cognitive process—including attention, perception, memory, information processing—are directly associated with creative problem solving.

Based on the concept of the Eduball method, it can be therefore assumed that it offers a valuable opportunity to foster children’s creativity within PE setting. Importantly, this potential may arise not only indirectly through its well-documented influence on academic performance and, consequently, on cognitive function—which are closely linked to creativity—but also directly through the nature of Eduball tasks themselves. These tasks are purposefully designed to create simultaneous cognitive and movement challenges, encourage nonlinear movement patterns and engage pupils in problem-oriented activities. This assumption, supported by previous research findings (47, 49, 51, 53, 57) led to the hypothesis that the Eduball method could be an effective approach for fostering both children’s cognitive and motor creativity in PE classes.

To test this a study was designed to evaluate the impact of the Eduball method on the development of cognitive creativity and motor creativity among early-age school pupils in PE settings. To achieve this goal, a specially designed eight-week intervention program using the Eduball method was implemented in PE classes for second-grade primary school pupils. The hypotheses of this study were as follows: (1) a specially designed educational program incorporating the Eduball method in PE classes will lead to greater improvements in children’s cognitive creativity and motor creativity compared to those participating in traditional PE classes; (2) the impact of PE classes utilizing the Eduball method on children’s motor fitness will be comparable to that of traditional PE classes.

Materials and methods

Participants

The study recruited 173 healthy children (83 girls and 90 boys) aged 8 to 9 from the second grade of three public primary schools in Poznan, Poland (urban area). The school’s PE curriculum followed the unified standards established by the Polish National Ministry of Education. The sample size calculation was conducted using G*Power 3.1 software, with an anticipated effect size of 0.25, a significance level (α) of 0.05 and statistical power set at 0.90, which resulted in a minimum sample size of 162. The research was carried out between January and May 2024. Exclusion criteria for participants were: (1) children younger than 8 and older than 9 years; (2) children with

congenital diseases; (3) children with intellectual developmental disorders or learning disabilities. The descriptive characteristics of the sample groups are presented in Table 1.

In addition, information on children's extracurricular activities was collected, including additional physical activity, organized or competitive sports (e.g., ball games), and non-sport activities such as creative arts. These activities were considered as potential variables influencing creativity. However, the activities were highly varied in type and intensity, and so significant correlations were found between these variables and either cognitive or motor creativity.

The study was conducted in accordance with the Declaration of Helsinki and the study protocol was approved by the Local Bioethics Committee of the Karol Marcinkowski University of Medical Science in Poznan (decision number 400/23 of 11 May 2023). Written informed consent was obtained from the parents or guardians of the child participants and verbal assent was also obtained from the children prior to participation.

Study procedure

Pre- and post-assessments were conducted in two experimental and one control groups. The assessments included measurements of anthropometric data (body weight and height), creativity, motor creativity, and motor fitness level. All measurements and tests were performed in a school setting (gym and classrooms). First, the creativity test was conducted in a classroom. Then, motor fitness and motor creativity tests were conducted in a school gym. The participants were informed about the test procedure and each test item was accompanied by detailed instructions. Creativity assessments were conducted by trained instructors under the supervision of a qualified psychologist, and motor fitness assessments were conducted by trained research specialists to ensure reliable measurements.

Assessment of anthropometric parameters

The measurement of body weight and height was conducted using anthropometric instruments (Wunder Sa. Bi. Srl., Milan, Italy) in accordance with the prevailing standard methodology. Participants were barefoot during the measurement. Weight was measured to the nearest 0.1 kg, while the participants wore a minimum of clothing. Height was measured to the nearest 0.1 cm. The participants were instructed to adopt an upright posture, maintain a forward-facing

gaze, and keep their knees straight, with their arms at their sides. All measurements were taken once by trained research assistants.

Creativity assessment

The Test for Creative Thinking-Drawing Production (TCT-DP) was used to assess pupils' creativity following Urban's protocol (58). The participants were asked to complete a drawing that begins with a square frame and six figural fragments placed on a test sheet following the Jellen and Urban method (59, 60). Additionally, the subjects were asked to provide a title for the drawing. It has been previously reported that eventual experience in drawing is unrelated to TCT-DP score (58). All pupils performed this test on their own. The instructions emphasized freedom of expression, and the participants were not informed about the time limit (although the maximum allowed time was 15 min, which was considered in the scoring) (58–60). The assessment of the TCT-DP consisted of fourteen criteria, which include the following: (1) continuations, (2) completions, (3) new elements, (4) connections made with a line, (5) connections that contribute to a theme, (6) boundary breaking that is fragment-dependent, (7) boundary breaking that is fragment-independent, (8) perspective, (9) humor and affectivity, (10) unconventionality with manipulation of the test material, (11) unconventionality with abstract elements, (12) unconventionality in the use of symbols, (13) unconventionality with unconventional usage of the given fragments, and (14) speed (58). A qualified psychologist assessed the creativity scores with the final TCT-DP result calculated as the total sum of points obtained across all the criteria.

The test has two versions (A and B) differing only in the positioning of the elements relative to the test item. In version B, the initial arrangement is rotated 180 degrees. In this study version A was used for the pre-test, while version B was used for the post-test. The reliability and validity of the TCT-DP have been confirmed in numerous studies (58, 60, 61). In Polish standardization studies internal consistency was assessed using Cronbach's alpha, with coefficient ranging from 0.62 (army cadet school students) to 0.80 (preschool children) (60).

Motor creativity assessment

Torrance's "Thinking Creatively in Action and Movement" (TCAM) test was used to assess pupils' motor creativity (36). The test administration and scoring guide were translated from English to

TABLE 1 Descriptive characteristics.

Variables		EG1 (n = 61)	EG2 (n = 39)	CG (n = 73)
		M ± SD	M ± SD	M ± SD
Sex	Boys	31 (50.8)	19 (48.7)	40 (54.8)
	Girls	30 (49.2)	20 (51.3)	33 (45.2)
Age (years)		8.05 ± 0.28	8.03 ± 0.16	8.03 ± 0.29
Body height (cm)		132.25 ± 6.93	134.03 ± 6.18	132.56 ± 6.29
Body weight (kg)		30.72 ± 7.99	31.05 ± 5.91	29.02 ± 5.39

M, mean; SD, standard deviation; cm, centimeters; kg, kilograms; EG1, Experimental Group 1; EG2, Experimental Group 2; CG, Control Group.

Polish using back-to-back translation method with appropriate adaptations. The test included four activities. In the first activity, the child was asked to cover the designated distance of three meters in as many different ways as possible. The second activity required the participant to imagine themselves in six fiction situations and perform appropriate actions accordingly. For the third activity the participant was asked to demonstrate or describe as many different ways as possible to place a paper cup into wastebasket located two-meter away. In the fourth activity the subject was asked to list or demonstrate different possible uses for a paper cup (36). The first, third and fourth activities were scored in two categories, motor fluency and originality, while second activity assessed imagination. Motor fluency is determined as the ability to create different, alternative movement patterns and was scored by the total number of ways and combinations of movements the child invented. Motor originality is determined by the ability to produce novel, unique, and unusual ways of movement and was scored by comparing the child's responses with a reference list based on the statistical infrequency of the responses, after which points were awarded accordingly. Imagination is defined by the ability to imagine, empathize, fantasize, and assume unaccustomed roles and was assessed on a five-point rating scale (from 1 = no movement to 5 = excellent imitation) for each fiction situation.

All scoring was conducted in accordance with the original manual (36). Overall testing time ranged between 10- and 30-min per child. The reliability coefficients for the individual activities are 0.71 for the first activity, 0.79 for the second activity, 0.67 for the third activity, and 0.58 for the fourth activity. The overall reliability coefficient for the Torrance TCAM test is 0.84 (36).

Motor fitness assessment

Participants' motor fitness level was assessed using selected tests from the Eurofit battery (Council of Europe, Committee for the Development of Sport, Strasbourg, France) (62). These included a 20-meter endurance Shuttle Run to evaluate cardiorespiratory endurance, and a 10 × 5-meter Shuttle Run (SHR) to assess running speed and agility. In addition, the Piorkowski test was used to evaluate eye-hand coordination, reaction speed and movements precision.

In the 20-meter Shuttle Run test, participants were asked to stand behind the starting line facing the second line, which was 20 m away. When a special sound signal was heard, they started running. Participants continued running between the two lines turning when the recorded signal sounded. They needed to run at a pace that ensured they reached the end of a 20-meter section when they heard the signal to change direction. Their task was to maintain the pace set by the sound signal for as long as possible. The test ended when a participant could no longer keep up with the signals or feels too tired to continue. The score was determined as a number of levels completed, based on the number of 20-meter shuttles reached before the participant was unable to keep up with the recorded sound signal. The final score was the last level completed (62).

The 10 × 5 m SHR test involved participants running back and forth over a 5-meter distance, changing direction 10 times, to measure speed and agility. The score was based on the time it took for the participant to complete this task (62).

The Piorkowski test was conducted using the Piorkowski apparatus (AP) (Psychology laboratory "Driver," Ustrzyki Dolne, Poland). The apparatus has 10 buttons arranged in one row with a LED above each button that lights up to indicate which button to press. Only one LED lights up at a time. The task was for the participant to press each subsequent button indicated by the apparatus using both hands. The right hand was to be used for buttons on the right side, and the left hand for buttons on the left side. The device does not wait for the correct press but sets its own pace, and the participant were required to hit the button correctly as many times as possible. In this study, the parameters included a 60-s period with a stimulus presentation frequency of 30 pulses. The outcome was measured by the number of correct responses. Thorough instructions were always provided before the examination. The test was previously conducted under Polish conditions in studies by Tomczak et al. (63) and Merksiz et al. (64) and proved reliable.

Intervention program

The pre-test, which was conducted between January and February 2024, utilized the aforementioned testing methods. Following this assessment, entire classes of participants were randomly divided into three groups: two experimental groups (EG1 and EG2) and one control group (CG). Randomization was performed at the class level to ensure that all children within a class received the same intervention. The intervention program commenced in March and was implemented over eight weeks under natural school conditions in two experimental groups. The experimental factor was a specially designed PA program implemented into PE classes. This program, based on plays and games using the Eduball set, aimed to stimulate children's creativity.

In accordance with the Polish PE curriculum for second grade, pupils are scheduled to have three PE classes per week. In this study, EG1 participated in the Eduball intervention program once per week, alongside two traditional PE classes. EG2 engaged in the Eduball program twice a week, with one traditional PE class. Meanwhile, CG followed the standard curriculum, receiving only traditional three PE classes without Eduball intervention. The purpose of creating two experimental groups was to compare the effect of the intervention program based on the frequency of Eduball sessions.

A total of 8 Eduball-integrated PE classes were conducted for EG1, while EG2 received 16 such classes. Each 45 min class was structured into three parts: an introduction (5 min), a main part (35 min), and a concluding synopsis (5 min). The main goal of each class was to stimulate pupils' creativity through movement-based problem-solving tasks using the Eduball method. These activities encouraged children to: create new movement patterns, generate multiple effective strategies for completing tasks, solve problem-based scenarios that combined movement and cognitive challenges in a nonlinear way. The mathematical numbers placed on the educational balls allowed for creation of tasks that stimulated creative thinking in solving mathematical operations, while the alphabet letters on the Eduball enabled plays and games that fostered creative thinking in word formation, sentence construction, and storytelling. Additionally, the five-color design

of the balls enhanced the creation of tasks that promoted children's creativity.

The scenarios for PE classes using Eduball were developed based on an established pool of Eduball examples [(46) (PDF available online), (65)]. Furthermore, some sample scenarios were presented in recent open-access Eduball studies (47, 51). These sample scenarios provide a detailed description of common Eduball-based activities, including their objectives and the specific skills they are aimed to develop. In this intervention, some scenarios were used in their original form, while others were modified to align with specific goals of this study.

Here are examples of some scenarios used in Eduball-intervention PE classes:

Scenario 1: The pupils are divided into four teams. They gather in four corners of the gymnasium. The balls are spread in the center circle of the basketball court. The pupils have to form any creation using of the specific features of the Eduballs (their colors, letters, numbers, mathematical signs, etc.). To move the necessary balls to their corners, the pupils need to cooperate. They may pass the ball from one to another, but they cannot move while carrying them. Only one ball at a time can be transported. They have five minutes to complete the task. At the end of the game, each team presents their work to the other teams, which try to determine what the creations are (65).

Scenario 2: The pupils are divided into two teams (yellow and green team). Each team gets a ball with the number "8" and places it on a rubber ring. Their task is to form as many mathematical operations involving addition, subtraction, multiplication and division as they can and resulting in "8." During the activity, the pupils are not allowed to carry the balls with their hands. They have 5 min to complete the task. Then, the teacher checks the correctness of the equations (65).

Scenario 3: Each pupil stands in the center circle of the basketball court. The teacher stands next to the balls in five colors on the rubber rings in front of students. When the teacher lifts a certain ball, the pupils have to behave and move according to the weather conditions, e.g., yellow—sun, blue—rain, green—wind, red—storm, orange—sunset. Variation: The pupils are divided into 5 groups. Each team has to announce and present the weather forecast using the balls in all the colors (65).

Scenario 4: The pupils have green or yellow balls. They move to the rhythm of the music and play with their ball. When the music is turned off, they form three-to-four-person groups. They have to create and write a sentence consisting of 3 or 4 words beginning with the letters on the balls, e.g., the pupils have "s," "b," "h" and "t," and they might form the sentence "She has two brothers" or "Ben sold this house" (65).

Scenario 5: The pupils are divided into four teams. The balls (fruits and vegetables) are spread all over the gym. The pupil's task is to make a fruit or vegetable salad. Each team moves as one body, holding hands, and collects as many balls as they can gather to their base. Then, they count the balls and state their salad ingredients, e.g., "Our fruit salad consists of 7 avocados, 3 strawberries, 1 plum, 1 orange and 12 bananas," "The ingredients of our vegetable salad are 2 carrots, 2 eggplants, 11 cucumbers, 1 tomato and 8 onions" (65).

After the eight-weeks intervention program, a post-test was conducted for all groups in May. The data of participants of

experimental groups who attended less than 60% of intervention program (fewer than 5 of 8 sessions in EG1 or fewer than 10 of 16 sessions in EG2) were excluded and not considered in the analysis of the experimental results. All Eduball sessions were conducted by previously trained PE teachers under the direct supervision of the project coordinator, and each session followed standardized, carefully designed scenarios. This approach ensured consistent delivery of the intervention maintained methodological rigor, and minimized variability, thereby guaranteeing the fidelity and integrity of the intervention throughout the study.

Statistical analysis

Statistical analyses were performed for creativity and motor fitness variables. After assessing normality using the Shapiro-Wilk test, the lack of normality of distribution was noticed. Therefore, to compare differences in creativity and motor fitness variables between experimental and control groups the one-way ANOVA on ranks (Kruskal-Wallis's H-test) was employed. The comparison of pre- and post-test results within the experimental and control groups was conducted using the Wilcoxon signed-rank test. The effect size was calculated for each statistical test used and interpreted based on the corresponding scale: Kruskal-Wallis's test: Small - 0.01, Medium - 0.06; Large - 0.14; Wilcoxon signed-rank test: Small - 0.1, Medium - 0.3, Large - 0.5 (66–68).

For statistical testing, Statistica 13.3. was used (Statsoft, Kraków, Poland), and statistical significance was set at $p < 0.05$.

Results

A comparison of creativity variables between the experimental and control groups at pre- and post-test is presented in Table 2. At the pre-test no statistically significant differences were found among the three groups in any of the creativity variables (TCT-DP score, TCAM: fluency, originality, imagination). However, statistically significant differences were observed in the post-test for the following parameters: TCT-DP test—significant differences were found between EG1 and EG2, and between CG and EG2, both in favor of EG2 ($p < 0.01$, effect size = 0.09); imagination (TCAM)—a significant difference was observed between EG1 and EG2, favoring EG2 ($p < 0.01$, effect size = 0.05). The within-group comparison of pre- and post-test results (Table 2) showed statistically significant improvement in fluency (TCAM) for all groups (effect size = 0.4). Imagination (TCAM) also improved significantly in all groups, with the largest improvement observed in EG2 (effect size = 0.7), while gains for EG1 and CG were comparable (effect size = 0.5). No significant changes were observed in TCT-DP and originality (TCAM) within EG1 or EG2; however, the effect size for TCT-DP in EG2 was 0.3, indicating a moderate practical improvement despite the lack of statistical significance. In contrast, CG showed statistically significant negative changes in TCT-DP (effect size = 0.2) and originality (effect size = 0.3).

A comparison of motor fitness variables between the experimental and control groups at pre- and post-test is presented in Table 3. At the pre-test no statistically significant differences were observed among the three groups in any motor fitness variable (20 m Shuttle Run,

TABLE 2 Comparison of median test scores for creativity variables between experimental and control groups ($n = 173$) at pre- and post-test.

Variables		EG1 ($n = 61$) 1	EG2 ($n = 39$) 2	CG ($n = 73$) 3	Between-group p values			η^2
					1 vs.2	1 vs.3	2 vs.3	
TCT-DP (pts)	Pre-test Mdn (Q1–Q3)	21 (16–30)	27 (16–34)	22 (16–29)	ns	ns	ns	0
	Post-test Mdn (Q1–Q3)	21 (16–30)	30 (21–27)	19 (15–25)	<0.01	ns	<0.01	0.09
	p	ns	ns	<0.05	–			
	r	0	0.3	0.2				
TCAM, Fluency (pts)	Pre-test Mdn (Q1–Q3)	22 (18–31)	22 (15–30)	21 (16–27)	ns	ns	ns	0
	Post-test Mdn (Q1–Q3)	27 (22–37)	25 (21–47)	25 (18–35)	ns	ns	ns	0
	p	<0.05	<0.05	<0.05	–			
	r	0.4	0.4	0.4				
TCAM, Originality (pts)	Pre-test Mdn (Q1–Q3)	22 (17–35)	25 (14–35)	24 (14–35)	ns	ns	ns	0
	Post-test Mdn (Q1–Q3)	25 (15–33)	23 (16–35)	18 (14–30)	ns	ns	ns	0
	p	ns	ns	<0.05	–			
	r	0.1	0.1	0.3				
TCAM, Imagination (pts)	Pre-test Mdn (Q1–Q3)	18 (15–21)	19 (15–22)	19 (15–22)	ns	ns	ns	0
	Post-test Mdn (Q1–Q3)	21 (19–24)	26 (21–30)	22 (19–27)	<0.01	ns	ns	0.05
	p	<0.05	<0.05	<0.05	–			
	r	0.5	0.7	0.5				

$p < 0.05$; Mdn, median; pts, points; TCT-DP, Test for Creative Thinking-Drawing Production; TCAM, Torrance's "Thinking Creatively in Action and Movement" test; EG1, Experimental Group 1; EG2, Experimental Group 2; CG, Control Group. η^2 (effect size - Wilcoxon test): Small - 0.01, Medium - 0.06, Large - 0.14 and above.
 r (effect size - ANOVA): Small - 0.1, Medium - 0.3, Large - 0.5 and above.

10 × 5 m SHR, AP test). Similarly, post-test comparison showed no significant differences between groups in 20 m Shuttle Run and 10 × 5 m SHR tests. However, post-test comparison revealed a statistically significant difference in the AP test between EG1 and EG2, and between CG and EG2, both in favor of EG2 ($p < 0.001$, effect size = 0.09). Within-group comparison (Table 3) indicated statistically significant differences in all motor fitness parameters across all the three groups indicating an improvement in post-test. The largest improvement was observed in the AP test for EG2 (effect size = 0.7), while gains for EG1 and CG were comparable (effect size = 0.4).

Discussion

The aim of this study was to examine the impact of an eight-week educational intervention program based on the Eduball method in PE classes on the development of cognitive creativity, motor creativity, and motor fitness in second-grade pupils. The findings indicated that the Eduball intervention had a positive influence, particularly on creativity-related outcomes, with some variability depending on the specific variable assessed and the frequency of the stimuli.

In terms of cognitive creativity, as measured by the TCT-DP test, the implementation of the Eduball-based activities in PE classes demonstrated a positive impact on this parameter in both experimental groups. Specifically, the findings revealed the emergence of statistically significant difference in post-test creativity score between groups, favoring EG2 (the one with more frequent stimuli). Although the within-group improvement in EG2 was not statistically significant, the effect size indicated a moderate effect, suggesting a potentially meaningful change that could reach statistical significance with a larger sample size. EG1 demonstrated a stable creativity score levels over time, while a statistically significant decrease in creativity was observed in CG. A possible explanation for the observed decline in creativity in the CG may be related to the lack of specific conditions that stimulate and support creativity. Previous research has shown that during the transition from early to middle childhood (ages 8–10), children increasingly shift from a spontaneous, pre-conventional mode of thinking toward more conventional and socially orientated responses, which may limit the expression of creativity in structured school contexts (69–71). In traditional educational settings, academic success is often associated with accuracy and rule compliance, while original responses are less encouraged (72). This tendency may suppress children's willingness to take risks and generate novel ideas,

TABLE 3 Comparison of median test scores for motor fitness variables between experimental and control groups (n = 173) at pre- and post-test.

Variables		EG1 (n = 61) 1	EG2 (n = 39) 2	CG (n = 73) 3	Between-group p values			η^2
					1 vs.2	1 vs.3	2 vs.3	
20 m Shuttle Run (lvl)	Pre-test Mdn (Q1–Q3)	3 (2.4–4.1)	2.5 (2.2–4.1)	3 (2.2–3.6)	ns	ns	ns	0
	Post-test Mdn (Q1–Q3)	3.4 (2.4–4.5)	3.5 (2.7–4.2)	3.3 (2.4–4.7)	ns	ns	ns	0
	p	<0.05	<0.05	<0.05	–			
	r	0.3	0.6	0.6				
10 × 5 m SHR (s)	Pre-test Mdn (Q1–Q3)	24.4 (23.2–26.6)	25.1 (23.9–26.2)	25.2 (23.3–27.1)	ns	ns	ns	0
	Post-test Mdn (Q1–Q3)	23.1 (21.9–25.0)	23.7 (22.3–26.1)	24.2 (21.8–25.3)	ns	ns	ns	0
	p	<0.05	<0.05	<0.05	–			
	r	0.4	0.6	0.5				
PA (no/30 pulses)	Pre-test Mdn (Q1–Q3)	25 (21–27)	26 (23–28)	25 (22–27)	ns	ns	ns	0
	Post-test Mdn (Q1–Q3)	26 (24–28)	28 (27–30)	27 (25–28)	<0.01	ns	<0.01	0.09
	p	<0.05	<0.05	<0.05	–			
	r	0.4	0.6	0.4				

$p < 0.05$; Mdn, median; lvl, level; s, seconds; no, number; SHR, 10 × 5 m shuttle run; PA, Piorowski apparatus; EG1, Experimental Group 1; EG2, Experimental Group 2; CG, Control Group. η^2 (effect size - Wilcoxon test): Small - 0.01, Medium - 0.06, Large - 0.14 and above. r (effect size - ANOVA): Small - 0.1, Medium - 0.3, Large - 0.5 and above.

even if their creative potential remains intact. Moreover, as school demands increase, children may prioritize strategies that emphasize correct answer over exploratory thinking, which can reduce observable creativity scores (73). Thus, the decline in creativity observed in CG may reflect the combined influence of developmental trends and the convergent orientation of traditional schooling. At the same time, the present results can also be interpreted in line with the “if you do not use it, you lose it” principle: children who did not engage in systematic creativity-promoting activities (as in the Eduball intervention) showed a measurable decline in creativity over time. This interpretation is consistent with previous findings emphasizing the importance of regular stimulation and practice in maintaining and enhancing creative abilities (56, 74). The observed pattern—decline in CG, stability in EG1, and improvement in EG2—suggests that exposure to enhanced creativity-oriented challenges is definitely required if the cultivation of the creative potential of children under development is a desirable educational objective. The dose–response relationship suggests that, to prevent loss of creative potential during this critical period, children must receive at least minimum dosage required for stability, while enhanced exposure produces meaningful improvements. In line with previous studies by Richard et al. (11), Bournelli and Mountakis (75) these findings demonstrate that creativity requires active cultivation during this sensitive developmental period to prevent natural decline, and creativity-oriented movement activities like the Eduball method represent an effective means of achieving this objective. Taken together, these findings underscore the importance of systematically cultivating creativity, while highlighting the added value of higher intervention frequency, as evidenced by the favorable outcomes in EG2.

Regarding motor creativity, the TCAM test revealed varied effects across different motor creativity variables. In this study, pupils from CG, who participated in traditional PE classes, as well as those from EG1 and EG2, who took part in an eight-week Eduball intervention program, demonstrated similar improvements in motor fluency. This finding suggests that motor fluency at this age has a natural tendency to develop, as previously reported by Domínguez et al. (76). The Eduball intervention did not produce an additional effect within the eight-week period. In contrast, Richard et al. (11), in a study examining the impact of a nonlinear pedagogy-based PE program on the motor creativity of nine-year-old children over a three-month intervention period (10 sessions), reported that while there were no significant differences in motor fluency between the groups in the pre-test, a statistically significant difference emerged in the post-test, favoring the experimental group. Similarly, a study by Ourda et al. (77), investigating the effect of motor creativity intervention conducted over one academic semester with 4- to 5-year-old children (20 sessions), showed a significant increase in motor fluency in the experimental group while no statistically significant change was observed in the control group. These discrepancies may be explained by differences in the nature of the intervention programs, as the cited studies may have included activities more directly targeting motor fluency, whereas the Eduball program was designed to stimulate creativity through a broader set of cognitive-motor challenges. Additionally, differences in intervention duration may also account for these divergent results. It therefore seems that enhancing motor fluency through the Eduball intervention may require a period longer than eight weeks to achieve significant improvements. Moreover, fluency, although frequently included in creativity assessments, has

been described as the most challenging and the least strongly associated with creativity (compared to, for example, originality) and is not recommended as a standalone indicator (78). These considerations help explain the absence of additional intervention effects on fluency despite improvements across all groups.

In contrast, motor originality variable in this study demonstrated a statistically significant decrease in CG, while the levels in both experimental groups remained unchanged. However, unlike the present study, the research of Asadi et al. (79), which examined the effect of nonlinear pedagogy on the motor creativity of 7-year-old children over a six-week intervention conducted three times per week, reported no significant changes in the control group, but a significant increase in the experimental group. Research by Domínguez et al. (76) indicated that motor originality naturally increases between the ages of 6 and 8, but tends to decline between the ages of 8 and 10. In this context, the observed decrease in motor originality in the CG in the current study with its absence in Asadi et al. (79), may be attributed to these age-related developmental changes. Thus, the implementation of nonlinear pedagogy in Asadi's study contributed to an additional enhancement of motor originality, complementing its natural developmental trend at this age. In contrast, the Eduball method in our study acted as a protective factor, preventing the age-related decline in motor originality and helping to maintain its level in both experimental groups. Notably, in this case, the frequency of Eduball classes per week did not appear to significantly impact the outcomes, suggesting that even a lower frequency of Eduball PE classes may be effective in preserving motor originality during this critical developmental stage in early-age school children. The similar stability of the results in EG1 and EG2 suggests that even one Eduball session per week may be sufficient to prevent a decline in this creativity parameter. However, it may not necessarily lead to an increase in motor originality over a short period, and a longer implementation period may be required to achieve more pronounced effects. Additionally, the differences across studies highlight certain discrepancies in findings, which may be explained not only developmental factors, but also by differences in assessment tools and scoring procedure. For example, variations between Bertsch's test (80), used in Asadi et al. (79), and the TCAM, used in the present study, involve differences in tasks, originality scoring criteria, and potentially outdated scoring norms.

Motor imagination, another variable of motor creativity, demonstrated statistically significant improvements across all three groups. However, the effect size for EG1 and CG was identical, while for EG2 it was notably higher. This finding aligns with the research by Domínguez et al. (76), who identified a natural tendency for the development of motor imagination between the ages of 8 and 10 years. This developmental trend was observed across all three groups in the present study. However, the additional improvement observed in EG2 suggests that the Eduball method may have had a positive impact on enhancing motor imagination in this group. Similarly, a study by Alper and Ulutaş (81), which examined the impact of a 12-week creative movement program (conducted twice weekly) on the creativity of 5-6-year-old children, revealed a statistically significant difference in post-test motor imagination scores between the experimental and control group, favoring the experimental group. Comparable results were reported in a study by Ourda et al. (77), which demonstrated a statistically significant difference in motor imagination between the experimental and control groups among 4- to 5-year-old children after 20 sessions of a motor creativity intervention program.

Previous studies investigating the effectiveness of various methods for developing motor creativity allow only limited comparison of changes in motor imagination for the two main reasons. First, some studies (11, 38, 39) employed different tests for motor creativity assessment that did not specifically measure motor imagination. Second, although other researchers (12, 77, 81, 82) employed the same test (TCAM), they focused on preschool-aged children (ages 3 to 6), which is critical factor and does not allow for a direct comparison. As a result, the specific impact of the Eduball method on motor imagination in older children cannot be directly contrasted against the other methods. From this perspective, the findings of the present study regarding motor imagination in 8- to 9-year-olds may be considered both novel and valuable for future research. At the same time, the criterion of imagination in TCAM should be interpreted with caution, as its relationship to creativity is debated and findings remain inconsistent (83, 84). Unlike fluency and originality, imagination is assessed only in TCAM among the main tests of motor creativity, which highlights both its potential value and its conceptual limitations. Therefore, the results on motor imagination should be regarded as complementary to other indicators of creative potential rather than as standalone evidence. Nevertheless, our findings confirm the positive impact of Eduball-based PE classes on children's motor imagination. Furthermore, the significantly higher effect size in EG2, along with the statistically significant difference in post-test results between EG1 and EG2 in favor of EG2, emphasizes the importance of intervention frequency, suggesting that more frequent sessions resulted in a more positive effect.

Regarding physical fitness, results from 20 m Shuttle Run and 10 × 5-m Shuttle Run tests showed no statistically significant differences in post-test results among the three groups. However, all groups demonstrated significant improvements in these parameters, indicating that both the Eduball method and traditional PE program had a similar effect on the development of children's physical fitness. These findings are consistent with studies of Rokita et al. (42, 85), Cichy et al. (86, 87), Pham et al. (88), which showed that PE classes using of Eduball enhance pupils' motor fitness to a comparable extend as traditional PE classes. As for the results of the Piorowski test, the study revealed a statistically significant difference in post-test in favor of EG2. This finding is in line with previous research of Cichy et al. (48), which demonstrated a more positive impact of Eduball activities on eye-hand coordination compared to traditional PE classes. Furthermore, the statistically significant difference in post-test outcomes between EG1 and EG2, favoring EG2 yet again emphasizes the impact of intervention program frequency, indicating that more frequent sessions had a more pronounced positive effect.

There are several strengths and limitations of this study that should be acknowledged when interpreting its outcomes. First, the sample size of EG2 may have limited the statistical power to detect significant effect—particularly in cognitive creativity, where moderate effect was observed but did not reach statistical significance. Second, the intervention lasted only eight weeks. Previous research suggest that longer intervention may be required to observe significant improvements in motor fluency and originality. Third, participants' absences from some intervention sessions could have influenced the outcomes, despite applying a 60% attendance threshold for inclusion in the analysis. Fourth, the findings are specific to children aged 8–9 years, which limits the generalizability of the results, especially during this critical stage of creativity development. Fifth, the

assessment of creativity was conducted by a single qualified psychologist, with the final TCT-DP result calculated as the sum of points obtained across all criteria. While appropriate blinding procedures were implemented, the single-rater approach may affect assessment reliability. Sixth, although the TCAM test is one of the most widely used measures of motor creativity in children, it presents several notable limitations. In particular, some of its criteria—such as fluency and imagination—have been criticized for their conceptual ambiguity and for their weaker or inconsistent associations with creativity (78, 83, 84). Moreover, TCAM is the only one of the most commonly used motor creativity tests that includes imagination, which makes it both unique and more difficult to compare across studies. Recent literature has highlighted these issues (32) and has called for the development of alternative or complementary approaches to assessing motor creativity (89). Thus, while TCAM remains a popular and practical tool, its limitations should be considered when interpreting the present findings. Finally, the study did not include a follow-up assessment to evaluate the sustainability of the observed improvements over time.

Conclusion

This study showed that the implementation of the Eduball method in PE classes in second grade pupils had a positive, dose-dependent impact on creativity parameters. Specifically, the enhanced Eduball program (EG2) contributed to improvements in cognitive creativity and preserved motor originality, while the basic program (EG1) helped maintain stability in these parameters. In contrast, the control group (CG) without intervention showed decline in both cognitive creativity and motor originality. Despite the fact that Eduball groups did not demonstrate significant improvements in motor originality, though they avoided the decline observed in the CG. Motor imagination increased in all groups, with EG1 and CG showing comparable gains, while improvements observed in EG2 were higher. Although the Eduball intervention program did not produce additional benefits in motor fluency compared to traditional PE (all groups improved equally), it prevented the deterioration seen in other creativity parameters, suggesting that active creativity-oriented interventions are necessary during this sensitive developmental period. Regarding physical fitness, overall gains were comparable between Eduball and traditional PE; however, eye-hand coordination improved more in EG2, underscoring the added value of higher intervention frequency. Taken together, these findings highlight the potential of the Eduball method as a pedagogical instrument for fostering children's creative potential in school settings.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Local Bioethics Committee of The Karol Marcinkowski University of Medical

Science in Poznan (decision number 400/23 of 11 May 2023). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

MK: Funding acquisition, Project administration, Writing – original draft, Data curation, Writing – review & editing, Conceptualization, Investigation, Methodology. LB: Investigation, Methodology, Writing – review & editing. AK: Writing – review & editing, Investigation. JK: Writing – review & editing, Investigation. ME: Investigation, Writing – review & editing. DA: Investigation, Writing – review & editing. MB: Conceptualization, Methodology, Writing – review & editing, Investigation, Supervision, Funding acquisition.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ATTACHMENT 3. EXEMPLARY EDUBALL LESSON SCENARIO


Developing Cognitive and Motor Creativity through Eduball Activities



Main goal: To develop pupils' cognitive and motor creativity through movement-based activities integrating academic with physical activity. To enhance coordination, spatial awareness and motor skills.



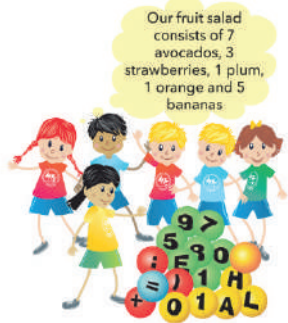
Additional goals: To enhance teamwork, communication, and enjoyment in learning.

Expected outcomes:

- Improvement of cognitive and motor creativity through problem-solving and movement expression.
- Better integration of cognitive and physical activity.
- Development of cooperation and social interaction.
- Increased engagement, imagination, and emotional well-being.
- Improvement of motor fitness.

Content	Duration	Specific goals for creativity objectives
I. Introduction	5 min	
<p>1. Pupils stand in the center circle line. Greeting, conducting organizational activities, and introducing the participants to the topic of the lesson.</p> <p>2. Warm-up “Weather and Movement” Pupils stand in the center circle. The teacher lifts balls of different colors; pupils move according to the “weather condition”:</p> <ul style="list-style-type: none"> • Yellow – sunshine (jumps, big open movements), • Blue – rain (small, gentle steps), • Green – wind (twisting, turning), • Red – storm (running freely), • Orange – sunset (slow stretching). 	<p>2 min</p> <p>3 min</p>	<p>Create a positive atmosphere, present the rules, and safety principles, motivate pupils for active participation.</p> <p>Activate motor imagination and physical readiness; connect colors with environmental concepts; support associative thinking.</p>
II. Main Part	35 min	
<p>1. “Ball Hunters”</p> <p>Balls are scattered in the gym. Pupils sit in a central circle. On the signal, they collect as many balls as possible. Then they count them and add the numbers. Next task is to collect balls in pairs or small</p>	7 min	Encourage original movement pattern; cooperation; stimulate fast decision-making and simple math reasoning.

<p>groups; pupils sum their numbers together or create equations.</p> 		
<p>2. “Creative Constructions”</p> <p>The pupils are divided into four teams. They gather in four corners of the gymnasium. The balls are spread in the center circle of the basketball court. The pupils have to form any creation using of the specific features of the Eduballs (their colors, letters, numbers, mathematical signs, etc.). To move the necessary balls to their corners, the pupils need to cooperate. They may pass the ball from one to another; but they cannot move while carrying them. Only one ball at a time can be transported. They have five minutes to complete the task. At the end of the game, each team presents their work to the other teams, which try to determine what the creations are.</p> 	<p>7 min</p>	<p>Promote motor originality and imagination, cognitive creativity, and teamwork; support planning and spatial awareness.</p>
<p>3. “Math Builders”</p> <p>The pupils are divided into two teams (yellow and green team). Each team gets a ball with the number “8” and places it on a rubber ring. Their task is to form as many mathematical operations involving addition, subtraction, multiplication and division as they can and resulting in “8”. During the activity, the pupils are not allowed to carry the balls with their hands. They have 5 minutes to complete the task. Then, the teacher checks the correctness of the equations.</p>	<p>7 min</p>	<p>Develop motor fluency and originality, strengthen logical reasoning and creativity in mathematics; connects motor action with abstract concepts.</p>

		
<p>4. “Language Builders”</p> <p>The pupils have green or yellow balls. They move to the rhythm of the music and play with their ball. When the music is turned off, they form three-to-four-person groups. They have to create and write a sentence consisting of 3 or 4 words beginning with the letters on the balls, e.g., the pupils have “s”, “b”, “h” and “t”, and they might form the sentence “She has two brothers” or “Ben sold this house”.</p> 	7 min	Develop linguistic creativity, cooperation, and spontaneous expression through movement and play.
<p>5. “Fruit and Vegetable Salad”</p> <p>Balls representing fruits and vegetables are scattered around. The pupil’s task is to make a fruit or vegetable salad. Each team moves as one body, holding hands, and collects as many balls as they can gather to their base. Then, they count the balls and state their salad ingredients, e.g., “Our fruit salad consists of 7 avocados, 3 strawberries, 1 plum, 1 orange and 12 bananas”, “The ingredients of our vegetable salad are 2 carrots, 2 eggplants, 11 cucumbers, 1 tomato and 8 onions”. Variation: Competition for the “healthiest” or most diverse salad.</p> 	7 min	Promote motor originality and fluency; support categorization, group decision-making, and social communication; develop coordination.

III. Conclusion	5 min	
1. "Relaxing Massage with Eduball" Pupils sit cross-legged in a circle. Teacher plays calming music and instructs pupils to massage the back of the classmate in front using the ball: drawing shapes (circle, triangle, square) or imitating natural phenomena (raindrops, rainbow, sunshine).	3 min	Promote relaxation, motor and cognitive imagination; enhance positive emotional closure, tactile perception and empathy.
2. Lining up. Educational and organizational activities related to the conclusion of the lesson. The teacher discusses the lesson. Encouragement of independent physical activity during free time.	2 min	Summarize the main activities and outcomes, encourage reflection and independent activity in free time, ensure calm, organized ending of the lesson.

The lesson scenario presented in this attachment is based on the material contained in Rokita et al. (2018) and incorporates figures reproduced from this source (see References for full bibliographic details).