



University of Zagreb

FACULTY OF KINESIOLOGY

Petra Rajković Vuletić

**IMPROVING PHYSICAL FITNESS AND
PHYSICAL ACTIVITY THROUGH THE
ENHANCEMENT OF KNOWLEDGE AND
UNDERSTANDING AS SUBDOMAINS OF
PHYSICAL LITERACY: THE EFFECTS OF
EDUCATIONAL INTERVENTION IN
PREADOLESCENTS**

DOCTORAL THESIS

Zagreb, 2026



Sveučilište u Zagrebu

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TJELESNE AKTIVNOSTI POBOLJŠANJEM
ZNANJA I RAZUMIJEVANJA KAO
SEGMENTA TJELESNE PISMENOSTI -
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Damir Sekulić was born in 1970 in Split, Croatia. He is a Full Professor at the University of Split, Faculty of Kinesiology. After completing his undergraduate studies at the Faculty of Physical Education in Zagreb, he obtained his PhD in Kinesiology from the same institution in 2001.

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He has supervised fifteen doctoral students in Croatia and abroad. In 2017, Professor Sekulić received the National Award for Science of the Republic of Croatia.

Biography

Petra Rajković Vuletić was born in 1988 in Split, Croatia. She completed her Master's degree in 2014 at the Faculty of Kinesiology, University of Split, where she distinguished herself as the top student of her graduate generation. During her studies, she received a scholarship based on excellence, worked as a demonstrator in the courses Quantitative Methods 1 and 2, and ranked among the top five percent of students in her cohort. In 2021, she enrolled in the postgraduate doctoral study program in Kinesiology at the Faculty of Kinesiology, University of Zagreb.

Since 2020, she has been employed as a teaching assistant at the Faculty of Kinesiology, University of Split, in the field of kinesitherapy and adapted physical activity. She is actively involved in teaching and serves as the coordinator of the Kinesitherapy course at the Professional Study of the Faculty of Kinesiology in Split, as well as the Erasmus coordinator for international cooperation.

She is the author and co-author of 17 scientific papers indexed in the Web of Science and Scopus database. Her main research interests include physical activity, physical fitness, and physical literacy in preadolescents and adolescents, kinesitherapy, and physical activity among individuals with developmental disabilities, with a particular focus on individuals with Down syndrome.

She has received recognition for the best scientific paper in the field of Education, as well as recognition for the best student paper at the 32nd Summer School of Kinesiology.

She is also the recipient of an award for teaching contribution at the Faculty of Kinesiology, University of Split.

She has been actively involved in various interdisciplinary projects and institutional collaborations, including Erasmus+ funded initiatives that integrate research, education, and community engagement. Among these, she highlights her participation in the project funded by the Croatian Science Foundation titled "Physical literacy in preadolescents and younger adolescents: Effects of targeted intervention on physical activity, physical fitness, and health outcomes," which focuses on improving health and lifestyle habits of children and youth through targeted kinesiology interventions.

Most important publications:

1. **Rajkovic Vuletic, P.**, Kesic, M. G., Gilic, B., Pehar, M., Uzicanin, E., Idrizovic, K., & Sekulic, D. (2023). Evaluation of physical literacy in 9-to 11-Year-Old children: reliability and validity of two measurement tools in three southeastern European countries. *Children*, 10(11), 1722.
2. **Rajkovic Vuletic, P.**, Kesic, M. G., Gilic, B., Pehar, M., Uzicanin, E., Idrizovic, K., & Sekulic, D. (2023). Evaluation of physical literacy in 9-to 11-Year-Old children: reliability and validity of two measurement tools in three southeastern European countries. *Children*, 10(11), 1722.
3. Gilic, B., **Rajkovic Vuletic, P.**, Maras, N., Sekulic, D., & Sajber, D. (2025). Physical Activity and Body Composition Outcomes of the "Primary School as a Whole-Day School" Program in Early School-Age Children from Croatia. *Applied Sciences*, 15(23), 12728.
4. Lilic, A. S., **Rajkovic Vuletic, P.**, Pehar, M., Uzicanin, E., Zovko, I. C., Bujakovic, B., & Zenic, N. (2024). Analyzing the Associations between Physical Literacy, Physical Activity Levels, and Sedentary Behavior: Cross-sectional Study in Preadolescent Children. *Sport Mont*, 22(2).
5. Škugor, B. G., **Rajković Vuletić, P.**, & Matijašević, P. (2025). Gender variations in physical literacy and objectively and subjectively measured physical activity: cross-sectional study in elementary school students. *Kinesiologia Slovenica: scientific journal on sport*, 31(3), 67-83.
6. **Rajkovic Vuletic, P.**, Matijasevic, P., & Pavlinovic, V. (2025). Is the PAQ-C a Valid Measurement Tool for Evaluating Physical Activity Levels in Rural Children? Cross-Sectional Study in Southern Croatia. *Sport Mont*, 23(1), 85-91.

7. Sekulic, D., Volaric, T., Pehar, M., Pranjić, T., & **Rajkovic Vuletic, P.** (2025). Exploring the role of different intensities of physical activity on fitness parameters in 9–11-year-old children: a framework for potential innovation of the physical education curriculum. *Pedagogy of physical culture and sports*, 29(2), 112-122.
8. Sekulić, D., Rodek, J., & **Rajkovic Vuletic, P.** (2025). Analysis of the associations between directly measured physical activity and physical fitness in preadolescents: contextualizing the influence of urban vs. Rural living environments. *Kinesiologia Slovenica: scientific journal on sport*, 31(1), 35-51.
9. **Rajkovic Vuletic, P.**, Gilic, B., Pavlinovic, V., Matijasevic, P., & Sekulic, D. (2026). Effects of a physical-literacy-based educational intervention on physical activity and body composition in preadolescent children: A school-based controlled trial. *Sports*, 14(2)
10. **Rajković Vuletić, P.**, Pranjić, T., Gilić Škugor, B., Lešnik, B., Sekulić, D., & Šajber, D. (2026). Physical literacy-focused education improves fitness markers in preadolescents: Implications for school-based health promotion. *Healthcare*, 14(5), 695.
11. Sekulic, D., Pranjić, T., Cerkez Zovko, I., Corluka, M., & **Rajkovic Vuletic, P.** (2026). Examining Qualitative Changes in Physical Fitness and Body Composition in a School-Based Physical Literacy Intervention: Methodological and Practical Considerations. *Sport Mont*, 24(1), 149-158.
12. **Rajkovic Vuletic, P.**, Geets-Kesic, M., Jurcev-Savicevic, A., Nurjanah, N., & Gilic, B. (2025). Metabolic, Hematological, and Functional Health in Adults with Down Syndrome and Significance of Parental Health Literacy: A Cross-Sectional Study. *Healthcare*, 13(10), 1212
13. Matijašević, P., & **Rajković Vuletić, P.** (2025). Relationship between injuries and motivation in recreational runners. *Journal of kinesiology and exercise sciences*, 35(110), 33-39.
14. Mudrinic, L., Musa, M., Metikos, B., **Rajkovic Vuletic, P.** & Sekulic, D. (2025). Rethinking sociodemographic predictors of physical literacy and health literacy in older females. *Sport Mont*, 23(2), 79-86.
15. Sunda, M., Gilic, B., **Rajkovic Vuletic, P.**, Pavlinovic, V., & Zenic, N. (2023). Mediating effects of the COVID-19 pandemic on the associations between physical activity and physical fitness; cross-sectional study among high school adolescents. *Journal of functional morphology and kinesiology*, 8(3), 131.
16. . Pooryamanesh, Lale; Kondrič, Miran; Rajković Vuletić, Petra; Blažević, Mateo; Daneshmandi, Hassan (2024). Static alignment of the upper limb and performance of athletes with spinal cord injuries. *Montenegrin Journal of Sports Science and Medicine*, 13(1); 81-85.
17. Šitić, K., **Rajković Vuletić, P.**, & Prižmić, G. (2018). Treating Posterior Cruciate Ligament Injury. *Indian journal of applied research*, 8(10), 71-72.

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Abstract

The concept of physical literacy (PL) represents a holistic framework that integrates motor competence, motivation, self-confidence, as well as knowledge and understanding related to physical activity (PA). Despite the growing interest in PA, existing research has yet to provide clear and consistent evidence regarding the effectiveness of interventions aimed at its development, particularly in relation to PA and physical fitness (PF) in children. Accordingly, the objectives of this dissertation were: (i) to determine the validity and reliability of the Croatian version of PL assessment questionnaires in preadolescents; (ii) to evaluate the reliability and validity of the Fitnessgram battery for assessing PF in Croatian preadolescents; (iii) to examine the relationships among PF, PA, and PL in this population; and (iv) to assess the effects of a specially designed PL-based intervention, implemented within the physical education (PE) curriculum, on PA, PF, and PL in preadolescents.

The empirical component of the dissertation is based on five original scientific studies conducted on a sample of children aged 9 to 11 years. The research primarily included participants from Croatia, with partial inclusion of children from other Southeast European countries. PL was assessed using the PLAYself and CAPL-2 questionnaires, which address the affective and cognitive domains of the construct. PF was evaluated using the Fitnessgram test battery, encompassing components such as aerobic endurance, muscular strength and endurance, flexibility, and body composition. PA was measured using a combination of objective methods (accelerometers) and subjective instruments (PAQ-C questionnaire). The PL-based intervention was implemented over a 12-week period as an integral part of PE classes, utilizing specially developed educational materials aimed at enhancing knowledge, motivation, and understanding of PA. The study employed an experimental design with a control group, including baseline (September), post-intervention (December), and retention (May) measurements.

The PLAYself questionnaire demonstrated satisfactory reliability and validity, whereas weaker psychometric properties were observed for the CAPL-2, likely due to its greater complexity and respondent burden. The Fitnessgram battery proved to be a reliable and valid tool for assessing PF. Significant intervention effects were observed for objectively measured PA, as the experimental group maintained their PA levels throughout the school year, while the control group exhibited a decline, consistent with known seasonal and school-related trends. Additionally, sedentary behavior did not increase in the experimental group, unlike in the control group. In contrast, subjective measures did not reveal significant changes, which may be attributed to inherent limitations such as recall bias, social desirability, and children's limited ability to accurately self-assess their activity levels.

The intervention produced selective improvements in PF, particularly in repetitive abdominal strength and jumping power. However, no significant changes were observed in aerobic endurance, flexibility, or body composition. These findings may be explained by the predominant influence of nutrition, the relatively short duration of the intervention, and developmental characteristics specific to this age group. Furthermore, no significant effects were found in the affective and cognitive domains of PL, which may reflect limitations associated with self-report measures.

Importantly, the qualitative component of the dissertation suggests that the PL-based intervention influenced not only isolated physical abilities but also the integration of multiple components of physical development, which is essential for long-term health and functional outcomes.

In conclusion, the findings indicate that a PL-based intervention can have a significant positive effect on maintaining PA levels and improving selected components of PF in children. However, achieving comprehensive and sustained outcomes likely requires longer intervention duration, increased volume and intensity of activities, and the inclusion of additional influencing factors such as nutrition and family environment.

Sažetak

Koncept tjelesne pismenosti (TP) predstavlja holistički pristup koji integrira motoričku kompetenciju, motivaciju, samopouzdanje te znanje i razumijevanje vezano uz tjelesnu aktivnost (TA). Unatoč rastućem interesu za TP, dosadašnja istraživanja nisu pružila jednoznačne odgovore o učinkovitosti intervencija usmjerenih na njezin razvoj, osobito u odnosu na TA i tjelesni fitnes (TF) djece.

Ciljevi ove disertacije bili su višestruki: (i) utvrditi valjanost i pouzdanost hrvatske verzije upitnika za procjenu TP (TP-upitnici) kod predadolescenata, (ii) utvrditi pouzdanost i valjanost Fitnessgram baterije u procjeni stanja TF kod predadolescenata iz Hrvatske, (iii) utvrditi povezanosti između TF, TA i TP kod predadolescenata, (iv) utvrditi učinke posebno osmišljene intervencije TP provedene kao dio kurikulumu TZK (intervencija temeljena na TP) na TA, TF i TP kod predadolescenata.

Empirijski dio disertacije temelji se na pet originalnih znanstvenih istraživanja provedenih na uzorku djece u dobi od 9 do 11 godina. Istraživanja su uključivala sudionike iz Hrvatske, a dijelom i iz drugih zemalja jugoistočne Europe. U svrhu procjene TP korišteni su upitnici PLAYself i CAPL-2, pri čemu su obuhvaćene afektivna i kognitivna domena ovog koncepta. TF je procijenjen pomoću Fitnessgram baterije testova koja obuhvaća različite komponente, uključujući aerobnu izdržljivost, mišićnu snagu i izdržljivost, fleksibilnost te sastav tijela. Razina TA procijenjena je kombinacijom objektivnih metoda (akcelerometri) i subjektivnih metoda (PAQ-C upitnik), čime je omogućena sveobuhvatna analiza.

Intervencija temeljena na TP provedena je tijekom 12 tjedana kao sastavni dio nastave, pri čemu su korišteni edukativni materijali i strukturirane aktivnosti usmjerene na razvoj znanja, motivacije i razumijevanja TA. Istraživanje je provedeno prema eksperimentalnom dizajnu s kontrolnom skupinom, uz primjenu inicijalnih, finalnih i retencijskih mjerenja, čime je omogućeno praćenje ne samo neposrednih, već i dugoročnijih učinaka intervencije.

Rezultati istraživanja pokazali su da PLAYself upitnik ima zadovoljavajuću pouzdanost i valjanost u populaciji djece predadolescentske dobi, dok CAPL-2 pokazuje slabije metrijske karakteristike, vjerojatno zbog veće kompleksnosti i zahtjevnosti pitanja. Fitnessgram baterija potvrđena je kao pouzdan i validan instrument za procjenu TF, čime je dodatno potvrđena njezina primjenjivost u školskim uvjetima.

U pogledu TA, rezultati dobiveni objektivnim mjerenjima pokazali su da intervencija ima pozitivan učinak, budući da je u eksperimentalnoj skupini održana razina TA tijekom školske godine, dok je u kontrolnoj skupini zabilježen njen pad, što je u skladu s poznatim sezonskim i školskim utjecajima. Također, u eksperimentalnoj skupini nije došlo do povećanja sedentarnog ponašanja, za razliku od kontrolne skupine. Suprotno tome, rezultati dobiveni subjektivnim metodama nisu pokazali značajne promjene, što se može objasniti ograničenjima upitnika, uključujući pristranost prisjećanja, socijalno poželjne odgovore i slabiju sposobnost djece da procijene vlastitu razinu aktivnosti.

Procjena TF pokazala je da intervencija ima selektivne učinke, pri čemu su zabilježena poboljšanja u komponentama koje su osjetljivije na kratkoročne promjene, poput repetitivne snage trbuha i eksplozivne snage donjih ekstremiteta. S druge strane, nisu zabilježene značajne promjene u aerobnoj izdržljivosti i fleksibilnosti, što se može objasniti činjenicom da razvoj tih sposobnosti zahtijeva dugotrajnije i intenzivnije programe. Također, nisu utvrđene značajne promjene u sastavu tijela, što je objašnjeno dominantnim utjecajem prehrane, ograničenim trajanjem intervencije i specifičnostima rasta i razvoja u ovoj dobi.

Rezultati nisu pokazali statistički značajan učinak na afektivnu i kognitivnu domenu TP, što se može pripisati ograničenoj osjetljivosti korištenog instrumenta, ali i prirodi samoprocjene koja je podložna različitim vrstama pristranosti.

Dio disertacije usmjeren na ispitivanje kvalitativnih promjena ukazuje da intervencija nije djelovala samo na razini pojedinačnih sposobnosti, već i na razini integracije različitih komponenti tjelesnog razvoja, što je posebno važno za dugoročno zdravlje i funkcionalnost.

Zaključno, rezultati potvrđuju da edukacijske intervencije temeljene na TP mogu imati značajan pozitivan učinak na očuvanje razine TA i unapređenje određenih komponenti TF kod djece. Međutim, za postizanje sveobuhvatnih i dugoročnih učinaka potrebno je osigurati dulje trajanje intervencija, veći volumen i intenzitet aktivnosti te integraciju dodatnih čimbenika, poput prehrane i obiteljskog okruženja.

1 Introduction

1.1 Physical activity and preadolescence

Physical activity (PA) of children is a fundamental factor for optimal growth, development and health, reducing risk factors such as blood pressure and lipids, and supporting the musculoskeletal and metabolic system through greater bone density and better insulin sensitivity (Kelley, Kelley, & Pate, 2022; McCaskie et al., 2022; W. Zhang et al., 2024). Furthermore, PA increases postural stability and all motor and functional abilities, and affects brain development by improving structural and functional aspects, including cognitive functions (Chacón-Cuberos, Zurita-Ortega, Ramírez-Granizo, & Castro-Sánchez, 2020; Manojlovic et al., 2023). In addition to physiological benefits, PA has a significant impact on the mental health and psychosocial development of children, contributing to greater self-confidence, better self-regulation of emotions and better social interactions (Fu, Li, Li, & Wang, 2025; Song et al., 2025; Wang, Gao, Cui, & Shi, 2025). However, despite the numerous proven benefits, PA levels in children have been continuously declining over the past few decades (Guthold, Stevens, Riley, & Bull, 2020; WHO, 2022a). It is generally accepted that the decline in PA is related to several factors, including increased sedentary time in school environments, limited opportunities for spontaneous movement, and increased exposure to digital media (Jones, Defever, Letsinger, Steele, & Mackintosh, 2020; WHO, 2022b).

Results from longitudinal and epidemiological studies show that PA levels in children and adolescents decrease continuously with age, with the most significant decline occurring in early and middle adolescence (Aubert et al., 2022; Aubert et al., 2021). World Health Organization data show that as many as 81% of adolescents do not achieve the recommended minimum of 60 minutes of moderate-to-vigorous PA (MVPA) per day (WHO, 2022a). What is of particular concern is that recent systematic reviews and meta-analyses of the scientific literature emphasize that the progressive decline in MVPA begins before adolescence, specifically in the preadolescent period (Farooq et al., 2020; Habyarimana, Tugirumukiza, He, Pathirana, & Ke, 2025). Given the obvious problem of decrease of PA during this period, it is particularly important to understand the specific developmental characteristics of preadolescence.

Preadolescence refers to the developmental period of transition from childhood to adolescence, typically spanning the ages of approximately 9 to 12, although some authors cite a start of this phase at age 10 (Gilmore & Meersand, 2014). This life phase is extremely dynamic because different components of development –(physical, hormonal, cognitive, behavioral and emotional) overlap and influence each other (Rathi & Rastogi, 2007). At the beginning of preadolescence, children are still in the early school-age developmental period. Early school age begins with initiation of formal school-education, around the age of six or seven. In the Croatian education system it includes the period of primary school, that is, grades one through four (Neljak, 2013). This developmental period is marked by relatively stable but continuous physical growth. The average annual height increase in younger school-age children is about 5-7 cm, while body mass increases approximately 3-3.5 kg per year. This quantitative growth is accompanied by qualitative changes in body composition: boys gradually develop a greater proportion of muscle mass, while girls accumulate adipose tissue to a somewhat greater extent, reflecting a natural gender-specific pattern of growth and development (Mardešić, 2016).

In primary school students (younger school age), morphological development does not occur at a linear pace, but in clearly identifiable phases. The first phase, from approximately the first to the third grade,

is characterized by slower and more stable growth. This is followed by a phase of accelerated growth, which usually begins in the fourth grade, or around the age of 9 or 10 (Tomljenović, 2018). This transitional age is particularly significant because it marks the beginning of accelerated biological maturation, noted by increasingly pronounced gender differences in the morphological and functional characteristics of boys and girls. During the first phase of development of motor and functional abilities, from the age of 6-7 to 8-9, children make significant progress thanks to intensive myelination of nervous tissue. This neurophysiological process, which enables faster and more efficient transmission of nerve impulses, reaches key stages in early childhood and ends approximately between the ages of 9 and 10 (Tomljenović, 2018). Consequently, during the transition period towards preadolescence, children achieve greater movement coordination, more precise motor reactions, and better body control.

Research confirms that it is precisely during preadolescence that fundamental motor skills, such as coordination, balance, agility and strength, improve significantly (C. Liu, Cao, Zhang, Gao, & Qu, 2023; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). These changes are the result of the maturation of neuromuscular and sensorimotor systems, which enables increasingly precise, economical and efficient execution of movements compared to earlier ages (McDonough, Liu, & Gao, 2020). In addition, recent research shows that there is a clear correlation between the level of motor competence and the functional status of children of this age. Specifically, children with higher motor competence usually show better cardiovascular (aerobic) endurance, agility and general coordination, as well as greater readiness for motor challenges in everyday and sports activities (Kokstejn, Grobar, Vampola, & Musalek, 2025; Stodden et al., 2008). Such a connection between motor skills and PA strengthens with age, implying that early development of motor competence can have lasting positive effects on a child's health and physical functioning.

Given the above, it can be concluded that pre-adolescence is an extremely sensitive and developmentally valuable period in which children achieve the basic prerequisites for optimal growth, motor development and the formation of healthy lifestyle habits. Timely encouragement of PA in this period has a key role, not only in improving morphological and functional characteristics, but also in encouraging self-regulation, social skills and positive body image (Gallahue, Ozmun, & Goodway, 2012; Robinson et al., 2015). It is therefore not surprising that scientific research is increasingly focusing on strategies for increasing PA and its positive impact on the development of morphological characteristics, motor skills and functional capacities in children (Hui, Wei, Luping, & Nannan, 2024; Moon et al., 2024). In this sense, the concept of "physical literacy" has recently been particularly emphasized as a kind of holistic approach that combines motor competence, self-confidence, motivation and knowledge about physical activities, enabling children to independently, with pleasure and a sense of competence, engage in a variety of movements throughout their lives.

1.2 Physical literacy

Physical literacy (PL) can be defined as the ability of each individual to have the motivation, confidence and physical abilities to exercise, to understand the health benefits of PA in order to develop habits and remain active throughout life (Whitehead, 2013). The concept of PL is increasingly recognized as a key mechanism for encouraging and maintaining lifelong engagement in PA. The importance of the concept of PL is also discussed in the Global Action Plan on PA 2018-2030 (GAPPA) developed by the World Health Organization, which emphasizes the importance of the concept of TP within the framework of quality physical education, and in terms of promoting lifelong active habits (WHO, 2019). UNESCO also supports the Quality Physical Education (QPE) guidelines, which aim to systematically promote TP within education systems. (UNESCO, 2017). Even the United Nations 2030 Development Goals have proposed PL as a worthy goal (Dudley & Cairney, 2021). Recent systematic reviews of the scientific

literature in Europe indicate that most countries describe PL as a relatively new concept recently introduced into practice, and that there is significant heterogeneity in the degree of its adoption and implementation across the continent, with limited current levels of application, but with predictions of increased study and wider acceptance in the coming period (Carl et al., 2023; Carl et al., 2025).

Various concepts of PL and tools for assessing its level have been developed worldwide, but there is no consensus on their optimal application (Jean de Dieu & Zhou, 2021; Y. Liu & Chen, 2021). The Canadian Assessment of Physical Literacy (CAPL) and the Physical Literacy Assessment of Youth (PLAY) tool stand out among the most widespread and commonly applied instruments for measuring PL in scientific research, which enable a comprehensive assessment of children and youth (Jean de Dieu & Zhou, 2021; Y. Liu & Chen, 2021). According to the Canadian definition, PL as a multifaceted concept consists of four domains: (i) physical competence, (ii) daily behaviour, (iii) motivation and confidence, and (iv) knowledge and understanding of PL (Longmuir et al., 2015). These domains of PL are interconnected and crucial for encouraging and maintaining participation in PA throughout childhood, adolescence, and later in adulthood, as they create the foundation for lasting habits.

Given the growing global and European interest in PL, research is increasingly focused on developing and evaluating intervention programs to improve it in children and young people. According to a systematic review by Carla et al. (2022), as well as additional recent studies not included in this review, slightly more than 20 intervention studies were identified that examined the impact of various educational, training and multidisciplinary interventions on the development of PL in healthy school-age children, i.e. preadolescents, using a variety of PL assessment instruments. (Carl et al., 2022; Nezondet, Gandrieau, Bourrelier, Nguyen, & Zunquin, 2023; Stoddart, Humbert, Kerpan, Cameron, & Kriellaars, 2023; Urbano-Mairena et al., 2025; D. Zhang, Shi, Zhu, Chen, & Liu, 2023). The duration of the interventions themselves varied from just a few days to the entire school year (Strobl, Ptack, Töpfer, Sygusch, & Tittlbach, 2020; Warner et al., 2021). Table 1 summarizes the studies that have addressed this issue

Table 1. Overview of the physical literacy-based intervention studies in children

Reference	Participants	Study variables	Intervention	Main findings
Lee et al., 2018	age 9-14 years (n = 258), no control group	CAPL and questionnaires (Y Kids Student Questionnaire, Y Kids Parent Questionnaire)	Y Kids Academy program - workshops on healthy eating and healthy lifestyle habits with organized physical activity and interactive tasks, with the aim of increasing knowledge and encouraging the adoption of a healthy lifestyle; 4 weeks / 1 week	Significant improvement in students' PL knowledge scores; parents reported more conversations about health topics and better health behaviors for children at home
Coyne et al., 2019	age 8-12 years (n = 310), no control group	CAPL and Heart rate	FMS (fundamental movement skills) program with a focus on track games; 10 weeks (2x per week)	Significant improvements in physical competence, knowledge/understanding, and overall PL; no changes in activity indicators; stronger performance in suburban school

Farias et al., 2020	age 12-14 years (n = 24), no control group	Qualitative (questionnaire, interviews, focus groups)	Sports education curriculum; after 3 years; school year (~10 months), 2× per week	Students developed enthusiasm, competence and PL; Attitudes towards PE and PA changed later
Gavigan et al., 2023	age 6-10 years (n = 925), no control group	Qualitative (focus groups, questionnaires)	Interventions based on theories of self-determination, constraints, and behavior change; 8 weeks	The model and intervention increased FMS skills, confidence, enjoyment and engagement; improved behavior (focus in the classroom)
George et al., 2016	age 6-12 years (n = 15), no control group	Heart rate, pedometer, questionnaires (Physical Activity Enjoyment Scale, Intrinsic Motivation Inventory, Rosenberg Self-Esteem Scale, Movement Assessment Battery for Children), 6MWT	Active video games with the Nintendo Wii system (Wii Sport, Wii Sport Resort, Wii Play, Just Dance); 6 weeks	No general effect over time; some gender-specific improvements in aspects of motivation and motor skills
Lloyd et al., 2016	1.-9. grade (Kanada, age ~6–15 years), no control group	Qualitative (phenomenological observations, group interviews, diary entries)	JungleSport Program-adventure -based learning with obstacle courses and vertical challenges; 3-5 days	The creative writing component encouraged expression; feelings of power and strength translated into bodily awareness
Mandigo et al., 2019	5.-8. grade (Kanada, age ~9–11 years, n = 22), no control group	Questionnaires (Active participation, Living skills), Fitness skills, Movement skills	PlaySport program-multi-sport program (various developmental games); implemented in the after-school program; 8 weeks (3x a week)	Significant progress in four of the 12 PL indicators (skills and participation domains); eight indicators did not change over time
Warner et al., 2021	age 6-10 years (n = 45), no control group	LaunchPad Fundamental Movement Skills Assessment (according to the PLAY model), modified PLAYself questionnaire	SFD (Sport for development) program with a focus on FMS and games; 2 weeks (8 sessions), camp	Significant improvements in self-perception of PL and FMS (especially running and balance); strongest effect on lower initial scores
Bremer et al., 2020	age 7-13 years (n = 90; intervention group 47, control group 43)	PLAYfun tool, questionnaires for the cognitive and affective domain (RISE, PLAYself, Intrinsic Motivation Inventory)	After-school TP intervention (15 min FMS station + 15 min active games); 12 weeks	Positive effects on program leaders' perceptions; most outcomes in children were insignificant; implementation challenges
Colella i Bonasia, 2019	1. grade (age 6,88 ± 0,61 years, n = 84; intervention group 40, control group 44)	TGMD2 AND self-report PSP_C	14 PE lessons according to the traditional curriculum; control group- traditional teacher; intervention group- expert teacher; 6 months	Significant improvements in motor index and self-efficacy in the experimental group, but not in the control group

Crozier et al., 2022	age 5-12 years (n = 29; intervention group 14, control group 15)	Anthropometric measures, TGMD-2, questionnaires (parents), accelerometers	Extracurricular programs (ASAP) focused on developing PL (EG); classic extracurricular programs (KG); 6 months	Changes between groups are not significant in most variables; differences were found in BMI, aerobic capacity and movement skills (in favor of IG)
Demetriou et al., 2018	age 8,06 ± 1,21 years (n = 169; sports-oriented school 79, regular school 90)	DMT 6-18 (physical fitness), MOBAK 2 and 3 (fundamental motor skills), questionnaires (physical activity, Intrinsic Motivation Inventory, attitudes towards physical activity), cognitive performance (Simon task, Flanker test)	Elementary school program with a focus on competitive sports; daily PE classes and additional TA during the school day; 6 months	Students from sports schools showed higher values in standing long jump and PA attitudes; sports focus did not affect cognitive performance
Invernizzi et al., 2019	age 10,5 ± 0,5 years (n = 121; intervention group 60, control group 61)	Multistage Fitness Test, TGMD-2 (motor ability), questionnaires (Self-Description Questionnaire, Physical Activity Enjoyment Scale, Physical Activity Questionnaire for Older Children)	Intervention with an integrated approach with multiple teaching styles and active reflection; 12 weeks (2× 1h sessions/week)	Children in the intervention group reported greater satisfaction and stronger improvements in tests of motor skills, pleasure and PA levels
Johnstone et al. 2017	average age = 7,0 years (SD = 1,1); n = 172 (intervention group) i 24 (control group)	Accelerometers, TGMD-2	Go2Play Active Play intervention (outdoor play and free play); 5 months	Significant time-group interactions in gross motor, locomotor, and PA during the school day (in favor of IG); insignificant effects for subject control skills
Kriellaars et al., 2019	age 9-12 years (n = 211; intervention group 101, control group 110)	PLAYfun, PLAYinventory, PLAYself	Circus arts in PE (clownism, aerial elements, acrobatics, balance, manipulation) with student-centered methods; 12 weeks	Significant improvements in motor skills for both groups; most outcomes favored the intervention group; narrowing of the gender gap
Pullen et al., 2020	age 11-14 years (n = 46; intervention group 22, control group 24)	Skills battery (RTSB), tuck jump assessment (TJA), questionnaires (Behavioural Regulation in Exercise Questionnaire-2, Perceived Physical Ability Scale for Children, Rosenberg Self-Esteem Scale)	Strength and conditioning program replaces regular PE class; 6 weeks	Significant improvement in resistance training skills for IG but not for CG; no changes in jumps; increasing the motivation of boys only
Santos et al., 2017	age 9,5 ± 0,7 years (n = 40; intervention group 22, control group 18)	Creative thinking (Torrance Test), motor performance (vertical jump - optojump, sprint 15 m, agility T-test), creative behavior in	Skills4Genius program – extracurricular sports activities with a focus on creative thinking; 5 months	The intervention significantly promoted creative thinking, creativity in play, and tactical performance; inconclusive effects on motor performance

		the game, tactical performance		
Strobl et al., 2020	age 11-17 years (n = 233; intervention group 116, control group 117)	Questionnaires	HKU (health-related knowledge and understanding) intervention; 1 school year	Knowledge and understanding of PL differed significantly between experimental and control schools
Caldwell et al., 2022	4., 5. and 6. grade (age ~9-12 years, n = 50), no control group	Questionnaires: PL (PLAYSELF), PA (PAQ-C), PACES (Physical Activity Enjoyment Scale), PROMIS (patient-Reported Outcomes Measures Information System)	BOXING intervention with comprehensive TA plans (20–45 min), short movement breaks (1–10 min) and games; 70 minutes per week, 2 months	Participation in BOKS provided a positive experience and could mitigate the COVID-19-related decline in PA
Li et al., 2022	age 9,7 ± 0,7 years (n = 79; intervention group 1 - 26, intervention group 2 - 26, control group - 27)	PA (ActiGraph accelerometers), PL (CAPL-2)	Three groups: "Quantity+Quality" (SSPlay – sit-stand desks and play-based recess), "Quality" (Play – play-based recess), control group	SSPlay and Play groups significantly improved in physical competence, knowledge/understanding, and cognitive flexibility; no interaction between groups
Liu et al., 2022	age 11-13 years (n = 49), no control group	CAPL-2, PA (behavioral questionnaire and pedometers), PF (PACER, Isometric Plank Hold, CAMSA)	SDT-led pedagogical workshop with the Heart PL model; children learn in pairs with different PL levels; 12 weeks	Results in the "progressing" stage; significant differences by gender, class, SES (socioeconomic status), BMI and ethnicity; the low PL group showed improvements
Mendoza-Muñoz et al., 2022	age 10,28 ± 0,43 years (n = 57; intervention group 29, control group 28)	PL (CAPL-2), PA (XIAOMI bracelet-number of steps per day and self-reported questionnaire), PF (plank, beep test, CAMSA)	Recreational (break during class) AB game-based program; 4 weeks (15 min daily)	Improvements in all CAPL-2 domains in the intervention group; significant differences in most domains
Nezondet et al., 2023	age 11,7 ± 1,09 years (n = 13), no control group	TANITA, 20 m Shuttle Walk/Run Test, Actigraph GT3X+ accelerometers, PA (Youth Risk Behavior Surveillance System questionnaire)	CAPACITES 64 intervention – different actions in PA and nutrition education in different living environments; 9 months	Improvements in PL, TF, BMI, body fat and increase in MVPA
Stoddart et al., 2023	age 6-12 years; intervention group: 3 teachers i ~65–66 students; control group: 3 teachers i ~65 students	PLAYfun, PLAYself, PLAYinventory	PLitPE (physical literacy enriched PE) intervention based on SDT; skill repetition and feedback with reinforcement; 8–9 weeks (3× per week)	Significant differences in favor of PLitPE: motor competence, movement vocabulary, participation environments; reduction of gender differences

Telford et al., 2021	age 10,4 ± 0,4 years (n = 318; intervention group- 152, control group- 166)	Questionnaires and accelerometers	PEPL intervention: (a) climate for PL, (b) availability of PE, (c) PA on the playground, (d) linking school and joint organizations; 33 weeks	Improvements in object control skills; modest effects on MVPA; qualitative data show enjoyment and greater motivation
Zhang et al., 2023	age 7,8 ± 0,7 years (n = 357; intervention group- 155, control group- 202)	Chinese National Student Physical Fitness Standard (CNSPFS) – tests: jump rope, sit and reach, 20 m shuttle run, handgrip, 50 m sprint	Intervention integrating PL into active breaks during school; 10 weeks	Significant group × time interactions in 20 m shuttle run and handgrip; greater improvements in IG than CG
Urbano-Mairena et al., 2025	age 8-12 years (n = 89; intervention group- 43, control group- 46)	CAPL-2	Structured active breaks during the school day (5–10 min per day) – Catch the Flag, Dodgeball, progressive games; 7 weeks	Higher scores in all CAPL-2 domains in IG; significant differences in most domains

Collectively, the results indicate generally positive acute effects of these interventions in improving different domains of PL. However, significant methodological limitations can be noted that limit the generalizability of the findings. First, it is evident that only 13 studies included a control group, while those studies that used a control group often showed the so-called "specialist facilitator effect". In other words, the experimental groups were mostly led by trained trainers or physical education (PE) teachers with specialized knowledge, while the control groups were conducted by standard classroom teachers without such a focus. This logically limits the attribution of effects to the intervention content itself. (Carl et al., 2022; Stoddart et al., 2023; Urbano-Mairena et al., 2025; Zhang et al., 2023). Second, it seems that all studies were focused exclusively on short-term (acute) effects without monitoring long-term retention or sustainability of results. This logically leaves open the question of the long-term effectiveness of such programs in a real school environment. (Carl et al., 2022; Nezondet et al., 2023; Stoddart et al., 2023; Urbano-Mairena et al., 2025; D. Zhang et al., 2023). Furthermore, the variables used in the studies were diverse, including PA, motor skills, physical fitness, or self-reported motor competence. However, physical fitness variables were rarely assessed with more than one test, and only a few studies simultaneously monitored PA levels and physical fitness (Carl et al., 2022). Next, only seven studies that assessed PA levels used objective measurement instruments such as accelerometers or pedometers (Crozier et al., 2022; George, Rohr, & Byrne, 2016; Johnstone, Hughes, Janssen, & Reilly, 2017; Li et al., 2022; Y. Liu & Chen, 2022; Nezondet et al., 2023; Telford et al., 2021). In the case of long-term interventions, different school programs (e.g. sports programs versus non-sports programs) or additional sports content during the school year have often been compared, which calls into question initial differences between groups, for example, differences in motivation for PA, prior motor knowledge, or general inclination towards exercise, or the possibility of "selection bias" in the results of the experimental group (Carl et al., 2022; Nezondet et al., 2023; D. Zhang et al., 2023). Finally, most interventions included "additional content" with a higher volume of work or greater intensity in the experimental group than in the control group, so the observed effects may have resulted from the increased scope of activities rather than from the specific quality or innovation of the content itself. (Carl et al., 2022; Nezondet et al., 2023; D. Zhang et al., 2023).

In Croatia, PL research is a relatively new area of research. Some studies have examined the relationship between PL and health literacy, concluding that they represent distinct, yet related, concepts. (Blažević, Blazevic, & Sekulic, 2024; Kesic, Peric, et al., 2022; Kesic, Savicevic, Peric, Gilic, & Zenic, 2022; Mudrinic,

Musa, Metikos, Vuletic, & Sekulic, 2025; Sestan, Zovko, & Sekulic, 2025). Furthermore, research focused on the reliability and validity of PL-measurement tools has shown satisfactory results of reliability and discriminant validity in Croatia, both in a sample of secondary school students (14-18 years old) and primary school students (12-15 years old), as well as in a sample of adults with moderate to satisfactory metric characteristics (Blažević et al., 2024; Gilic, Sekulic, Munoz, Jaunig, & Carl, 2025; Lončar Kubura, 2025; Šunda, 2022). To date, two intervention studies have been published in Croatia addressing this topic. exempling the first one, Šunda (2022) developed educational video content aimed at improving PL in her doctoral dissertation, which she applied in her work with high school students. The results of her distance learning intervention showed significant effects on improving cardiovascular endurance and maintaining body mass index (Šunda, 2022). These results were later partially published in a scientific paper reporting the intervention's effects (Gilic et al., 2023). Second, Lončar Kubura (2025) developed educational video materials with the same goal of improving facets of PL and applied them to a population of elementary school students. However, the 12-week intervention did not result in changes in PL levels or physical fitness among elementary school students (Lončar Kubura, 2025). Overall, existing research highlights that PL could present a key paradigm and a fundamental pillar that should be integrated into educational and public health initiatives to ensure adequate PA during adolescence and across the wider population.

2 Research problem

It is clear that the topic of PL is increasingly attracting the attention of scientists and experts in the fields of education and health. However, previous intervention studies conducted on younger school-age students (preadolescents) have not provided clear answers to questions about the effectiveness of programs targeting PL in improving students' physical fitness and PA levels. This is primarily because of the following issues

- Previous studies designed the interventions through "additional work" (and therefore the increase in the total volume of work could have caused positive effects regardless of the content of the work). Interventions done so far had a clear influence of "professional guidance" (the experimental programs were regularly led by trainers/kinesiologists, and the control programs (if any) were led by teachers).
- Authors monitored a smaller number of fitness variables (and in addition to the lack of information on the effects of the interventions on the overall fitness status, there was also no possibility of analyzing qualitative changes - changes in the relationships between the variables);
- Studies did not analyze the retention of the achieved changes (and therefore it is not known whether the treatment effects obtained were acute or chronic).
- Finally, the lack of research on TP in Croatia is evident, and it is emphasized that future research should focus on younger groups (lower primary school grades) (Lončar Kubura, 2025; Šunda, 2022).

3 Study aims and hypotheses

The main aims of this dissertation were:

- (i) to determine the validity and reliability of the Croatian version of the questionnaires for the assessment of PL (PL-questionnaires) in preadolescents
- (ii) to determine the reliability and validity of the Fitnessgram battery in evaluation of the physical fitness status (PF) in preadolescents from Croatia
- (iii) to determine the associations between PF, PA and PL in preadolescents
- (iv) to determine the effects of the specifically designed PL intervention delivered as a part of physical education curriculum (PL-based intervention) on PA, PF and PL in preadolescents

Accordingly, the hypotheses of the dissertation were:

- H1: The PL-questionnaires will have appropriate validity and reliability
- H2: Fitnessgram battery will have appropriate validity and reliability
- H3: The positive associations between PF, PA, and PL in preadolescents will be established
- H4: The PL-based intervention will have significant positive effect on PA, PF and PL in preadolescents

4 Methods

The dissertation is consisted of five original studies published in WoS/Scopus Journals, and each study has specific methods (i.e. participants, variables, statistics). The detailed methods are presented in later, as a part of each study. Therefore, following text includes only general information on participant, variables, and methodology.

4.1 Participants

Participants were preadolescents aged 9-to-11 years. All of them were included in regular school program. In some studies (validation studies) the sample included participants from Croatia, Bosnia and Herzegovina, and Montenegro (Vuletic et al., 2023) while in other studies and researches the sample involved only children from Croatia (Rajkovic Vuletic, Gilic, Pavlinovic, Matijasevic, & Sekulic, 2026; Rajkovic Vuletic et al., 2024; Rajkovic Vuletic, Pranjic, et al., 2026; Sekulic, Pranjic, Cerkez Zovko, Corluka, & Rajkovic Vuletic, 2026)

All children were in good health, and regularly participated in physical education classes. They were informed on study purposes and risks, and parental consent was obtained prior to each research they were involved at.

Complete protocol of the researches included in this dissertation was pre-approved by Ethical Committee of the University of Zagreb, Faculty of Kinesiology (Ref. no.93/2024, date of approval 3 September 2024).

4.2 Variables

Variables included tests evaluating PL, PF, and PA.

The PL was evaluated by Croatian version of the PLAYself and CAPL-2 questionnaires (Gilic, Malovic, Sunda, Maras, & Zenic, 2022; Sunda, Gilic, Sekulic, et al., 2022; Vuletic et al., 2023).

The PF status was evaluated by tests included in the Fitnessgram battery, including tests of aerobic endurance (multi-stage Beep test), abdominal muscular strength and endurance (curl up test), torso extensor strength and flexibility (torso lift test), flexibility for the lower back and hamstring muscles (sit-and-reach test), upper body strength and endurance (push-up test), body height, body mass and body composition (measured by Tanita BC digital diagnostic scale) (Meredith & Welk, 2005). In addition, a standing long jump test was included to assess the jumping performance/power capacity.

The PA was indirectly evaluated by Croatian version of the Physical Activity Questionnaire for Older Children (PAQ-C) (Crocker, Bailey, Faulkner, Kowalski, & McGrath, 1997; Samaržija & Mišigoj-Duraković, 2013). Also, direct measurement of the PA was done GENEActiv triaxial accelerometers (Activinsights Ltd., Cambridge, UK) (Esliger et al., 2011)

4.3 Study protocol

Study protocol consisted of several phases.

- (i) In the first phase, the school authorities were contacted, and selection of schools which will be involved in the experiment was done. Also, preliminary meetings with teachers and parents were done, and parental consents were collected.
- (ii) In the second phase, reliability and validity of the PL-questionnaires, and PF-measurement tools was established.
- (iii) The third phase consisted of development of the PL-intervention and preparation of the educational materials (video clips).
- (iv) In the fourth phase, PL-intervention was applied in the experimental group. Pre- post- and retention-testing design was applied ¹

4.4 Statistics

Specific statistical analyses were done in each study and are presented in details later. Statistics generally included:

- descriptive statistics
- calculation of the reliability parameters
- factor analyses and correlation analyses (validity analyses)
- factorial analysis of variance for repeated measurements (analyses of quantitative effects of PL-based intervention effects)
- comparison of correlation coefficients and factor structures (analysis of the qualitative effects of the PL-based intervention)

¹ Please see original studies for specific details on experimental design

5 Original studies

The dissertation includes five original studies:

1. Rajkovic Vuletic, P., Kesic, M. G., Gilic, B., Pehar, M., Uzicanin, E., Idrizovic, K., & Sekulic, D. (2023). Evaluation of physical literacy in 9-to 11-Year-Old children: reliability and validity of two measurement tools in three southeastern European countries. *Children*, 10(11), 1722.
2. Rajkovic Vuletic, P., Gilic, B., Zenic, N., Pavlinovic, V., Kesic, M. G., Idrizovic, K., Sunda, M., Manojlovic, M., & Sekulic, D. (2024). Analyzing the associations between facets of physical literacy, physical fitness, and physical activity levels: Gender-and age-specific cross-sectional study in preadolescent children. *Education sciences*, 14(4), 391
3. Rajkovic Vuletic, P., Gilic, B., Pavlinovic, V., Matijasevic, P., & Sekulic, D. (2026). Effects of a Physical-Literacy-Based Educational Intervention on Physical Activity and Body Composition in Preadolescent Children: A School-Based Controlled Trial. *Sports*, 14(2), 77.
4. Rajković Vuletić, P., Pranjić, T., Gilić Škugor, B., Lešnik, B., Sekulić, D., & Šajber, D. (2026). Physical literacy-focused education improves fitness markers in preadolescents: Implications for school-based health promotion. *Healthcare*, 14(5), 695.
5. Sekulic, D., Pranjić, T., Cerkez Zovko, I., Corluka, M., & Rajkovic Vuletic, P. (2026). Examining Qualitative Changes in Physical Fitness and Body Composition in a School-Based Physical Literacy Intervention: Methodological and Practical Considerations. *Sport Mont*, 24(1), 149-158.

- 5.1 Rajkovic Vuletic, P., Kesic, M. G., Gilic, B., Pehar, M., Uzicanin, E., Idrizovic, K., & Sekulic, D. (2023). Evaluation of physical literacy in 9-to 11-Year-Old children: reliability and validity of two measurement tools in three southeastern European countries. *Children*, 10(11), 1722.

Article

Evaluation of Physical Literacy in 9- to 11-Year-Old Children: Reliability and Validity of Two Measurement Tools in Three Southeastern European Countries

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Abstract: The awareness of the importance of physical literacy (PL) is globally increasing; however, knowledge of the applicability of PL measurement tools in southeastern Europe is limited. The aim of this study was to evaluate the reliability and validity of translated versions of the CAPL-2 and PLAYself questionnaires in 9- to 11-year-old elementary school children from Croatia, Bosnia and Herzegovina, and Montenegro. The participants were 303 children (141 girls; all 9 to 11 years of age) from Croatia ($n = 71$), Bosnia and Herzegovina ($n = 162$), and Montenegro ($n = 70$), enrolled in regular elementary school. The participants were tested throughout a test–retest procedure using two PL evaluation tools, i.e., the Canadian Assessment of Physical Literacy (shorter version, CAPL-2) and the Physical Literacy Assessment of Youth (PLAYself) questionnaires. With an intraclass correlation (ICC) of 0.70–0.80 for specific questionnaire subscales and 0.84 for the total score, PLAYself was found to be reliable. With Kappa values of 0.11–0.23 and a percentage of absolute agreement of less than 62%, CAPL-2 appeared to be less reliable. Factors related to sport participation were significantly positively associated with the PLAYself score, indicating its proper validity. In conclusion, we suggest the usage of the PLAYself questionnaire in further studies examining PL in children of a similar age in the region. Future studies in other age groups and languages are also warranted.

Keywords: physical literacy; primary school; test–retest; internal consistency; criterion validity



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1. Introduction

Although the benefits of physical activity (PA) are well known, people, including children, are insufficiently physically active [1]. Current research clearly indicates that PA decreases with age, especially in adolescence [2–4]. Of special concern is the fact that recent reviews highlighted a progressive decline in moderate- and high-intensity PA even before adolescence, starting from early and middle childhood [5]. Consequently, the interest in strategies that could positively influence the overall PA level in children and youth and in the concept of physical literacy (PL) has increased [6,7]. PL can be defined as a “disposition to capitalize on our human-embodied capability wherein the individual has the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for maintaining purposeful physical pursuits and activities throughout the life course” [8]. In other words, it is expected that “physically-literate-individuals” will be more likely to achieve a “physically active way of life” [9]. Consequently, it is of utmost

importance to identify individuals with low levels of PL in order to educate them about the necessity of PA and on how to achieve appropriate levels of PA. To do this, it is necessary to identify the most appropriate ways of evaluating PL in different sub-populations.

So far, various strategies to evaluate PL have been developed, but there is no clear consensus on the most appropriate one [10–13]. The most popular PL evaluation tools are the (i) Canadian Assessment of Physical Literacy (CAPL) [14] and the (ii) Physical Literacy Assessment of Youth (PLAY) [10] protocols. The CAPL protocol (as well as its shorter version CAPL-2) consists of a battery of standardized evaluation protocols that have been regularly proven to be valid and reliable for PL evaluation in children and adolescents [15,16]. The CAPL-2 consists of three protocols aimed at the evaluation of physical competence, two protocols focused on daily behavior, and a questionnaire of 22 items used to evaluate knowledge, understanding, motivation, and self-confidence during physical exercising. The PLAY evaluation protocol consists of six tools; namely, PLAYfun, PLAYbasic, PLAYself, PLAYparent, PLAYcoach, and PLAYinventory, which use workbooks, forms, and score sheets to achieve a specific measurement of PL in children and youth [17]. As for the CAPL, the PLAY tools are also proven to be reliable and valid for the evaluation of PL in children and youth [18,19].

The concept of PL is multidimensional, and scientists share the opinion that each component of PL should be evaluated. However, this is challenging, as it requires significant resources and time. Therefore, most studies have used standardized questionnaires that partially define PL and/or some of its features. The most used questionnaires are those included in CAPL-2 and PLAY [17,20]. The CAPL questionnaires examine the cognitive domain of PL (knowledge and understanding) through questions aimed to evaluate (i) the understanding of the recommendations regarding PA and sedentary behavior, (ii) the knowledge of overall fitness parameters and movement and how to improve them, and (iii) the different perceptions of health [13,21]. On the other hand, the PLAYself questionnaires include items aimed to access (i) confidence and motivation, (ii) knowledge and understanding, and (iii) environmental engagement ability [19].

From this literature overview, it is clear that the concept of PL deserves special attention, particularly in children and youth. Meanwhile, CAPL-2, and PLAYself questionnaires were repeatedly found to be reliable and valid measurement tools [19,21–25]. However, the reliability and validity of the PL-measurement tools in southeastern Europe is rarely evidenced, and only one study examined this issue in adolescents [26], while: (i) there is an evident lack of research examining this issue in younger children, and (ii) to the best of our knowledge, no study has been conducted on elementary school children in southeastern Europe (the territory where similar Slavic languages are spoken) [27]. Therefore, the aim of this study was to evaluate the reliability and validity of translated versions of the CAPL-2 and PLAYself questionnaires in 9- to 11-year-old children from Croatia, Bosnia and Herzegovina, and Montenegro. We hypothesized that both questionnaires would be reliable and valid tools for the evaluation of PL among the studied participants. Considering the similarity of the languages spoken in the examined region, we believe that the study findings will be applicable in a wider context and in other surrounding countries.

2. Materials and Methods

2.1. Participants

The participants in this study were 303 children (141 girls), elementary school students from Croatia ($n = 71$), Bosnia and Herzegovina ($n = 162$), and Montenegro ($n = 70$). At the moment of testing, all children were between 9 and 11 years of age and attended the 3rd or 4th grade of the regular school program. Their parents (legal guardians) were informed about the study protocol and aims and provided their written consent for the participation of the children in the investigation. The study was approved by the Ethical Committee of the University of Split, Faculty of Kinesiology (EBO: 2181-205-02-01-21-0011; date of approval, 23 September 2021).

2.2. Variables and Testing

The variables in this study were school grade (3rd or 4th grade; younger vs. older school age), gender (male and female), age (in years), sport factors, CAPL-2 and PLAYself questionnaires.

The evaluation of the sport factors involved questions on current sport participation (yes or no), experience in sport (in years, i.e., one, two, three, four, five, etc.), and the number of training sessions per week (one, two, three, etc.).

The CAPL-2 knowledge and understanding questionnaire included 12 questions aimed at evaluating the participants' knowledge of the necessity and importance of daily PA, the problem of sedentarism, the importance and definition of cardiorespiratory fitness and muscular strength, the concept of fitness and its impact on a physically active lifestyle, ways of improving one's motor skills, and the components of overall fitness. Here are some examples of the questions we asked: "There are many different kinds of fitness, for example, endurance fitness, aerobic fitness, cardiorespiratory fitness. What is cardiorespiratory fitness?"; "if you wanted to improve a sport skill (like kicking and catching a ball), what would be the best type of training?" the participants had to choose the correct answer from four options; each correct answer was assigned 1 point, while each incorrect answer received a score of 0, resulting in a total score from 0 to 12.

The PLAYself questionnaire is used in children and adolescents in order to establish their perceived level of PL and includes four subsections: (i) environment, assessing the degree of movement confidence in different environments (i.e., gym, water, snow); (ii) affective and cognitive aspects related to PL that determine individuals' self-efficacy with respect to their participation in PA through items such as "It does not take me long to learn new skills, sports, or activities", "I think that being active is important for my health and well-being", and "I understand the words that coaches and PE teachers use"; (iii) relative ranking of literacy, numeracy, and physical literacy in different settings including school, home, and social life with friends, examining how much an individual values each literacy type; and (iv) fitness, whose evaluation is determined by the score assigned to the item "My fitness is good enough to let me perform all the activities I choose", which is not included in the final score. The final score consists of the subtotals from the first three subsections divided by the number of questions (27 in total). The maximum PLAYself score is 100, representing a high self-perceived PL.

The children were tested during school hours using the test-retest procedure, with 5–7 days between the testing sessions. Online questionnaire forms using the SurveyMonkey platform were prepared and answered in computer classrooms. The questionnaires were anonymized, and no personal data were asked. However, for the purpose of pairing the test and retest results (please see later for statistical analyses), the children were asked to use a self-selected code in both testing sessions, which they should send by SMS/WhatsApp to one of their parents (in case it was forgotten). One of the examiners was available if the children needed help during the test, but the examiner was positioned behind the computer screen and could not see the answers. Testing was carried out in small groups, up to 10 children, and the children could not see the other participants' answers. PLAYself and CAPL-2 questionnaires were previously proven to be feasible, valid, and reliable for 14- to 18-year-old Croatian adolescents [26,28]. However, knowing the similarity of the Croatian, Bosnian and Herzegovinian, and Montenegrin languages (other than some grammar and punctuation differences, these three languages are practically equal), only some minor corrections and adaptations were applied for conducting the tests in Bosnia and Herzegovina, and Montenegro.

2.3. Statistical Analyses

The statistical analyses were performed in several phases. In the first phase, the test-retest reliability of PLAYself was established by calculating intraclass correlation coefficients (ICC) with 95% confidence intervals (95%CI), using a two-way mixed-effect model with absolute agreement. The ICC values were interpreted as poor if <0.5 , moderate if between

0.5 and 0.75, good if between 0.75 and 0.9, and excellent if >0.90 [29]. Cronbach's alpha coefficients (CA) were calculated to define the internal consistency of the test and retest. The CA values were interpreted as previously suggested, i.e., as unacceptable if <0.5 , poor if ≥ 0.5 and <0.60 , questionable if ≥ 0.60 and <0.7 , acceptable if ≥ 0.70 and <0.8 , good if ≥ 0.80 and <0.9 , and excellent if ≥ 0.90 [30]. In brief, the CA is an indicator of the correlation of items, and therefore, a high CA value in general justifies the summarizing of the related items. To evaluate the test–retest reliability of the CAPL-2, somewhat different statistical analyses were conducted, because the responses in this questionnaire were generally dichotomous. Consequently, for each question, weighted Cohen's Kappa coefficients (C_k) with 95%CI and percent of the overall agreement (p_0) were calculated. The C_k values were interpreted as follows: slight = 0.00–0.20, fair = 0.21–0.40, moderate = 0.41–0.60, substantial = 0.61–0.80, and almost perfect = 0.81–1.00. A $p_0 \geq 80\%$ was considered acceptable [31].

Following the calculation of the reliability, the evaluation of the test validity comprised several analyses. Firstly, construct validity was evaluated by principal component factor analysis, using the Gutman–Kaiser criterion of extraction with a varimax raw rotation. The discriminative validity of CAPL-2 and PLAYself were determined by a *t*-test for independent samples, calculating the differences between (i) boys and girls, (ii) older and younger children (according to their school grade), and (iii) children involved in sports and children non-involved in sports. Additionally, Cohen's *d* as effect size (ES) with 95% confidence intervals (95%CI) were calculated and interpreted for significant *t*-test differences, with ≥ 0.2 as small ES, ≥ 0.5 as medium ES, and ≥ 0.8 as large ES. Also, we calculated the Spearman's rank order correlations to evidence the association between the PL scores of time dedicated to sport activities and number of training session per week, which allowed us to additionally evaluate the criterion-related validity of the applied questionnaires. The Pearson's *r* values were interpreted as very weak if in the range of 0.00–0.19, weak if in the range of 0.20–0.39, moderate if in the range of 0.40–0.69, strong if in the range of 0.70–0.89, and very strong if in the range of 0.90–1.00 [32].

The statistical significance of 95% ($p = 0.05$) was applied, and the statistical analyses were performed by Statistica version13 (Palo Alto, California, CA, USA).

3. Results

In general, PLAYself showed acceptable internal consistency. While the “literacy” and “numeracy” subsections presented somewhat low α values (0.55–0.60), other subsections had higher alpha values, indicating acceptable-to-good internal consistency of the questionnaire for early-school-age children. With values ranging between 0.70 and 0.84, the ICC values indicated good test–retest reliability (Table 1).

Table 1. Test–retest reliability and internal consistency of the PLAYself questionnaire (α —Cronbach Alpha, ICC—Test–retest intraclass correlation coefficient, CI—confidence interval).

Variable/Subscale	Test	Retest	Reliability
	α	α	ICC (95%CI)
Environment	0.72	0.81	0.80 (0.75–0.85)
Self-description	0.74	0.77	0.77 (0.70–0.84)
Literacy	0.59	0.60	0.72 (0.64–0.82)
Numeracy	0.55	0.57	0.70 (0.61–0.79)
Physical literacy	0.78	0.79	0.78 (0.71–0.87)
Total score			0.84 (0.75–0.93)

The calculated C_k values and percent of absolute agreement of the test and retest responses showed a low reliability for the CAPL-2 questionnaire. In brief, none of the C_k values exceeded 0.23 (interpreted as “fair”), while the percent of absolute agreement was generally low, reaching a maximum of 61.1% (Table 2).

Table 2. Test–retest reliability analysis for the CAPL-2 questionnaire (C κ —Cohen’s kappa coefficient; 95%CI—95% confidence interval, p0—percent of absolute agreement/test retest percentage of the equally responded queries).

Item	C κ	p0
Q1	0.23 (0.13–0.33)	56.6
Q2	0.18 (0.08–0.28)	45
Q3	0.17 (0.07–0.28)	54
Q4	0.20 (0.10–0.30)	61.1
Q5	0.11 (0.01–0.21)	35.6
Q6	0.12 (0.03–0.23)	33.2
Q7	0.15 (0.05–0.26)	47.9
Q8	0.13 (0.03–0.33)	36.6
Q9	0.14 (0.04–0.25)	28.4
Q10	0.17 (0.07–0.28)	59.3
Q11	0.22 (0.12–0.33)	73.9
Q12	0.18 (0.08–0.28)	47.7

On the basis of the Gutman–Kaiser criterion (e.g., variance of the factor > 1), the factor analysis extracted two significant latent dimensions of the PLAYself questionnaire. The first latent dimension (F1) explained 44% of the variance, being saturated with the variance of the last three subscales. The second latent dimension was correlated to the first two subscales and explained 33% of the system variance (Table 3).

Table 3. Factor analysis with varimax rotation of the PLAYself questionnaire.

	F1	F2
Environment	−0.06	−0.89
Self-description	0.12	−0.88
Literacy	0.93	0.08
Numeracy	0.93	0.07
Physical literacy	0.66	−0.29
Factor variance	2.19	1.65
Explained variance	44%	33%

The descriptive statistics and *t*-test differences between boys and girls in the PLAYself subscores (Figure 1A) and total score (Figure 1B) evidenced higher scores for girls in literacy-subscale (*t*-test = 3.11, *p* < 0.05; ES (95%CI): 0.63 (0.18–1.07)—medium ES), numeracy-subscale (*t*-test = 3.14, *p* < 0.05; ES (95%CI): 0.67 (0.22–1.18)—medium ES), and physical literacy subscale (*t*-test = 2.89, *p* < 0.05; ES (95%CI): 0.59 (0.14–1.03)—medium ES), and no significant difference between boys and girls in the PLAYself total score (*t*-test = 0.31, *p* > 0.05).

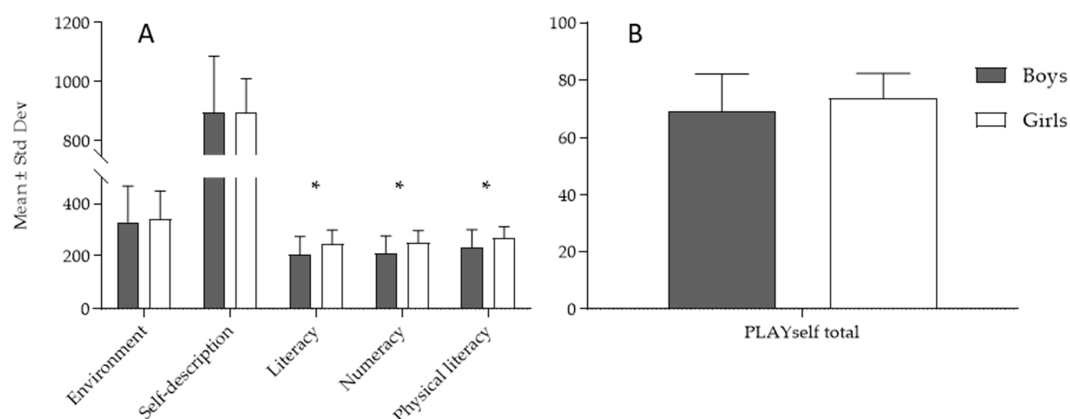


Figure 1. Descriptive statistics and significance of the *t*-test differences (* denotes significance with *p* < 0.05) between boys and girls in the PLAYself subscores (A) and total score (B).

When school ages were compared in relation to the PLAYself subscores (Figure 2A) and PLAYself total score (Figure 2B), no significant differences were found between younger and older children

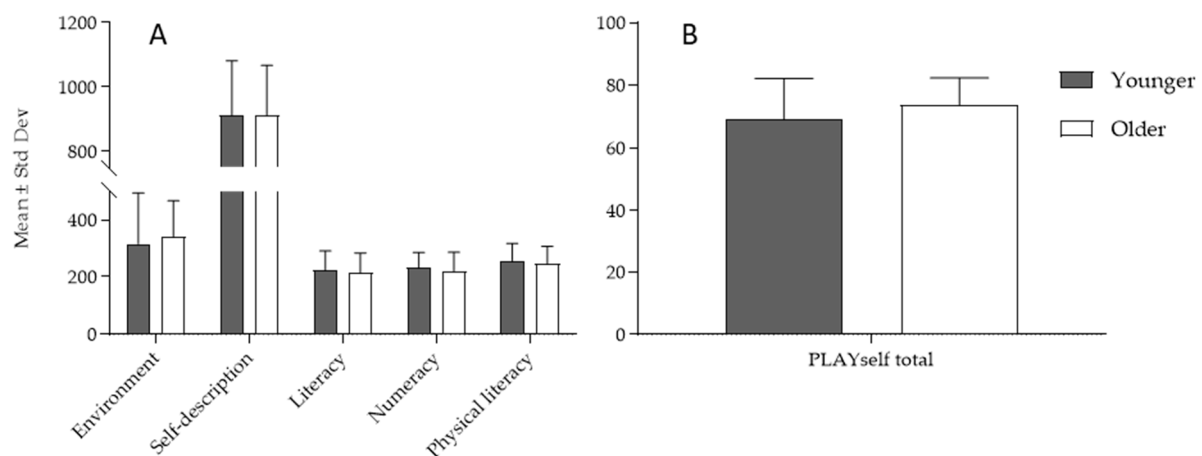


Figure 2. Descriptive statistics in younger and older children in the PLAYself subscores (A) and total score (B).

The children involved in sport (Athletes) achieved higher scores in environment- (t -test = 8.14, $p < 0.001$; ES (95%CI): 1.23 (0.76–1.71)—large ES), and self-description- (t -test = 3.14, $p < 0.01$; ES (95%CI): 0.73 (0.28–1.18)—medium ES) -subscales of PLAYself (Environment and Self-description) than their peers who were not involved in sports (Nonathletes). Nonathletes reported higher scores in the literacy-subscore (t -test = 3.14, $p < 0.05$; ES (95%CI): 0.66 (0.21–1.10)—medium ES) and numeracy-subscore (t -test = 3.13, $p < 0.05$; ES (95%CI): 0.64 (0.19–1.09)—medium ES) (Figure 3A). Generally, the Athletes obtained a higher PLAYself total score, indicating the proper validity of the PLAYSelf questionnaire (t -test = 3.15, $p < 0.05$; ES (95%CI): 0.68 (0.23–1.12)—medium ES) (Figure 3B)

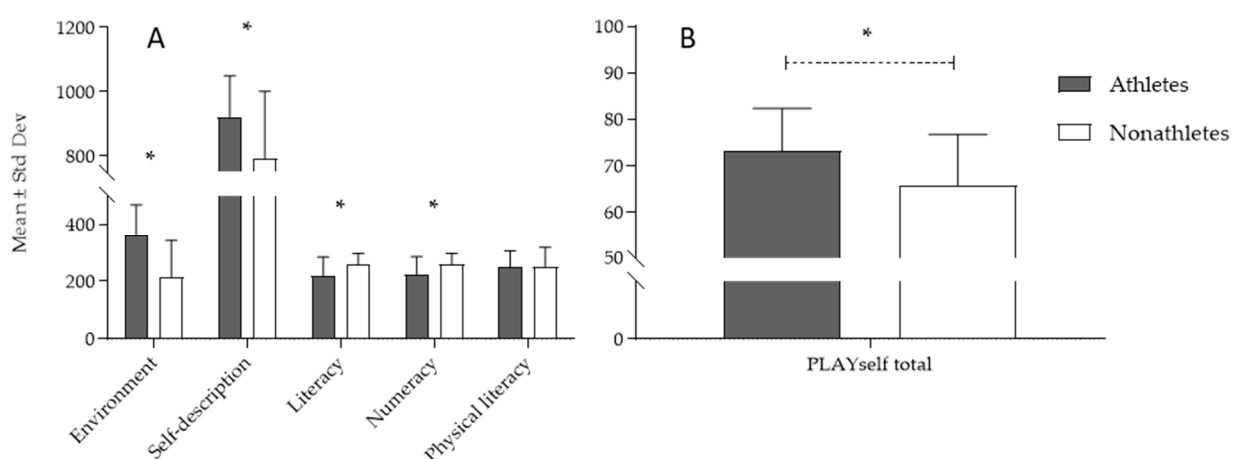


Figure 3. Descriptive statistics and significance of the t -test differences (* denotes significance with $p < 0.05$) between children participating in sports (Athletes) and those not involved in sports (Nonathletes) in the PLAYself subscores (A) and total score (B).

The children who reported a longer involvement in sport achieved higher PLAYself scores (Pearson's correlation = 0.42, $p < 0.01$; moderate correlation) than those who had recently started to practice sport, and a higher number of training sessions per week was also positively correlated with the PLAYself score (Pearson's correlation = 0.43, $p < 0.01$; moderate correlation). These results support the positive association between involvement in sports and PL.

4. Discussion

This study aimed to evaluate the reliability and validity of the translated versions of the tools aimed at the evaluation of PL in children aged 9 to 11 years. The most important findings of our research are as follows. First, we evidenced the proper reliability of the translated version of the PLAYself questionnaire and the insufficient reliability of the CAPL-2 in three studied southeastern European countries. Second, since sport participation was positively associated with the PLAYself total score, PLAYself showed good validity for 9- to 11-year-old children. Initially, we hypothesized the proper reliability and validity of both PL questionnaires, but our findings indicated that the initial study hypothesis could be only partially accepted.

4.1. Reliability

With good internal consistency and test–retest correlation, the translated version of PLAYself showed appropriate stability of the measurements and, therefore, was confirmed as a reliable tool for the evaluation of PL in early-school-age children. This could be due to several factors. Firstly, PLAYself is a questionnaire designed to assess participation in different environments, the affective/cognitive domains of physical literacy, and the valuing of the different types of literacy [17,19]. The questions included in this measurement tool seemed to be clear and understandable for 9- to 11-year-old children, which is the main prerequisite of testing reliability. Also, in the current investigation, follow-up testing was carried out after 5–7 days. During such a short period, the children most likely did not change their personal opinions on the tested issue. Consequently, the results remained consistent, which assured a high reliability.

At the same time, the translated version of the CAPL-2 did not result as reliable. A possible reason for this could be that the CAPL-2 is a questionnaire designed to test knowledge and understanding by focusing on the theoretical knowledge of PL and its importance. Despite the short period between the baseline and the follow-up tests, it is possible that the children learned something new about the examined topics. This resulted in dissimilarities between the baseline and the follow-up tests, decreasing the correlation between test and retest, which consequently altered the reliability parameters. Also, it is possible that the questions in the CAPL-2 were too difficult to understand or answer for 9- to 11-year-old children. As a result, the children were not able to find the correct answers and “guessed” them, which additionally reduced the consistency of the results [33].

Some studies already examined the reliability of the CAPL-2 and PLAYself questionnaires in children, and mostly confirmed the proper reliability of both measurement tools. For example, Jefferies et al. investigated 8- to 14-year-old Canadian children and revealed a moderate reliability of the PLAYself questionnaire, while another study investigating 8- to 14-year-old Canadian children demonstrated a strong inter-reliability of the PLAYself questionnaire [18,19]. Analyzing the knowledge and understanding of PL among 8- to 12-year-old Canadian children, Longmuir et al. (2018) confirmed the reliability of CAPL-2 as well [21]. However, these studies rarely simultaneously evaluated the reliability of different questionnaires. In one of these few studies investigating 14- to 18-year-old Croatian adolescents, Šunda found that both PLAYself and CAPL-2 were reliable, but PLAYself showed higher reliability and suggested that these differences in reliability could be due to specific features of the physical education curriculum in Croatia [26]. The physical education curricula in the three studied countries are mostly oriented toward the development of motor skills and conditioning capacities, while the (theoretical) knowledge and understanding of the importance of PA are poorly considered [26]. If this was the case for older participants (14-to-18 years old), it is certainly even truer for younger children, resulting in the previously discussed issues and in the poor reliability of the CAPL-2 for 3rd and 4th grade elementary school children.

4.2. Validity

A test is valid only if it can distinguish the groups under study [34,35]. To evaluate the validity of the questionnaires assessing PL, differences by gender, age, and sport participation (i.e., involved vs. not involved in sports) were analyzed. In regard to gender differences, the PLAYself results for boys and girls did not differ. Since PLAYself is designed to carry out assessments within a population group (i.e., within participants of the same gender, not between groups of different genders), such results are not surprising. First, physical education in Croatia, Bosnia and Herzegovina, and Montenegro takes place in mixed classes, and the school systems in the three countries apply standardized norms for monitoring, checking, and evaluating the kinanthropological characteristics of the students by gender [36]. Therefore, comparisons are typically carried out among girls or among boys. As the students do not compare themselves to those of the opposite gender, differences between boys and girls are actually not considered nor expected. Indeed, such results are consistent with previous studies confirming no gender differences in PL measures between boys and girls [18,20,28,37,38].

We did not find differences in PLAYself between 3rd- and 4th-grade students. Although studies rarely directly compared age groups in PL evaluations as we did herein, but mostly correlated age with PL, we can say that the results of previous studies are equivocal. For example, our results are in contrast with those of a Canadian study reporting that PL increases with age [21], but support a study investigating 14-to-18-year-old Croatian adolescents which revealed no to trivial associations between age and PL identified by PLAYself and CAPL-2, respectively [37]. Although age could be expected to be correlated with PL, we believe that our findings (i.e., no difference in PL between the studied age categories) are somewhat specific. Firstly, as said previously, the physical-education systems in the studied countries are mostly focused on the development of motor abilities (i.e., motor and functional abilities and motor knowledge), while the development of an overall theoretical knowledge of PL (i.e., importance in everyday life, benefits for improving and preserving health, lifestyle habits, etc.) is negligible [37]. This was especially evident for the children in the first four grades of elementary school, as physical education classes are taught by elementary school teachers and not by physical education teachers [39]. Secondly, it is most likely that the previously mentioned specificities of PLAYself (i.e., assessment within a population group) also had an impact on our results. Possibly, 3rd -grade students compared themselves to other 3rd -grade students, while 4th-grade students compared themselves to other 4th-grade students, which resulted in no association between age and PA.

The validity of the PL measurements was additionally analyzed according to the level of sport participation. Our results revealed differences in the PLAYself scores between students participating and students not participating in sport. Previous studies regularly reported that sport participation is directly linked to a higher PL [19,37,38]. Therefore, it can be concluded that the translated version of the PLAYself questionnaire has appropriate validity for 3rd- and 4th-grade students. The positive correlations of PLAYself with “experience in sport” and “number of training sessions per week” examined in the current study additionally support such conclusions. Specifically, given that PLAYself is a questionnaire that assesses one’s abilities and self-efficacy in practicing PA, physical exercise, and sports, it was reasonable to expect that the children who practiced sport activities for longer times and more frequently would report a better PL. Since the evaluation of self-efficacy involves the judgment of one’s own ability to organize and perform certain tasks [40], it was logical that facets of sport participation would be positively associated with PL. These considerations are supported by previous studies showing that sports participation is positively related to self-efficacy among 13- to 17- year-old students [41].

4.3. Limitations and Strengths of the Study

The main limitation of this study is the evaluation of PL using questionnaires that assessed only the cognitive (knowledge and understanding) and affective (confidence and

motivation) domains of PA. This was due to the fact that the concept of PL in the studied countries is still developing. We did not evaluate other PL variables such as fitness status to further determine the validity of the questionnaire, mostly because of the differences in fitness evaluation standards in the three countries. However, as studies investigating elementary school children are lacking, we decided to carry out a preliminary assessment of PL in this group to establish a foundation for further research on the physical education concept related to PL and its development in the elementary school.

Meanwhile, this is one of the first studies in Europe, and possibly the first in south-eastern Europe, investigating PL among children of young school ages. This is also one of the rare studies that simultaneously investigated the reliability and the validity of two PL assessment tools, allowing an objective comparison between them. Although we studied versions of the PL evaluation tools in only three countries from the territory of former Yugoslavia, where similar Slavic languages are spoken, we hope that our results will allow a wider usage of these measurement tools.

5. Conclusions

We confirmed good reliability of the translated version of the PLAYself questionnaires for children aged 9–11 years. In contrast, the reliability of the CAPL-2 was not confirmed. Therefore, we suggest the usage of PLAYself in further studies examining PL in children of similar ages in the region.

The validity of PLAYself was found to be appropriate. This conclusion is based on (i) the significant differences that we observed between the children involved in sports and those not involved (with better PL for those who participated in sports) and (ii) the significant correlation of the PLAYself scores relative to the time of the sport involvement and training frequency.

While this study involved specific groups of participants (school-age children) from urban regions, further analyses are needed in other age groups and environments. In addition, intervention studies aimed at finding the most effective methods to improve PL in school-age children are warranted.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the Faculty of Kinesiology, University of Split, Croatia (EBO: 2181-205-02-01-21-0011; date of approval, 23 September 2021).

Informed Consent Statement: Written consent was obtained from parents/legal guardians of all children involved in study, while children gave their informal consent.

Data Availability Statement: Data are available upon reasonable request.

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References

1. Dampoudani, N.; Giakouvaki, A.; Diamantoudi, D.; Skoufi, G.; Kontogiorgis, C.A.; Constantinidis, T.C.; Nena, E. Physical Activity, Body Mass Index (BMI) and Abdominal Obesity of Pre-Adolescent Children in the Region of Thrace, NE Greece, in Relation to Socio-Demographic Characteristics. *Children* **2022**, *9*, 340. [[CrossRef](#)] [[PubMed](#)]
2. Sanchez-Oliva, D.; Sanchez-Miguel, P.A.; Leo, F.M.; Kinnafick, F.E.; Garcia-Calvo, T. Physical Education Lessons and Physical Activity. Intentions Within Spanish Secondary Schools: A Self-Determination Perspective. *J. Teach. Phys. Educ.* **2014**, *33*, 232–249. [[CrossRef](#)]

3. Van der Horst, K.; Paw, M.J.C.A.; Twisk, J.W.R.; Van Mechelen, W. A brief review on correlates of physical activity and sedentariness in youth. *Med. Sci. Sports Exerc.* **2007**, *39*, 1241–1250. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Dumith, S.C.; Gigante, D.P.; Domingues, M.R.; Kohl, H.W. Physical activity change during adolescence: A systematic review and a pooled analysis. *Int. J. Epidemiol.* **2011**, *40*, 685–698. [\[CrossRef\]](#)
5. Farooq, A.; Martin, A.; Janssen, X.; Wilson, M.G.; Gibson, A.M.; Hughes, A.; Reilly, J.J. Longitudinal changes in moderate-to-vigorous-intensity physical activity in children and adolescents: A systematic review and meta-analysis. *Obes. Rev.* **2020**, *21*, e12953. [\[CrossRef\]](#)
6. Krenz, L.; Grauduszus, M.; Klaudius, M.; Stolz, I.; Wessely, S.; Joisten, C. Development of a German Physical Literacy Assessment for Children in the Context of Health Promotion—An Explorative Approach. *Children* **2022**, *9*, 1908. [\[CrossRef\]](#)
7. Durden-Myers, E.J.; Bartle, G.; Whitehead, M.E.; Dhillon, K.K. Physical Literacy and Intentionality. *J. Phys. Educ. Recreat. Dance* **2021**, *92*, 42–49. [\[CrossRef\]](#)
8. Whitehead, M. Definition of physical literacy and clarification of related issues. *Icsp Bull.* **2013**, *65*, 29–35.
9. Lounsbury, M.A.F.; McKenzie, T.L. Physically literate and physically educated: A rose by any other name? *J. Sport Health Sci.* **2015**, *4*, 139–144. [\[CrossRef\]](#)
10. de Dieu, H.J.; Zhou, K. Physical Literacy Assessment Tools: A Systematic Literature Review for Why, What, Who, and How. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7954. [\[CrossRef\]](#)
11. Tremblay, M.S.; Longmuir, P.E. Conceptual Critique of Canada’s Physical Literacy Assessment Instruments Also Misses the Mark. *Meas. Phys. Educ. Exerc.* **2017**, *21*, 174–176. [\[CrossRef\]](#)
12. Longmuir, P.E.; Tremblay, M.S. Top 10 Research Questions Related to Physical Literacy. *Res. Q. Exerc. Sport* **2016**, *87*, 28–35. [\[CrossRef\]](#)
13. Francis, C.E.; Longmuir, P.E.; Boyer, C.; Andersen, L.B.; Barnes, J.D.; Boiarskaia, E.; Cairney, J.; Faigenbaum, A.D.; Faulkner, G.; Hands, B.P.; et al. The Canadian Assessment of Physical Literacy: Development of a Model of Children’s Capacity for a Healthy, Active Lifestyle Through a Delphi Process. *J. Phys. Act. Health* **2016**, *13*, 214–222. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Longmuir, P.E.; Gunnell, K.E.; Barnes, J.D.; Belanger, K.; Leduc, G.; Woodruff, S.J.; Tremblay, M.S. Canadian Assessment of Physical Literacy Second Edition: A streamlined assessment of the capacity for physical activity among children 8 to 12 years of age. *BMC Public Health* **2018**, *18*, 1047. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Longmuir, P.E.; Boyer, C.; Lloyd, M.; Yang, Y.; Boiarskaia, E.; Zhu, W.M.; Tremblay, M.S. The Canadian Assessment of Physical Literacy: Methods for children in grades 4 to 6 (8 to 12 years). *BMC Public Health* **2015**, *15*, 767. [\[CrossRef\]](#)
16. Gunnell, K.E.; Longmuir, P.E.; Woodruff, S.J.; Barnes, J.D.; Belanger, K.; Tremblay, M.S. Revising the motivation and confidence domain of the Canadian assessment of physical literacy. *BMC Public Health* **2018**, *18*, 1045. [\[CrossRef\]](#)
17. Kriellaars, D.; Kozera, T.; Robillard, B. Physical Literacy Assessment for Youth. PLAY Workbook. Available online: http://physicalliteracy.ca/wp-content/uploads/2016/08/PLAYfun_workbook.pdf (accessed on 1 September 2023).
18. Caldwell, H.A.; Di Cristofaro, N.A.; Cairney, J.; Bray, S.R.; Timmons, B.W. Measurement properties of the Physical Literacy Assessment for Youth (PLAY) Tools. *Appl. Physiol. Nutr. Metab.* **2021**, *46*, 571–578. [\[CrossRef\]](#)
19. Jefferies, P.; Bremer, E.; Kozera, T.; Cairney, J.; Kriellaars, D. Psychometric properties and construct validity of PLAYself: A self-reported measure of physical literacy for children and youth. *Appl. Physiol. Nutr. Metab.* **2021**, *46*, 579–588. [\[CrossRef\]](#)
20. Tremblay, M.S.; Longmuir, P.E.; Barnes, J.D.; Belanger, K.; Anderson, K.D.; Bruner, B.; Copeland, J.L.; Nystrom, C.D.; Gregg, M.J.; Hall, N.; et al. Physical literacy levels of Canadian children aged 8–12 years: Descriptive and normative results from the RBC Learn to Play-CAPL project. *BMC Public Health* **2018**, *18*, 1036. [\[CrossRef\]](#)
21. Longmuir, P.E.; Woodruff, S.J.; Boyer, C.; Lloyd, M.; Tremblay, M.S. Physical Literacy Knowledge Questionnaire: Feasibility, validity, and reliability for Canadian children aged 8 to 12 years. *BMC Public Health* **2018**, *18*, 1035. [\[CrossRef\]](#)
22. Dania, A.; Kaioglou, V.; Venetsanou, F. Validation of the Canadian Assessment of Physical Literacy for Greek children: Understanding assessment in response to culture and pedagogy. *Eur. Phys. Educ. Rev.* **2020**, *26*, 903–919. [\[CrossRef\]](#)
23. Li, M.H.; Sum, R.K.W.; Tremblay, M.; Sit, C.H.P.; Ha, A.S.C.; Wong, S.H.S. Cross-validation of the Canadian Assessment of Physical Literacy second edition (CAPL-2): The case of a Chinese population. *J. Sports Sci.* **2020**, *38*, 2850–2857. [\[CrossRef\]](#) [\[PubMed\]](#)
24. Elsborg, P.; Melby, P.S.; Kurtzhals, M.; Tremblay, M.S.; Nielsen, G.; Bentsen, P. Translation and validation of the Canadian assessment of physical literacy-2 in a Danish sample. *BMC Public Health* **2021**, *21*, 2236. [\[CrossRef\]](#) [\[PubMed\]](#)
25. Pastor-Cisneros, R.; Carlos-Vivas, J.; Adsuar, J.C.; Barrios-Fernández, S.; Rojo-Ramos, J.; Vega-Muñoz, A.; Contreras-Barraza, N.; Mendoza-Muñoz, M. Spanish Translation and Cultural Adaptation of the Canadian Assessment of Physical Literacy-2 (CAPL-2) Questionnaires. *Int. J. Environ. Res. Public Health* **2022**, *19*, 8850. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Sunda, M.; Gilic, B.; Sekulic, D.; Matic, R.; Drid, P.; Alexe, D.I.; Cucui, G.G.; Lupu, G.S. Out-of-School Sports Participation Is Positively Associated with Physical Literacy, but What about Physical Education? A Cross-Sectional Gender-Stratified Analysis during the COVID-19 Pandemic among High-School Adolescents. *Children* **2022**, *9*, 753. [\[CrossRef\]](#)
27. Carl, J.; Bryant, A.S.; Edwards, L.C.; Bartle, G.; Birch, J.E.; Christodoulides, E.; Emeljanovas, A.; Froberg, A.; Gandrieau, J.; Gilic, B.; et al. Physical literacy in Europe: The current state of implementation in research, practice, and policy. *J. Exerc. Sci. Fit.* **2023**, *21*, 165–176. [\[CrossRef\]](#)

28. Gilic, B.; Malovic, P.; Sunda, M.; Maras, N.; Zenic, N. Adolescents with Higher Cognitive and Affective Domains of Physical Literacy Possess Better Physical Fitness: The Importance of Developing the Concept of Physical Literacy in High Schools. *Children* **2022**, *9*, 796. [\[CrossRef\]](#)
29. Koo, T.K.; Li, M.Y. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J. Chiropr. Med.* **2016**, *15*, 155–163. [\[CrossRef\]](#)
30. Connelly, L.M. Cronbach's alpha. *Medsurg Nurs.* **2011**, *20*, 45–47.
31. McHugh, M.L. Interrater reliability: The kappa statistic. *Biochem. Med.* **2012**, *22*, 276–282. [\[CrossRef\]](#)
32. Akoglu, H. User's guide to correlation coefficients. *Turk. J. Emerg. Med.* **2018**, *18*, 91–93. [\[CrossRef\]](#) [\[PubMed\]](#)
33. Frary, R.B.; Cross, L.H.; Lowry, S.R. Random guessing, correction for guessing, and reliability of multiple-choice test scores. *J. Exp. Educ.* **1977**, *46*, 11–15. [\[CrossRef\]](#)
34. Uljevic, O.; Spasic, M.; Sekulic, D. Sport-specific motor fitness tests in water polo: Reliability, validity and playing position differences. *J. Sports Sci. Med.* **2013**, *12*, 646. [\[PubMed\]](#)
35. Sekulic, D.; Pehar, M.; Krolo, A.; Spasic, M.; Uljevic, O.; Calleja-González, J.; Sattler, T. Evaluation of basketball-specific agility: Applicability of preplanned and nonplanned agility performances for differentiating playing positions and playing levels. *J. Strength Cond. Res.* **2017**, *31*, 2278–2288. [\[CrossRef\]](#) [\[PubMed\]](#)
36. Novak, D.; Podnar, H.; Emeljancova, A.; Marttinen, R. Comparison of Fitness Levels between Croatian and Lithuanian Students. *Montenegrin J. Sport. Sci. Med.* **2015**, *4*, 5–12.
37. Šunda, M. Utjecaj Učenja na Daljinu i Unaprjeđenja Tjelesne Pismenosti na Promjene Stanja Fitnesa i Tjelesne Aktivnosti adolescenata. Ph.D. Thesis, University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia, 2022. (In Croatian).
38. Telford, R.M.; Telford, R.D.; Cochrane, T.; Cunningham, R.B.; Olive, L.S.; Davey, R. The influence of sport club participation on physical activity, fitness and body fat during childhood and adolescence: The LOOK Longitudinal Study. *J. Sci. Med. Sport* **2016**, *19*, 400–406. [\[CrossRef\]](#)
39. Petračić, T. Povezanost Nekih Odrednica Rada i Kvalitete Provedbe Nastave Tjelesne i Zdravstvene Kulture u Primarnoj Edukaciji. Ph.D. Thesis, University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia, 2023. (In Croatian).
40. Bandura, A. Self-efficacy: Toward a unifying theory of behavioral change. *Psychol. Rev.* **1977**, *84*, 191. [\[CrossRef\]](#)
41. Arribas-Galarraga, S.; Luis-de Cos, I.; Luis-de Cos, G.; Urrutia-Gutierrez, S. Mediation effect of perceived fitness on the relationship between self-efficacy and sport practice in Spanish adolescents. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8800. [\[CrossRef\]](#)

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Article

Analyzing the Associations between Facets of Physical Literacy, Physical Fitness, and Physical Activity Levels: Gender- and Age-Specific Cross-Sectional Study in Preadolescent Children

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Abstract: Physical literacy (PL) is theorized to be an important determinant of physical fitness (PF) and physical activity levels (PALs), but studies have rarely examined possible correlations between PL, PF, and PAL in preadolescent children. This study aimed to evaluate age-specific and gender-specific correlations between the affective and cognitive domains of PL (PL_{AC}), PF, and PAL in preadolescents. Additionally, the test–retest reliability of the applied PF tests was examined. The participants were 107 children (9 to 11 years of age; 53 girls). Apart from gender and school age (third graders, fourth graders), the variables included PL_{AC}, PAL, and PF. PF was evaluated by anthropometrics and body composition indices, sit-ups, push-ups, PACER tests, torso lifts, and broad jump. PL_{AC} was evaluated using the PLAYself questionnaire, and the PAQ-C was used to evaluate PAL. The test–retest reliability of the PF tests was appropriate to high (ICC: 0.65–0.91). Analyses showed nonsignificant associations between PL_{AC} and PAL in both genders and age groups. PAL was significantly correlated with PL in girls (low correlation) and fourth graders (moderate correlation). The nonsignificant associations between PL_{AC} and PF could be a consequence of the influence of biological maturity on PF in this age group. The correlation between PAL and PL_{AC} can be explained by the differences in physical activity habits between genders and age groups, with participation in structured physical activities (organized sports and physical education) being the most important source of PAL in girls and older children.

Keywords: physical education; sports; reliability; school-aged children; physical literacy



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1. Introduction

Physical fitness (PF) is a state of health and well-being and, more specifically, the ability to perform aspects of sports, occupations, and daily activities [1]. A good PF in childhood and adolescence is the basis for a healthy lifestyle and an important indicator of the current and future health status, because high levels of PF during childhood and adolescence have a positive effect on the health in adulthood [2,3].

It is well-known that maintaining satisfactory PF in children and adolescents reduces the risks of obesity, cardiovascular diseases, and diabetes in adulthood [4,5]. Furthermore, the results of research on mental health indicate a positive connection between PF and overall mental health in children and young people [6]. Finally, studies have confirmed the positive association between PF, quality of life, and the health of children and adolescents,

in addition to a strong body of evidence demonstrating a positive relationship between PF and academic success [7,8].

Physical activity (PA) is considered a crucial factor in achieving good PF. There is strong evidence that PA has multiple benefits for children and adolescents, such as improving physical and mental health; sleep quality; brain development; bone health; and social, psychological, and cognitive health [9]. Furthermore, PA is recognized as an important factor in the prevention of excess body weight and obesity in children and in slowing the development of obesity in adulthood [10]. During childhood, adequate levels of PA are a fundamental prerequisite for developing basic cognitive, motor, and social skills, as well as musculoskeletal, cardiovascular, and metabolic health [11]. Unfortunately, most of the young population is not physically active, i.e., 81% of children and adolescents do not have a sufficient level of PA [12], and studies that state that children and adolescents have an insufficient level of PF emphasize that the reason is mainly insufficient PA [12–14].

Previous studies have investigated the influence of PA on PF [15,16]. In general, an increase in PA is considered to lead to an improvement in PF [14,17,18]. However, some studies indicate that increasing PA alone is insufficient for children [19]. The reason for this is that the risk of cardiovascular diseases in the future is determined by the level of PF [20], so the emphasis should be on promoting physical activity that will directly increase the level of PF [21]. Recently, in this sense, there has been an increasingly visible interest in the issue of “physical literacy”.

Physical literacy (PL) is defined as “the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engagement in physical activities for life” [22]. The domains of PL (i.e., physical competence, motivation and self-confidence, and knowledge) are inter-related and are crucial for supporting participation in PA while growing up and in adulthood [23]. The concept of PL is seen as a way of encouraging and maintaining lifelong engagement in PA. Indeed, PL is a holistic concept and consists of numerous domains including PA behavior, physical competence, motivation, confidence, knowledge, and understanding, which emphasize the affective, physical, and cognitive predispositions necessary to take part in PA throughout the life course [24,25]. The affective domain, which is potentially the most important for lifelong participation in PA, includes confidence, motivation, enjoyment, commitment, autonomy, self-esteem, and perceived physical competence [25].

Different concepts of PL and tools for assessing PL levels have been developed worldwide, and there is no consensus on which is the most appropriate [26,27]. Among the most popular and commonly used tools for assessing PL in the research are the Canadian Assessment of Physical Literacy (CAPL) and the Physical Literacy Assessment of Youth (PLAY) [27,28]. Attributes of physical competence in the multidimensional concept of PL have a close link with individual domains of PF and, as constructs, are connected through common basic components [29]. It is, therefore, not surprising that researchers have addressed the relationship between the affective and cognitive domains of PL (PL_{AC}) and PF measures. For example, Canadian studies performed with children aged 8 to 12 and 9 to 11 years have reported a positive association between cardiorespiratory fitness (aerobic fitness) and PL_{AC} [29,30]. This is supported by a very recent French study with children aged 11 and 12, where the authors reported that PL_{AC} was positively related to the percentage of muscle mass and negatively related to the percentage of body fat [31].

From the previous literature overview, it is clear that the affective and cognitive domains of PL may be related to the overall fitness status of children. However, it seems that studies have rarely examined various indices of PF in relation to PL_{AC} in preadolescent children, and those that did were mostly focused on cardiovascular fitness [29–31]. Also, it seems that studies on the relationships between PF and PL performed so far have observed different age groups at the same time [29–31], which may have introduced bias. Specifically, previous investigations have highlighted that children evaluate their PL based on comparison with their similarly aged peers [32]. This means that different age groups should be observed as stratified samples, at least in situations when PL is intended to

be correlated with objectively measured PF. Therefore, this study aimed to evaluate the age-stratified and gender-stratified associations between PL_{AC}, PAL, and various indices of PF in preadolescent children (9 to 11 years of age). Additionally, we examined the test–retest reliability of the PF tests in the studied preadolescent children. Initially, we had two study hypotheses: (i) PL will be positively associated with PF, and (ii) facets of PL will be positively associated with PAL in preadolescents.

2. Materials and Methods

2.1. Participants and Study Design

The participants in this study were 107 preadolescent children (53 girls) from Croatia. When conducting the research, all participants were between the ages of 9 and 11, attended the 3rd ($n = 52$) or 4th grade ($n = 55$) of elementary school, were in good health, and regularly attended physical education (PE) classes. Children who were ill or had a locomotor injury during the two weeks prior to the test did not participate in this study. Prior to this study, the parents/guardians were informed by the research team about the goals and procedures of this research, and they signed informed consent for the children's participation. For the reliability study, a subsample of 21 randomly selected children was tested across a test and retest trial, within the time frame of 7–10 days. The number of participants tested in the reliability study ensured we gained a sufficient number of observations in order to achieve a normal distribution of results, while, at the same time, allowing for similar testing conditions in relatively short time period, which was crucial for the stability of testing.

The research was approved by the Ethics Committee of the Faculty of Kinesiology, University of Split. The study design is presented in Figure 1.

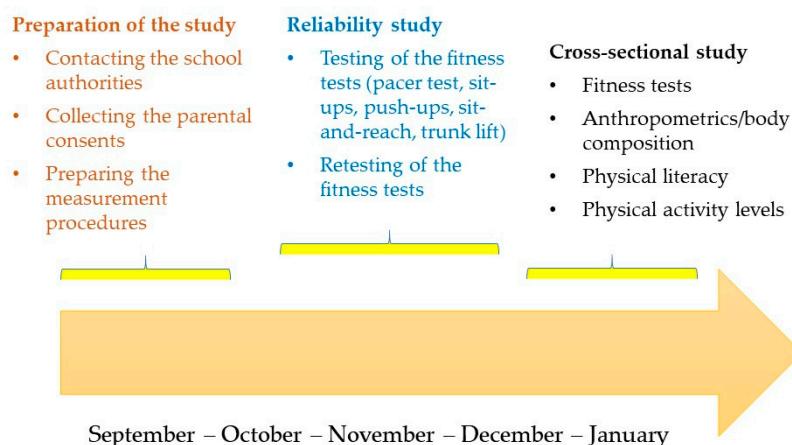


Figure 1. Study design and time frames.

2.2. Variables and Procedures

In addition to the school grade (3rd or 4th), gender (male or female), and age (years), we also observed anthropometric and body composition indices, PL, PF (including anthropometric/body composition indices), and PAL. Body composition and anthropometrics were evaluated by a highly skilled technician with long-term experience in testing. Fitness tests were carried out by physical education teachers, where one examiner tested all children at once. Altogether five examiners tested all children. All evaluators were experienced and specifically instructed in performing the tests before this study. Furthermore, the PF tests were well-known to all evaluators (please see later for details) because they are regularly used in schools in Croatia.

The PL_{AC} was evaluated by the PLAYself questionnaire, a part of the PLAY tools (PLAYfun, PLAYbasic, PLAYself, PLAYparent, PLAYcoach, and PLAYinventory) [33]. This questionnaire is used by children and adolescents for self-assessment of their PL_{AC} level and has four subdomains: (i) Environment, which assesses the degree of confidence of movement in different environments (e.g., activities in the gym, in and on water, and on

snow and ice). (ii) Self-report of PL, which assesses a number of affective and cognitive segments (e.g., motivation, confidence, and self-esteem) related to PL that determine an individual's self-efficacy and ability to participate in PA, including questions such as "It does not take me long to learn new skills, sports or activities", "I think that being active is important for my physical and mental health", "I think that exercise makes me happier", and "I understand the words used by trainers and PE teachers". (iii) The relative ranking of literacy with its subdomains of Literacy, Numeracy, and Physical Literacy assesses literacy in different environments (e.g., school, home, and friends) and assesses how much an individual values each of the mentioned literacies. (iv) The state of fitness (fitness) is determined by the question, "My state of fitness is good enough to allow me to participate in all the activities I choose". However, this subdomain is not included in the final score of PLAYself. The final result of the questionnaire consists of the sum of points from the first three subdomains divided by the number of questions (27 in total). The maximum number of PLAYself points is 100, which represents a high self-concept of PL_{AC}. The Croatian version of the PLAYself questionnaire has recently proved to be feasible and reliable in Croatian children aged 9 to 11 [32].

The level of PA was assessed using the "Physical Activity Questionnaire for Older Children" (PAQ-C) [34]. The PAQ-C-Croatian version of the questionnaire for assessing the level of physical activity was constructed for children of a similar age to those sampled (from 8 to 14 years) to quantitatively assess the overall level of physical activity [35]. The questionnaire consists of 9 questions that are evaluated on a 5-point scale, for example, "In the last 7 days, what did you mostly do during a long break (except eating a snack)?" and "Indicate how often you were engaged in some physical activity (e.g., sports, games, dancing or any other physical activity) every day of the last week." The total physical activity score is predicted based on the mean of the answers given. A score of 5 is the maximum value of the PAQ-C and represents high activity, while a score of 1 represents very low or no activity. For the testing of the PAL and PL_{AC}, an online testing platform was used, and children were tested in school classroom in small groups. One of the examiners was available if the children needed help during the test, but the examiner was positioned behind the computer screen and could not see the answers. Testing was carried out in small groups, of up to 10 children, and the children could not see the other participants' answers.

The PF was evaluated by tests included in the FitnessGram battery [36]. The battery includes tests to assess aerobic endurance, abdominal muscular strength and endurance, torso extensor strength and flexibility, upper body strength and endurance, flexibility, body height, body mass, and body composition. Additionally, we included a broad jump test because this procedure is regularly used in Croatian PE.

Body height (BH) was measured with an altimeter. The measurement is performed with the participant standing barefoot on a flat and firm surface in an upright position. The position of the participant's head fulfills the requirement of the Frankfurt horizontal, looking straight ahead. The result is measured in centimeters, with an accuracy of 0.1 cm. Body mass (BM) was measured with a digital diagnostic scale (Tanita BC 418 scale; serial number 15010067, 2015). The measurement is performed with the participant standing barefoot and upright on the scale, wearing a sports shirt and shorts. The result is expressed in kilograms with an accuracy of 0.1 kilograms. The scale also measures body composition using the bioimpedance method (Tanita BC 418 scale; serial number 15010067, 2015), and, in this research, we assessed body fat percentage and muscle mass percentage.

The 15 m PACER test was used to assess aerobic endurance. The test consists of 21 or more levels of 7 or more intervals of running segments of 15 m. Students run from one end to the other of a segment marked with cones and must touch the line when the buzzer sounds. At the sound of the beep, they turn and run back to the other end. Participants continue to do this until they reach the line before two beeps. The goal is to cross as many levels as possible, and the result is expressed numerically in levels. Additionally, we calculated VO₂ max/kg using the Leger et al. equation: $\text{VO}_2 \text{ max/kg} = 31.025 + 3.238 (\text{running speed in km/h}) - 3.248 (\text{age in years}) + 0.1536 (\text{running speed} \times \text{age})$ [36,37].

The curl-up test was used to assess abdominal muscular strength and endurance. The test is performed by having the participant lift the torso as many times as possible, up to a maximum of 75. The result is the maximum number of correctly performed torso lifts.

The torso lift test assessed torso extensor strength and flexibility. On cue, the participant independently raises the cervical and thoracic parts of the spine in a controlled manner to their maximum, with the head in a neutral position in line with the spine.

The push-up test was used to assess upper body strength and endurance. The test is performed so the participant takes a pronated position on the mat with the palms under the shoulders, fingers extended, legs extended and parallel, and feet slightly apart, resting on the toes. The participant pushes off the mat with their hands until their arms are extended, keeping their legs and back straight. The participant then lowers their body using their arms until their elbows are bent at 90 degrees and their upper arms are parallel to the floor. The result is the maximum number of correctly performed push-ups [36,38].

The sit-and-reach test was used to obtain the flexibility for the lower back and hamstring muscles. The participant sits on the floor with their legs extended straight ahead, feet shoulder-width apart, and positioned against the box or measuring device. With their palms down and fingers pointing forward, the individual reaches forward along the measuring device as far as possible, holding the position for at least two seconds. Three trials are performed and the average score is used as a final result.

The standing long jump assessed the jumping performance/power capacity. The test is performed so the participant stands behind the starting mark and jumps from the place with bare feet as far as they can. A standardized measurement mat was used (ELAN, Begunje, Slovenia). The result was measured in centimeters, as a best of three attempts [39].

2.3. Statistics

In the first phase, all variables were checked for normality by the Kolmogorov–Smirnov test (Supplementary Table S1). For normally distributed variables, means and standard deviations were reported, while counts and percentages were reported for categorical and ordinal variables (i.e., gender, age).

To identify the reliability of the fitness tests, intraclass correlation coefficients (ICCs) were calculated for multiple trial tests (e.g., torso lift, standing long jump, sit-and-reach), while test–retest correlation was calculated for single-trial tests (sit-ups, push-ups, PACER test). To identify potential measurement bias, analysis of variance (ANOVA) was calculated among trials for multiple-trial tests (with the consecutive Scheffe post hoc test), while a *t*-test for dependent samples was calculated for single-trial tests.

Two-way factorial analysis of variance (2-way ANOVA) with “Group” (3rd vs. 4th class) and “Gender” as the main effects and “Group x Gender” as the interaction effect was performed to evaluate the differences in the study variables.

The associations between study variables were evaluated by Pearson’s correlations (Pearson’s *R*) calculated for the total sample, gender-stratified sample, and age-stratified sample. Numerical values of correlation coefficients were translated into magnitude-based descriptors, as previously suggested (very low correlation (0.00–0.20), low correlation (0.21–0.40), moderate correlation (0.41–0.60), high correlation (0.61–0.80), and very high correlation (0.81–1.00)) [40].

Statistica ver. 14.0 (Tibco Inc., Palo Alto, CA, USA) was used for all calculations, and a statistical significance of $p < 0.05$ was applied.

3. Results

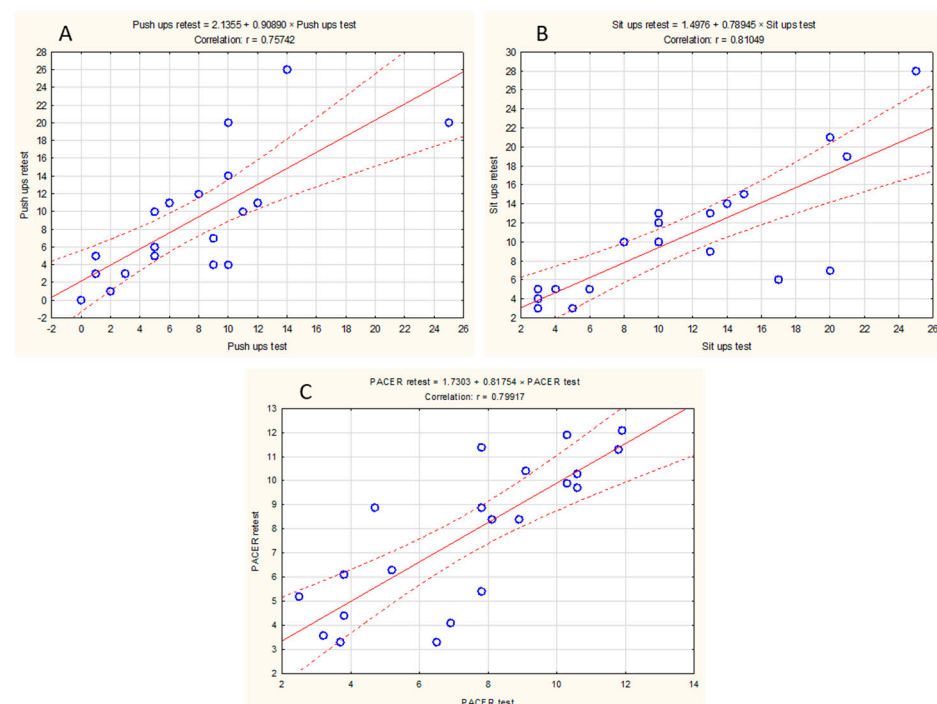
The results of the reliability analyses for multiple-trial tests are shown in Table 1. The highest reliability was obtained for the broad jump test, followed by the sit-and-reach test and the torso lift test.

Table 1. Between-testing reliability of the multiple trial fitness tests in preadolescent children (ICC—intraclass correlation, CI—confidence interval).

	ICC	95% CI
Trunk lift	0.66	0.61–0.71
Broad jump	0.91	0.89–0.93
Sit and reach	0.83	0.80–0.86

ANOVA revealed differences among the testing trials for the broad jump (F -test = 14.11, $p < 0.01$). In general, the test results improved across trials (Trial 1: 127.17 ± 18.9 , Trial 2: 131.16 ± 20.97 , Trial 3: 134.19 ± 20.47 cm) but significant post hoc differences ($p < 0.05$) were detected only between the first and remaining two trials, indicating stabilization of the results until the third trial. Similarly, significant ANOVA differences among testing trials were found for trunk lift (F -test = 6.36, $p < 0.01$), with significant ($p < 0.05$) post hoc differences when the results of the first and second trials were compared to those of the third trial. Finally, the ANOVA effect was significant for the sit-and-reach test ($F = 15.11$, $p < 0.01$), as was the difference between the first and remaining two trials. Therefore, the reliability and stability of the measurements were evidenced for all multiple-trial fitness tests.

Figure 2 presents the test–retest correlations for the push-up (Figure 2A), sit-up (Figure 2B), and PACER tests (Figure 2C).

**Figure 2.** Test–retest correlations for the push-ups (A), sit-ups (B), and PACER test (C) in preadolescent children.

The test and retest results for all three tests were significantly correlated, with 64% common variance in the PACER test, 66% in the sit-up test, and 57% in the push-up test. A dependent-samples t -test revealed no significant differences between the test and retest results for any of the single-item tests, altogether indicating the reliability of the single-trial fitness tests (t test = 1.47, 0.91, and 0.90 for sit-ups, push-ups, and the PACER test, respectively; all $p > 0.05$).

Descriptive statistics and the results of the Kolmogorov–Smirnov tests for the total sample are presented in Supplementary Table S1. The results of the two-way ANOVA are

presented in Table 2. Significant main effects for gender were evidenced for the torso lift, sit-and-reach, PACER, and push-ups. Significant interaction effects were found for the body mass, body mass index, fat mass, and muscle mass.

Table 2. Two-way ANOVA results for study variables.

	Main Effects				Interaction	
	Group		Gender		Group x Gender	
	F-Test	p	F-Test	p	F-Test	p
Body height	3.31	0.07	0.78	0.38	1.53	0.22
Body mass	0.40	0.53	0.29	0.59	5.09	0.03
Body mass index	0.42	0.52	0.05	0.82	4.2	0.04
Fat mass	0.32	0.57	0.01	0.94	7.86	0.01
Muscle mass	0.86	0.36	0.20	0.65	4.00	0.06
Torso lift	0.47	0.49	14.31	0.001	0.01	0.94
Broad jump	6.05	0.02	2.68	0.11	0.22	0.64
Sit and reach	0.88	0.35	18.82	0.001	0.09	0.76
PACER	1.22	0.29	12.11	0.001	3.47	0.08
Sit-ups	0.73	0.40	0.87	0.35	0.05	0.82
Push-ups	0.56	0.46	7.55	0.01	2.38	0.13
PLAYself	0.46	0.50	0.00	1.00	0.39	0.53
PAQ-C	3.55	0.06	0.23	0.63	1.17	0.28

The descriptive statistics for specific subgroups and post hoc differences are presented in Table 3. Boys achieved better results than girls in the PACER test (in third grade) and push-ups (in third and fourth grades). Girls were better than boys in the torso lift and sit-and-reach test in both grades. In third grade, boys were heavier and had more fat mass than girls, but the figures were the opposite in fourth grade.

Table 3. Descriptive statistics (means $\pm$ standard deviations) for study variables according to gender and age group with post hoc differences (* denotes significant differences between genders, $^{\text{¥}}$ indicates significant differences within genders).

	Third Grade		Fourth Grade	
	Boys (n = 27)	Girls (n = 25)	Boys (n = 27)	Girls (n = 28)
Body height (cm)	143.79 $\pm$ 5.8	143.85 $\pm$ 6.2	147.42 $\pm$ 6.29	144.93 $\pm$ 7.06
Body mass (kg)	36.37 $\pm$ 7.34 * $^{\text{¥}}$	39.1 $\pm$ 8.63 $^{\text{¥}}$	40.54 $\pm$ 8.78 *	36.49 $\pm$ 7.49
Body mass index (kg/m ²)	17.49 $\pm$ 2.8 *	18.83 $\pm$ 3.54 $^{\text{¥}}$	18.32 $\pm$ 3.05	17.24 $\pm$ 2.47
Fat mass (%)	22.86 $\pm$ 4.08 * $^{\text{¥}}$	25.78 $\pm$ 5.57	25.64 $\pm$ 6.43	23.55 $\pm$ 5.2
Muscle mass (%)	43.67 $\pm$ 2.31	42.52 $\pm$ 3.85	42.08 $\pm$ 3.63	43.26 $\pm$ 2.95
Torso lift (cm)	16.62 $\pm$ 3.88 *	19.45 $\pm$ 5.19	17.46 $\pm$ 4.45 *	20.48 $\pm$ 3.94
Broad jump (cm)	134.79 $\pm$ 19.38	131.00 $\pm$ 13.58	145.71 $\pm$ 20.63	137.16 $\pm$ 22.15
Sit and reach (cm)	42.41 $\pm$ 7.72 *	53.00 $\pm$ 15.27	41.75 $\pm$ 11.4 *	55.00 $\pm$ 9.69
PACER (ml/kg/min)	56.65 $\pm$ 6.81 *	50.85 $\pm$ 4.5	54.63 $\pm$ 6.5	52.32 $\pm$ 3.9
Sit-ups (reps)	12.24 $\pm$ 8.46	13.82 $\pm$ 13.92	9.83 $\pm$ 6.91	12.32 $\pm$ 10.17
Push-ups (reps)	8.97 $\pm$ 6.39 *	6.5 $\pm$ 6.05	11.73 $\pm$ 9.96 *	6.2 $\pm$ 6.79
PLAYself (score)	71.6 $\pm$ 13.31	73.06 $\pm$ 10.66	75.18 $\pm$ 8.69	73.57 $\pm$ 10.99
PAQ-C (score)	3.38 $\pm$ 0.62	3.43 $\pm$ 0.68	3.69 $\pm$ 0.38	3.48 $\pm$ 0.6

Correlations between study variables for the total sample are presented in Supplementary Table S2.

Age-stratified correlations with numerical values of Pearson's correlation coefficients and corresponding 95% CI between study variables are presented in Supplementary Table S3, while Figure 3 presents the magnitudes of correlations for the two observed age groups.

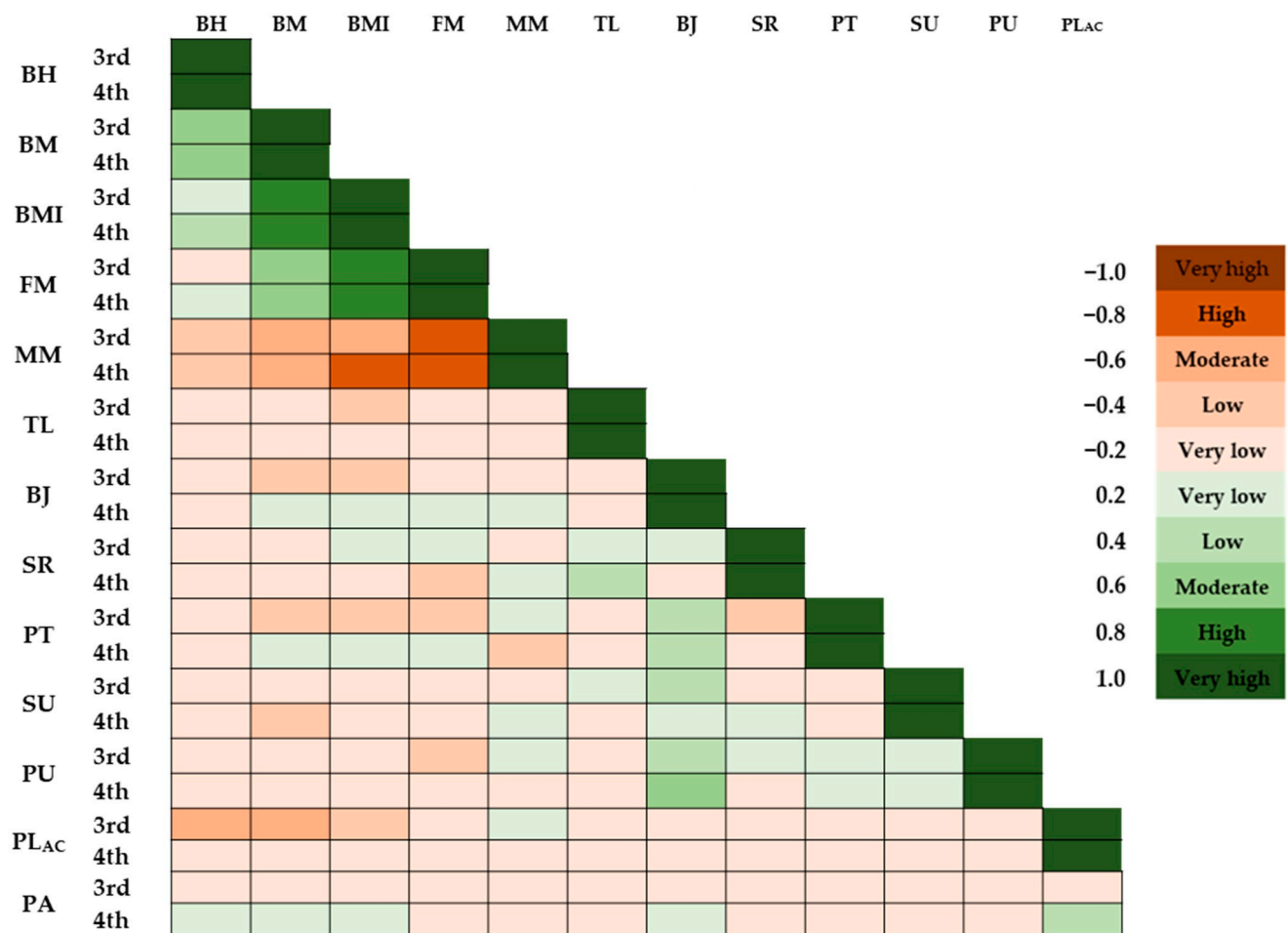


Figure 3. Age-stratified (3rd—3rd grade, 4th—4th grade) magnitudes of correlations between study variables (BH—body height, BM—body mass, BMI—body mass index, FM—fat mass, MM—muscle mass, TL—torso lift, BJ—broad jump, SR—sit and reach, PT—PACER test, SU—sit-ups, PU—push-ups, PL_{AC}—physical literacy (affective and cognitive domains) obtained by PLAYself questionnaire, PA—physical activity obtained by PAQ-C).

In addition to the logical correlations between anthropometric indices (i.e., fat mass was highly correlated with BMI, body mass was highly correlated with BMI, fat mass was moderately correlated with body mass, and muscle mass was highly negatively correlated with fat mass), several important correlations were also found. In third graders, the PACER test (aerobic endurance) had a low negative correlation with the body mass, BMI, and body fat, and a low positive correlation with the broad jump. Push-ups were moderately positively correlated with the broad jump (in fourth graders), while same variables had low correlations in third graders.

In third graders, PL_{AC} was moderately negatively correlated with the body mass and body height, and it was moderately correlated with PAL in fourth graders.

Numerical values of the gender-stratified correlations between study variables are presented in Supplementary Table S4, while the magnitudes of correlations are shown in Figure 4. This time, apart from logical correlations between different anthropometric indices in both genders (i.e., high positive correlations between BMI and body mass, and between fat mass and body mass), other correlations were generally very low to low in magnitude. Push-ups were moderately positively correlated with the broad jump among boys, and the PL and PAL had a low positive correlation in girls.

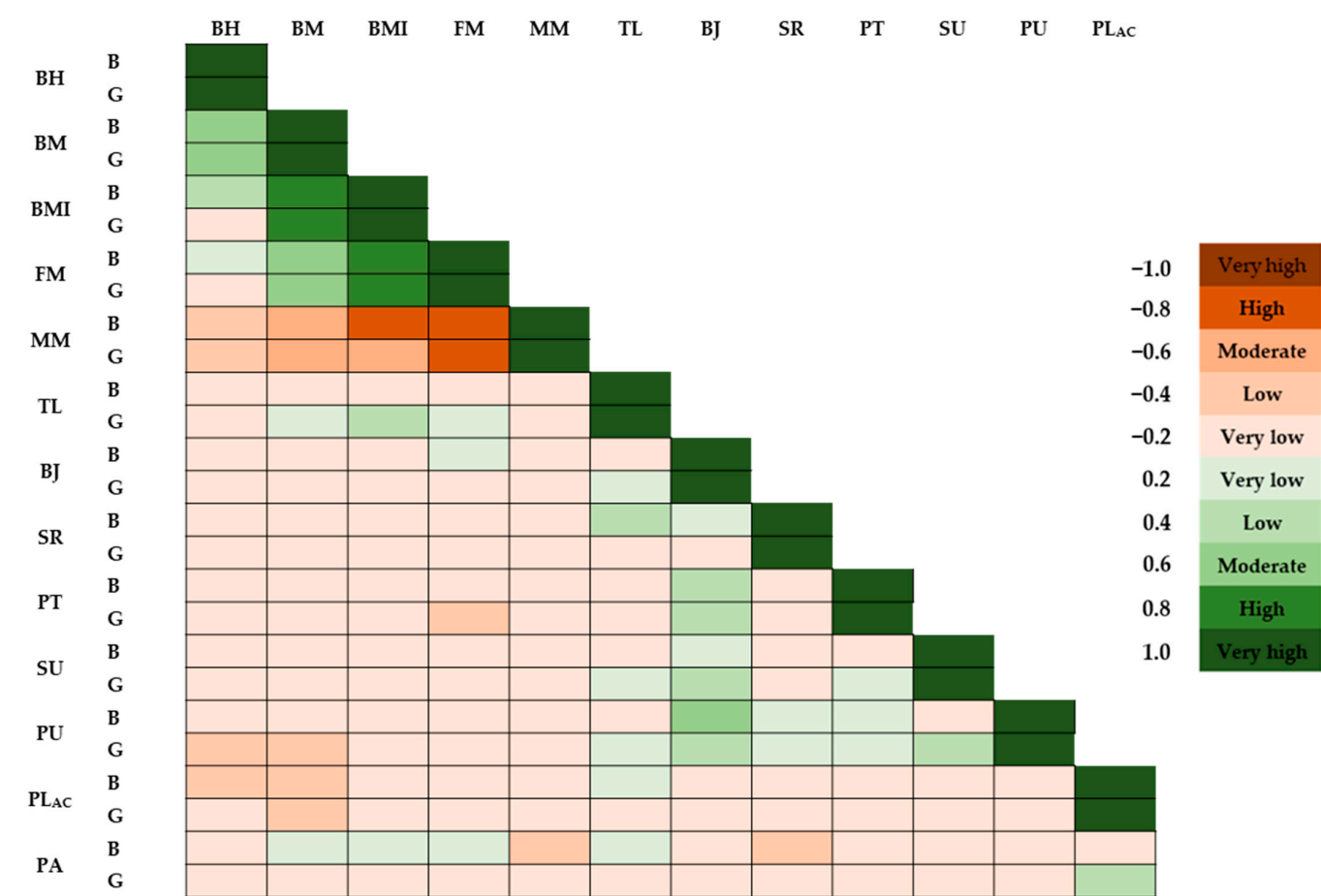


Figure 4. Gender-stratified (B—boys, G—girls) magnitudes of correlations between study variables (BH—body height, BM—body mass, BMI—body mass index, FM—fat mass, MM—muscle mass, TL—torso lift, BJ—broad jump, SR—sit and reach, PT—PACER test, SU—sit-ups, PU—push-ups, PL_{AC}—physical literacy (affective and cognitive domains) obtained by PLAYself questionnaire, PA—physical activity obtained by PAQ-C).

4. Discussion

This study evaluated the associations between PF, PL_{AC}, and PAL in preadolescent children. With regard to the main study aims, there were two important findings. First, the PF was not correlated with PAL in any of the study groups. Second, PAL was significantly correlated with PL_{AC} in girls (mixed ages) and in fourth graders (mixed genders). Therefore, our first hypothesis must be rejected, while the second one can be partially accepted. Before discussing the main findings of this study, we will provide an overview of the reliability of the applied PF tests.

4.1. Reliability of the Physical Fitness Tests in Preadolescent Children

Reliability is a crucial characteristic of any measurement tool since it indicates consistency in measurement [41]. High reliability indicates low measurement error and ensures there is a stable evaluation of the tested capacity/characteristic [42]. Therefore, in the first phase of our investigation, we examined the inter-testing and intra-testing reliability of the applied fitness tests. Studies frequently report the reliability of the fitness tests in children, and tests included in the FitnessGram battery are also examined. However, it seems that studies rarely simultaneously examine the reliability of various fitness tests in early school-aged children (preadolescent children), including FitnessGram fitness tests [43,44]. Specifically, several studies report a good reliability for the push-ups test, with unsystematic differences in reliability between genders [45,46]. Likewise, the test–retest reliability

of the curl-up test in 10–12-year-old children is also found to be appropriate [47]. In a study that involved children aged 8–15 years, the authors examined the reliability of the beep test performed at a 20 m distance and found a high test–retest correlation and no systematic differences between results obtained over two testing sessions [48]. High reliability was reported even for the broad jump in studies performed with 5–12- and 6–12-year-old children [49,50]. Finally, in a study performed with 5–12-year-old children, the authors investigated the reliability of the various FitnessGram tests. They found good reliability for the curl up, torso lift, 90° push up, and shoulder stretch [43].

Collectively, it seems that our results demonstrating a good reliability for push-ups, curl-ups, the sit-and-reach test, the PACER test (as a part of FitnessGram battery), and the broad jump correspond with previous studies performed with early school-aged children. This is particularly important considering the characteristics of our participants. Namely, our study involved children of a relatively narrow age span and, therefore, of similar biological maturity. On the other hand, in some of the previous investigations, the participants varied in age (i.e., 5–12-, 8–15-, 6–12-, and 5–14-year-old children) [43,48–50]. Since motor fitness in children is highly influenced by their biological maturity, it is possible that variations in biological maturity increased the variance of the fitness tests, resulting in (i) high correlations between tests and retests, and (ii) high reliability in the studied fitness tests [51].

In brief, the calculation of reliability parameters is based on the level of correlation between measurements (i.e., testing trials), and correlation is proportional to the (co)variance of executed trials [52]. Specifically, the higher the (co)variance (which is certainly the case in samples that include children of a wide age span), the higher the correlation coefficient. In most common wording, if one (or both) variable(s) have a high variability (large differences among the individual data points), this can affect the correlation. Large variance can accentuate the differences between data points and potentially lead to a higher correlation coefficient. Conversely, lower variability may result in a weaker correlation coefficient. Therefore, our results on the reliability of the studied fitness tests for the participants of a narrow age span (and consequently small variance of results) additionally confirm the reliability of the applied fitness tests.

The simultaneous investigation of the reliability performed here for different fitness tests allowed us to compare their reliability. Although differences in test type (some tests, such as beep tests, were performed as single-trial tests, while others, such as the sit-and-reach, were multi-trial tests) did not allow a precise comparison between them, some general considerations are still possible. For example, it is clear that the broad jump and sit-and-reach tests had the highest intra-testing and inter-testing reliability of all applied tests and, therefore, should be considered highly stable measurement tools. This is probably a consequence of the fact that these tests are regularly used in the school system as a part of the PE fitness-testing battery. Also, the tests are simple and performed with standardized procedures and equipment, which additionally ensure the stability of the measurements and high reliability [53].

On the other hand, the somewhat lower reliability of the torso lift could be attributed to the relative non-familiarity of participants and testers with this measurement tool. As long-term professionals in PE, the authors of this study are quite sure that our participants had not performed this test prior to this investigation. This almost certainly negatively influenced the stability of their test achievement in the test and retest. Also, the testers themselves were introduced to the testing protocol just before the study (i.e., this test is not included in physical education in the country), which could have altered the consistency of the testing and decreased the reliability.

4.2. Association between Physical Literacy and Physical Fitness

It seems that most authors who have investigated correlations between PL and PF have been interested in cardiovascular fitness and its association with PL facets. In particular, several studies have found a favorable association between cardiorespiratory fitness and

PL_{AC} in preadolescent children [54]. Meanwhile, it seems that the associations between various PF indicators (i.e., strength, flexibility, power) and PL have so far been investigated only in adolescents.

In a recent study, the authors highlighted that adolescents with higher PL_{AC} performed better in strength, power, flexibility, and cardiovascular endurance [55]. However, our analyses indicated poor relationships between fitness tests and PL_{AC} in the studied children. It is also important that our associations between PF and PL_{AC} were low and nonsignificant, even when all participants were observed as unique samples (i.e., not dividing younger from older children and/or genders) and in gender- and age-stratified analyses.

The most probable explanation for the lack of correlation between PL_{AC} and fitness tests in our sample can be attributed to biological (sexual) maturity and its influence on PF in preadolescent children [56]. In general, it is well-known that more biologically mature children have an advantage in the level of motor performance [57]. Indeed, studies have repeatedly confirmed that biological maturity is one of the most important determinants of fitness status in children, with those children who are advanced in maturity status having a better performance on various fitness tests, including power, strength, and endurance [57].

It is also important to note that biological maturity influences not only the current level of motor performance of children but also their responses to learning and training stimuli [57]. In other words, more mature children can tolerate intensive workouts more effectively and learn better while performing physically demanding exercises. This could have resulted in the smaller influence of the PL_{AC} on PF in our studied participants.

4.3. Correlations between Physical Literacy and Physical Activity Levels

Studies have rarely investigated the associations between PL and PAL in preadolescent children, and the results have generally been inconsistent. While some investigations have shown positive correlations, others have found no significant association between PAL indices and PL in children and adolescents [58,59], while research on preschool children has found that PL is predictive of PAL in girls but not in boys [60]. Since we found a significant correlation between PL_{AC} and PAL in girls and fourth graders, and no significant association in boys and third graders, we may say that our results are not surprising. Possible explanations of such findings are discussed in the following.

There is a substantial body of evidence that structural and organized PA are almost exclusive sources of PA among girls, while boys are, in addition to organized sports, more likely to be engaged in unstructured PA (i.e., free play) [61–64]. In other words, girls are more likely to reach their PAL through organized sports than through non-organized activity. It is logical that (only) those girls who were engaged in structural activities had higher PAL and higher results for PL_{AC}. This leads to a significant correlation between PL_{AC} and PAL among girls. Similarly, older children (fourth graders) are less likely to be engaged in free play, and their PAL is more a consequence of participation in structured sport activities. Indeed, research consistently shows a decline in free play as children age, with factors such as daycare attendance, parental fear of risk, and changes in family structure contributing to this trend [65]. Logically, girls are more likely to follow this trend. In the meantime, the PAL among boys and younger children is not related only to structured activities (i.e., sports and PE) but is also a consequence of other unstructured activities and free play. Although unstructured activities are directly related to higher PAL, those activities are not likely to influence PL_{AC} as much as organized and supervised participation in structured sports [32,66,67]. Consequently, this results in the low correlation between PL_{AC} and PAL among boys.

In support of this, previous research has found that youth engaged in sports have higher PL levels than their peers not involved in sports. Specifically, a study conducted on adolescents aged 14–18 years from Croatia reported that students who participated in sports had better PL_{AC} compared to those who did not participate in organized sports [68]. Moreover, a recent study on children aged 9–11 years from Croatia also supported the idea that sports are an important determinant of PL_{AC}, as the years of organized sports training

were positively associated with PL_{AC} [32]. Thus, as sports are an important mediator in reaching optimal PL_{AC} , the finding that girls with higher PAL (which is most likely a consequence of sports participation) have better PL_{AC} is also logical.

One could argue that PE could also positively influence the PL in children. However, in this study, we are not able to discuss such an influence in more detail. In brief, PE is a mandatory school subject for all (healthy) children, and we observed only children who regularly participated in PE classes (please see the Methods section for the inclusion criteria). Therefore, we could not calculate the eventual differences between the groups of interest (included vs. non-included in PE).

In explaining gender-specific correlations between PL_{AC} and PAL, we should also highlight differences in social support for physical activity engagement. Specifically, boys are generally perceived as active and involved in sports and free play, while girls are more engaged in sedentary activities and play that does not include vigorous movement activities. In support of this, research shows that during school recess, boys tend to engage in competitive games, while girls often use the time to socialize with their friends [69]. Moreover, a study on elementary school children found that girls had lower levels of school-based moderate-to-vigorous physical activity time compared to boys [70]. As we are actively involved in school activities and observe the situations during school recess and after-school activities, we can comment that boys are usually involved in various kinds of vigorous activities during free time, while girls at the same time are sitting, drawing, playing with dolls, or talking. This altogether could at least partially result in a higher correlation between PAL and PL in girls than in boys.

4.4. Limitations and Strengths

This study was cross-sectional, and such a design does not allow for a clear interpretation of the causality between variables. Therefore, in order to more precisely evaluate the possible relationships between PL_{AC} , PF, and PAL, intervention studies are needed. Furthermore, we observed participants from urban communities exclusively, and, therefore, the results should be generalized only to similar samples. In addition, since only one study has examined the validity of the PL_{AC} questionnaire in local languages in the region (i.e., the territory of former Yugoslavia) so far, we do not have definite proof of the validity of this measurement tool. Also, in this study, we performed gender-specific and age-stratified correlation analyses while using simple univariate procedures; in further studies, more complex (multiple) regression analyses are needed to consider possible interactions between the variables of interest. Next, the PAL was evaluated by a questionnaire and not directly monitored, which should certainly be observed as a study limitation. Finally, this study examined only the affective and cognitive domains of PL, and, in the future, a more holistic approach is needed in order to evaluate the associations between the observed factors in more detail.

This is one of the first studies that has examined the associations between PL_{AC} , various indices of PF, and PAL in preadolescents. This represents a valuable contribution to the literature, and since we included children of a relatively narrow age span, this allowed for the precise identification of the characteristics of the studied associations. Additionally, we evaluated PF by using various PF tests, which has rarely been performed previously. Finally, the gender-specific and age-specific approaches were important strengths of this investigation.

5. Conclusions

The results of this study confirm the reliability of the applied PF tests in preadolescent children, including those included in the FitnessGram battery. However, while the reliability was almost perfect for tests that are regularly used in PE, the results showed lower reliability for tests that the participants and testers had not performed prior to this study. Therefore, it is clear that systematic familiarization with the testing procedures is needed in order to achieve stability and consistency of a PF evaluation in this age group.

The PF and PL_{AC} were poorly correlated in both boys and girls. It is likely that the more mature children were more successful in the PF tests, which consequently diminished the eventual influence of PL_{AC} on PF achievement in this age group. In future studies, larger cohorts of children should be explored, allowing for eventual clustering of the participants into maturity-homogenous groups and for a more precise evaluation of the association between PL and PAL.

PAL and PL_{AC} were significantly correlated among girls and the older group of children. The gender difference in participation in structured and unstructured activities probably explains such findings. Namely, the PAL of the girls and older children is more a consequence of their participation in structured activities (i.e., organized sport, PE), which simultaneously increases the PAL and improves the PL.

While this study has made initial process toward defining the correlations between fitness, physical activity, and PL indices, further intervention studies are needed. Specifically, it will be important to identify the effects of targeted interventions—aimed at specific factors (i.e., PL)—on changes in PL, as well as corresponding changes in PF and PAL.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/educsci14040391/s1>, Table S1: Descriptive statistics and results of the Kolmogorov–Smirnov test (KS) for the total sample of participants; Table S2: Correlations between study variables for the total sample of participants (* denotes $p < 0.05$), where results are presented as Pearson’s correlation (95% CI); Table S3: Age-stratified correlations (3rd graders and 4th graders) between study variables (* denotes $p < 0.05$), where results are presented as Pearson’s correlation (95% CI); Table S4: Gender-stratified (B—boys, G—girls) correlations between study variables for the total sample of participants (* denotes $p < 0.05$), where results are presented as Pearson’s correlation (95% CI).

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Informed Consent Statement: Written consent was obtained from the parents of the children who participated in this study. Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: Data will be provided to all interested parties upon reasonable request.

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References

1. Siedentop, D.; Van der Mars, H. *Introduction to Physical Education, Fitness, and Sport*; Human kinetics: Champaign, IL, USA, 2022.
2. Moliner-Urdiales, D.; Ruiz, J.R.; Ortega, F.B.; Jiménez-Pavón, D.; Vicente-Rodriguez, G.; Rey-López, J.P.; Martínez-Gómez, D.; Casajús, J.A.; Mesana, M.I.; Marcos, A.; et al. Secular trends in health-related physical fitness in Spanish adolescents The AVENA and HELENA Studies. *J. Sci. Med. Sport* **2010**, *13*, 584–588. [[CrossRef](#)] [[PubMed](#)]
3. Silventoinen, K.; Maia, J.; Jelenkovic, A.; Pereira, S.; Gouveia, É.; Antunes, A.; Thomis, M.; Lefevre, J.; Kaprio, J.; Freitas, D. Genetics of somatotype and physical fitness in children and adolescents. *Am. J. Hum. Biol.* **2021**, *33*, e23470. [[CrossRef](#)] [[PubMed](#)]
4. Hills, A.P.; Andersen, L.B.; Byrne, N.M. Physical activity and obesity in children. *Brit J. Sport Med.* **2011**, *45*, 866–870. [[CrossRef](#)] [[PubMed](#)]
5. Smith, J.J.; Eather, N.; Morgan, P.J.; Plotnikoff, R.C.; Faigenbaum, A.D.; Lubans, D.R. The Health Benefits of Muscular Fitness for Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Med.* **2014**, *44*, 1209–1223. [[CrossRef](#)]

6. Cadenas-Sanchez, C.; Mena-Molina, A.; Torres-Lopez, L.V.; Migueles, J.H.; Rodriguez-Ayllon, M.; Lubans, D.R.; Ortega, F.B. Healthier Minds in Fitter Bodies: A Systematic Review and Meta-Analysis of the Association between Physical Fitness and Mental Health in Youth. *Sports Med.* **2021**, *51*, 2571–2605. [[CrossRef](#)] [[PubMed](#)]
7. Bermejo-Cantarero, A.; Álvarez-Bueno, C.; Martínez-Vizcaino, V.; Redondo-Tébar, A.; Pozuelo-Carrascosa, D.P.; Sánchez-López, M. Relationship between both cardiorespiratory and muscular fitness and health-related quality of life in children and adolescents: A systematic review and meta-analysis of observational studies. *Health Qual. Life Outcomes* **2021**, *19*, 127. [[CrossRef](#)]
8. Rodriguez, C.C.; de Camargo, E.M.; Rodriguez-Añez, C.R.; Reis, R.S. Physical Activity, Physical Fitness and Academic Achievement in Adolescents: A Systematic Review. *Rev. Bras. Med. Esporte* **2020**, *26*, 441–448. [[CrossRef](#)]
9. Alvarez-Pitti, J.; Mallen, J.A.C.; Trabazo, R.L.; Lucia, A.; de Lara, D.L.; Aznar, L.A.M.; Martinez, G.R. Exercise as medicine in chronic diseases during childhood and adolescence. *An. Pediatr.* **2020**, *92*, 173.e1–173.e8. [[CrossRef](#)]
10. Ariza, C.; Sanchez-Martinez, F.; Serral, G.; Valmayor, S.; Juarez, O.; Pasarin, M.I.; Castell, C.; Rajmil, L.; Lopez, M.J.; Ariza, C.; et al. The Incidence of Obesity, Assessed as Adiposity, Is Reduced After 1 Year in Primary Schoolchildren by the POIBA Intervention. *J. Nutr.* **2019**, *149*, 258–269. [[CrossRef](#)]
11. Whiting, S.; Buoncristiano, M.; Gelius, P.; Abu-Omar, K.; Pattison, M.; Hyska, J.; Duleva, V.; Musić Milanović, S.; Zamrazilová, H.; Hejgaard, T. Physical activity, screen time, and sleep duration of children aged 6–9 years in 25 countries: An analysis within the WHO European childhood obesity surveillance initiative (COSI) 2015–2017. *Obes. Facts* **2021**, *14*, 32–44. [[CrossRef](#)]
12. Guthold, R.; Stevens, G.A.; Riley, L.M.; Bull, F.C. Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc. Health* **2020**, *4*, 23–35. [[CrossRef](#)] [[PubMed](#)]
13. Giroir, B.P.; Wright, D. Physical Activity Guidelines for Health and Prosperity in the United States. *J. Am. Med. Assoc.* **2018**, *320*, 1971–1972. [[CrossRef](#)] [[PubMed](#)]
14. Pojskic, H.; Eslamis, B. Relationship Between Obesity, Physical Activity, and Cardiorespiratory Fitness Levels in Children and Adolescents in Bosnia and Herzegovina: An Analysis of Gender Differences. *Front. Physiol.* **2018**, *9*, 1734. [[CrossRef](#)] [[PubMed](#)]
15. Escapite, A.O.; Lopez-Alonzo, S.J.; Barron-Lujan, J.C.; Guedea-Delgado, J.C.; Balderrama, C.V.V. Physical education, motor development and physical activity in preschool children: A systematic review. *Viref-Rev. Educ. Fis.* **2022**, *11*, 28–41.
16. Goodyear, V.A.; Skinner, B.; McKeever, J.; Griffiths, M. The influence of online physical activity interventions on children and young people's engagement with physical activity: A systematic review. *Phys. Educ. Sport Peda* **2023**, *28*, 94–108. [[CrossRef](#)]
17. Holt, N.L.; Deal, C.J.; Pankow, K. Positive youth development through sport. In *Handbook of Sport Psychology*, 4th ed.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2020; pp. 429–446.
18. Kriemler, S.; Meyer, U.; Martin, E.; van Sluijs, E.M.F.; Andersen, L.B.; Martin, B.W. Effect of school-based interventions on physical activity and fitness in children and adolescents: A review of reviews and systematic update. *Brit J. Sport Med.* **2011**, *45*, 923–930. [[CrossRef](#)] [[PubMed](#)]
19. Twisk, J.W.R.; Kemper, H.C.G.; van Mechelen, W. The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age. The Amsterdam Growth and Health Longitudinal Study. *Study Int. J. Sports Med.* **2002**, *23*, S8–S14.
20. Kodama, S.; Saito, K.; Tanaka, S.; Maki, M.; Yachi, Y.; Asumi, M.; Sugawara, A.; Totsuka, K.; Shimano, H.; Ohashi, Y. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: A meta-analysis. *JAMA* **2009**, *301*, 2024–2035. [[CrossRef](#)] [[PubMed](#)]
21. Martínez-Vizcaino, V.; Sánchez-López, M. Relación entre actividad física y condición física en niños y adolescentes. *Elsevier Doyma* **2008**, *61*, 108–111. [[CrossRef](#)]
22. Whitehead, M. Definition of physical literacy and clarification of related issues. *Icsp Bull.* **2013**, *65*, 28–33.
23. Cairney, J.; Dudley, D.; Kwan, M.; Bulten, R.; Kriellaars, D. Physical Literacy, Physical Activity and Health: Toward an Evidence-Informed Conceptual Model. *Sports Med.* **2019**, *49*, 371–383. [[CrossRef](#)] [[PubMed](#)]
24. Holler, P.; Carl, J.; van Poppel, M.N.M.; Jaunig, J. Development of the Perceived Physical Literacy Questionnaire (PPLQ) for the adult population. *J. Exerc. Sci. Fit.* **2023**, *21*, 424–433. [[CrossRef](#)] [[PubMed](#)]
25. Shearer, C.; Goss, H.R.; Boddy, L.M.; Knowles, Z.R.; Durden-Myers, E.J.; Fowweather, L. Assessments Related to the Physical, Affective and Cognitive Domains of Physical Literacy Amongst Children Aged 7–11.9 Years: A Systematic Review. *Sports Med. Open* **2021**, *7*, 37. [[CrossRef](#)] [[PubMed](#)]
26. Liu, Y.; Chen, S.L. Physical literacy in children and adolescents: Definitions, assessments, and interventions. *Eur. Phys. Educ. Rev.* **2021**, *27*, 96–112. [[CrossRef](#)]
27. de Dieu, H.J.; Zhou, K. Physical Literacy Assessment Tools: A Systematic Literature Review for Why, What, Who, and How. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7954. [[CrossRef](#)]
28. Geets-Kesić, M.; Maras, N.; Gilić, B. Analysis of the Association Between Health Literacy, Physical Literacy, and Scholastic Achievement; A Preliminary Cross-Sectional Study Among High-School Students From Southern Croatia. *Montenegrin J. Sports Sci. Med.* **2023**, *12*. [[CrossRef](#)]
29. Zhang, C.; Liu, Y.; Xu, S.; Sum, R.K.W.; Ma, R.S.; Zhong, P.; Liu, S.X.; Li, M.H. Exploring the Level of Physical Fitness on Physical Activity and Physical Literacy Among Chinese University Students: A Cross-Sectional Study. *Front. Psychol.* **2022**, *13*, 833461. [[CrossRef](#)]

30. Caldwell, H.A.T.; Di Cristofaro, N.A.; Cairney, J.; Bray, S.R.; MacDonald, M.J.; Timmons, B.W. Physical Literacy, Physical Activity, and Health Indicators in School-Age Children. *Int. J. Environ. Res. Public Health* **2020**, *17*, 5367. [CrossRef] [PubMed]
31. Nezondet, C.; Gandrieau, J.; Nguyen, P.; Zunquin, G. Perceived Physical Literacy Is Associated with Cardiorespiratory Fitness, Body Composition and Physical Activity Levels in Secondary School Students. *Children* **2023**, *10*, 712. [CrossRef]
32. Vuletic, P.R.; Kesic, M.G.; Gilic, B.; Pehar, M.; Uzicanin, E.; Idrizovic, K.; Sekulic, D. Evaluation of Physical Literacy in 9-to 11-Year-Old Children: Reliability and Validity of Two Measurement Tools in Three Southeastern European Countries. *Children* **2023**, *10*, 1722. [CrossRef]
33. Kriellaars, D.; Kozera, T.; Robillard, B. Physical literacy assessment for youth. PLAY Workbook. Canadian Sport Institute—Pacific. 2013. Available online: <http://sportforlife.ca/wp-content/uploads/2016/12/PLAYbasic-workbook.pdf> (accessed on 10 February 2024).
34. Crocker, P.; Bailey, D.A.; Faulkner, R.A.; Kowalski, K.C.; McGrath, R. Measuring general levels of physical activity: Preliminary evidence for the Physical Activity Questionnaire for Older Children. *Med. Sci. Sports Exerc.* **1997**, *29*, 1344–1349. [CrossRef] [PubMed]
35. Samaržija, D.V.; Mišigoj-Duraković, M. Reliability of Croatian version of the questionnaire for assessment of overall level of physical activity of younger school children. *Hrvat. Športskomedicinski Vjesn.* **2013**, *28*, 24–32.
36. Meredith, M.D.; Welk, G. *Fitnessgram and Activitygram Test Administration Manual-Updated*, 4th ed.; Human Kinetics: Champaign, IL, USA, 2010.
37. Leger, L.A.; Mercier, D.; Gadoury, C.; Lambert, J. The multistage 20 metre shuttle run test for aerobic fitness. *J. Sports Sci.* **1988**, *6*, 93–101. [CrossRef] [PubMed]
38. Chen, W.Y.; Hammond-Bennett, A.; Hypnar, A.; Mason, S. Health-related physical fitness and physical activity in elementary school students. *BMC Public Health* **2018**, *18*, 195. [CrossRef]
39. Thomas, E.; Petrigna, L.; Tabacchi, G.; Teixeira, E.; Pajaujiene, S.; Sturm, D.J.; Sahin, F.N.; Gomez-Lopez, M.; Pausic, J.; Paoli, A.; et al. Percentile values of the standing broad jump in children and adolescents aged 6–18 years old. *Eur. J. Transl. Myol.* **2020**, *30*, 240–246. [CrossRef]
40. Schober, P.; Boer, C.; Schwarte, L.A. Correlation Coefficients: Appropriate Use and Interpretation. *Anesth. Analg.* **2018**, *126*, 1763–1768. [CrossRef]
41. Sekulic, D.; Uljevic, O.; Peric, M.; Spasic, M.; Kondric, M. Reliability and Factorial Validity of Non-Specific and Tennis-Specific Pre-Planned Agility Tests; Preliminary Analysis. *J. Hum. Kinet.* **2017**, *55*, 107–116. [CrossRef]
42. Uljevic, O.; Esco, M.R.; Sekulic, D. Reliability, validity, and applicability of isolated and combined sport-specific tests of conditioning capacities in top-level junior water polo athletes. *J. Strength. Cond. Res.* **2014**, *28*, 1595–1605. [CrossRef]
43. Gogoi, P.; Bhattacharyya, N.C. Interrater reliability of fitness gram test to be used as a reliable tool for assessing physical fitness for school children in guwahati urban society of north-east india. *Int. J. Res. Med. Sci.* **2020**, *8*, 312. [CrossRef]
44. Morrow, J.R.; Martin, S.B.; Jackson, A.W. Reliability and Validity of the FITNESSGRAM®: Quality of Teacher-Collected Health-Related Fitness Surveillance Data. *Res. Q. Exerc. Sport* **2010**, *81*, S24–S30. [CrossRef]
45. McManis, B.G.; Baumgartner, T.A.; Wuest, D.A. Objectivity and reliability of the 90 push-up test. *Meas. Phys. Educ. Exerc.* **2000**, *4*, 57–67. [CrossRef]
46. Saint Romain, B.; Mahar, M.T. Norm-referenced and criterion-referenced reliability of the push-up and modified pull-up. *Meas. Phys. Educ. Exerc.* **2001**, *5*, 67–80. [CrossRef]
47. Patterson, P.; Bennington, J.; De la Rosa, T. Psychometric properties of child- and teacher-reported curl-up scores in children ages 10–12 years. *Res. Q. Exerc. Sport* **2001**, *72*, 117–124. [CrossRef] [PubMed]
48. Pitetti, K.H.; Fernhall, B.; Fagoni, S. Comparing two regression formulas that predict VO using the 20-m shuttle run for children and adolescents. *Pediatr. Exerc. Sci.* **2002**, *14*, 125–134. [CrossRef]
49. Fernandez-Santos, J.R.; Ruiz, J.R.; Cohen, D.D.; Gonzalez-Montesinos, J.L.; Castro-Piñero, J. Reliability and Validity of Tests to Assess Lower-Body Muscular Power in Children. *J. Strength. Cond. Res.* **2015**, *29*, 2277–2285. [CrossRef] [PubMed]
50. Fjortoft, I.; Pedersen, A.V.; Sigmundsson, H.; Vereijken, B. Measuring Physical Fitness in Children Who Are 5 to 12 Years Old With a Test Battery That Is Functional and Easy to Administer. *Phys. Ther.* **2011**, *91*, 1087–1095. [CrossRef] [PubMed]
51. Katzmarzyk, P.; Malina, R.; Beunen, G. The contribution of biological maturation to the strength and motor fitness of children. *Ann. Hum. Biol.* **1997**, *24*, 493–505. [CrossRef] [PubMed]
52. Huck, S.W. *Reading Statistics and Research: Pearson New International Edition*; Pearson Education: London, UK, 2013.
53. Neljak, B.; Novak, D.; Sporiš, G.; Višković, S.; Markuš, D. *Cro-Fit Norme*; Faculty of Kinesiology, University of Zagreb: Zagreb, Croatia, 2012. (In Croatian)
54. Lang, J.J.; Chaput, J.P.; Longmuir, P.E.; Barnes, J.D.; Belanger, K.; Tomkinson, G.R.; Anderson, K.D.; Bruner, B.; Copeland, J.L.; Gregg, M.J.; et al. Cardiorespiratory fitness is associated with physical literacy in a large sample of Canadian children aged 8 to 12 years. *BMC Public Health* **2018**, *18*, 1041. [CrossRef] [PubMed]
55. Gilic, B.; Malovic, P.; Sunda, M.; Maras, N.; Zenic, N. Adolescents with Higher Cognitive and Affective Domains of Physical Literacy Possess Better Physical Fitness: The Importance of Developing the Concept of Physical Literacy in High Schools. *Children* **2022**, *9*, 796. [CrossRef]
56. Jones, M.A.; Hitchen, P.J.; Stratton, G. The importance of considering biological maturity when assessing physical fitness measures in girls and boys aged 10 to 16 years. *Ann. Hum. Biol.* **2000**, *27*, 57–65. [CrossRef]

57. Marta, C.C.; Marinho, D.A.; Izquierdo, M.; Marques, M.C. Differentiating maturational influence on training-induced strength and endurance adaptations in prepubescent children. *Am. J. Hum. Biol.* **2014**, *26*, 469–475. [[CrossRef](#)] [[PubMed](#)]
58. Belanger, K.; Barnes, J.D.; Longmuir, P.E.; Anderson, K.D.; Bruner, B.; Copeland, J.L.; Gregg, M.J.; Hall, N.; Kolen, A.M.; Lane, K.N.; et al. The relationship between physical literacy scores and adherence to Canadian physical activity and sedentary behaviour guidelines. *Bmc Public Health* **2018**, *18*, 1042. [[CrossRef](#)] [[PubMed](#)]
59. Yan, W.; Meng, Y.; Wang, L.; Zhang, T.; Chen, L.; Li, H. Research on the Relationship between Physical Literacy, Physical Activity and Sedentary Behavior. *Int. J. Environ. Res. Public Health* **2022**, *19*, 16455. [[CrossRef](#)] [[PubMed](#)]
60. Cairney, J.; Clark, H.J.; James, M.E.; Mitchell, D.; Dudley, D.A.; Kriellaars, D. The Preschool Physical Literacy Assessment Tool: Testing a New Physical Literacy Tool for the Early Years. *Front. Pediatr.* **2018**, *6*, 138. [[CrossRef](#)] [[PubMed](#)]
61. Bucksch, J.; Sigmundova, D.; Hamrik, Z.; Troped, P.J.; Melkevik, O.; Ahluwalia, N.; Borraccino, A.; Tynjälä, J.; Kalman, M.; Inchley, J. International Trends in Adolescent Screen-Time Behaviors From 2002 to 2010. *J. Adolesc. Health* **2016**, *58*, 417–425. [[CrossRef](#)] [[PubMed](#)]
62. Jekauc, D.; Reimers, A.K.; Wagner, M.O.; Woll, A. Physical activity in sports clubs of children and adolescents in Germany: Results from a nationwide representative survey. *J. Public Health-Heid* **2013**, *21*, 505–513. [[CrossRef](#)]
63. Kalman, M.; Inchley, J.; Sigmundova, D.; Iannotti, R.J.; Tynjälä, J.A.; Hamrik, Z.; Haug, E.; Bucksch, J. Secular trends in moderate-to-vigorous physical activity in 32 countries from 2002 to 2010: A cross-national perspective. *Eur. J. Public Health* **2015**, *25*, 37–40. [[CrossRef](#)]
64. Van Hecke, L.; Loyen, A.; Verloigne, M.; van der Ploeg, H.P.; Lakerveld, J.; Brug, J.; De Bourdeaudhuij, I.; Ekelund, U.; Donnelly, A.; Hendriksen, I.; et al. Variation in population levels of physical activity in European children and adolescents according to cross-European studies: A systematic literature review within DEDIPAC. *Int. J. Behav. Nutr. Phy* **2016**, *13*, 70. [[CrossRef](#)] [[PubMed](#)]
65. Carsley, S.; Liang, L.Y.; Chen, Y.; Parkin, P.; Maguire, J.; Birken, C.S.; Collaboration, T.A.K. The impact of daycare attendance on outdoor free play in young children. *J. Public Health* **2017**, *39*, 145–152. [[CrossRef](#)]
66. Jefferies, P.; Bremer, E.; Kozera, T.; Cairney, J.; Kriellaars, D. Psychometric properties and construct validity of PLAYself: A self-reported measure of physical literacy for children and youth. *Appl. Physiol. Nutr. Metab.* **2021**, *46*, 579–588. [[CrossRef](#)]
67. Šunda, M. Utjecaj Učenja na Daljinu i Unaprjeđenja Tjelesne Pismenosti na Promjene Stanja Fitnesa i Tjelesne Aktivnosti Adolescencata. Ph.D. Thesis, Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia, 2022.
68. Sunda, M.; Gilic, B.; Sekulic, D.; Matic, R.; Drid, P.; Alexe, D.I.; Cucui, G.G.; Lupu, G.S. Out-of-School Sports Participation Is Positively Associated with Physical Literacy, but What about Physical Education? A Cross-Sectional Gender-Stratified Analysis during the COVID-19 Pandemic among High-School Adolescents. *Children* **2022**, *9*, 753. [[CrossRef](#)] [[PubMed](#)]
69. Ridgers, N.D.; Salmon, J.; Parrish, A.M.; Stanley, R.M.; Okely, A.D. Physical Activity During School Recess A Systematic Review. *Am. J. Prev. Med.* **2012**, *43*, 320–328. [[CrossRef](#)] [[PubMed](#)]
70. Gu, X.; Chen, S.; Zhang, X. Physical Literacy at the Start Line: Young Children’s Motor Competence, Fitness, Physical Activity, and Fitness Knowledge. *J. Teach. Phys. Educ.* **2019**, *38*, 146–154. [[CrossRef](#)]

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Article

Effects of a Physical-Literacy-Based Educational Intervention on Physical Activity and Body Composition in Preadolescent Children: A School-Based Controlled Trial

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Abstract

Improving physical literacy (PL) is recognized as a potentially effective approach for enhancing overall physical activity (PA) and fitness status, including body composition, but few studies have examined the impact of PL-oriented education on directly measured PA and body composition in children. The aim of this study was to evaluate the effects of a three-month quasi-experimental PL-based educational intervention, delivered as part of the regular physical education (PE) curriculum, in preadolescent children. A total of 119 children aged 9–11 years (51 girls) from southern Croatia participated in the study and were assigned to either a control group ($n = 68$) or an intervention group ($n = 51$). The intervention group received a PL-focused educational program integrated into regular PE classes, whereas the control group followed the standard PE curriculum. PA was assessed using accelerometers, and body composition was measured using bioimpedance analysis. A pre–post–retention design was applied (baseline at the start of the school year, post-intervention in December, and retention testing at the end of the school year), and a three-way repeated-measures ANOVA (group $\times$ gender $\times$ time) was conducted. The intervention prevented declines in vigorous physical activity (VPA) and step count (STEPS) and maintained overall sedentary time (ST) in the experimental group throughout the school year. Significant group $\times$ time interaction effects were detected for VPA, STEPS, and ST ($F = 4.01, 4.09, \text{ and } 5.34$, respectively; all $p < 0.05$). No significant effects were found for body composition. In conclusion, the PL-based intervention allowed effective mitigation of the typical seasonal decline in activity levels observed during the school year. Further studies evaluating the effects of similar interventions on other indices of fitness status are warranted.

Keywords: health education; child; curriculum; physical education; physical activity levels



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1. Introduction

Physical fitness (PF) is a state of health and well-being and, more specifically, refers to the ability to perform aspects of sports, occupations, and daily activities [1]. Optimal PF forms the foundation of a healthy lifestyle and is one of the key indicators of both current and future health status. In this sense, childhood and adolescence are especially important, as high PF levels at these ages directly and positively influence health outcomes in adulthood [2–5]. Longitudinal studies have shown that maintaining proper PF in

children and adolescents reduces the risk of obesity, cardiovascular diseases, and diabetes in adulthood [6–8]. Additionally, research on mental health indicates a positive association between PF and general mental health in children and youth [9,10]. However, despite its importance, PF levels among children and adolescents have been steadily declining [11,12].

It is widely accepted that reaching optimal levels of physical activity (PA) is fundamental in achieving and maintaining optimal physical fitness (PF) [13]. However, it is also well known that PA and PF are closely interconnected and influence one another. Research on children and adolescents has confirmed that PA is the primary mechanism for developing and maintaining key PF components such as body composition, cardiorespiratory function, and muscular strength, with high-intensity PA being the most important in exerting the most significant effect on PF [14]. On the other hand, higher PF levels enable children to participate in vigorous PA more easily and for longer periods, as they can withstand greater workloads and sustain high intensity for extended time frames [14–17]. Research has demonstrated that childhood and adolescence are the most critical phases for establishing such positive cycles between PA and PF [18–20].

In general, the prevailing opinion is that increases in PA result in improvements in various abilities among children, including attention, concentration, and different PF capacities [21–24]. Specifically regarding PF, a study conducted on US children aged 9–11 years reported that PA is positively associated with all components of PF [21]. Similar results were obtained in Spanish children aged 8–12 years, confirming that children with higher levels of PA achieve better PF [22]. Similarly, a Danish study with children aged 8–10 years showed that children involved in sports activities and had higher PA demonstrated better cardiorespiratory capacity, faster sprint times, better coordination, lower body fat indices, and a more favorable cardiovascular profile than their inactive peers [23]. Estonian authors longitudinally followed children from kindergarten to 11–12 years for six years and reported that 73% of children who were continuously physically active achieved healthy levels of PF, whereas only 24% of inactive children did [25]. Finally, a recent Polish study revealed positive effects of increased hours of physical education (PE) on PF in 11- to 12-year-old children [26]. Finally, higher levels of PA, particularly of moderate-to-vigorous intensity, are associated with favorable changes in body composition among children, including reductions in fat mass and improvements in lean mass [27,28].

However, despite the evidence for a positive association between higher PA and better PF in children, a growing body of evidence indicates that simply increasing PA is not always sufficient to improve PF in children, highlighting the fact that emphasis should be placed on promoting specific forms of exercise and targeting those intensities of PA that directly increase PF levels [14,29–31]. Given the established intercorrelations between PA and PF, the concept of “physical literacy,” which encompasses a holistic approach to their development, has attracted increased attention over the last decade.

Physical literacy (PL) is defined as the ability of an individual to have the motivation, confidence, and physical competence to engage in PA and to understand the health benefits of PA to develop habits and stay active throughout life [32–34]. Research shows that improving PL has beneficial effects on PA and PF in children and adolescents [35–37]. For example, a five-month intervention consisting of structured play and active games resulted in positive changes in PA and reduced sedentary behavior in children aged 6–9 years [38]. Furthermore, an eight-week intervention based on a pedagogical approach aimed at developing PL had significant positive effects on balance, stability, and cardiorespiratory endurance in children aged 8–12 years [39]. Similarly, a six-month program aimed at developing PL showed encouraging results in terms of body composition variables in children aged 5–12 years [40]. Positive effects on the PA and PF of 9- to 11-year-old children were evidenced in a twelve-week intervention targeting PL improvement, which included

physical education classes conducted by a specialized teacher [41]. Although not all studies reported positive effects of PL improvement on PF and/or PA collectively, it seems that interventions integrating various domains of PL are beneficial in children of younger school age (preadolescents) [42–44].

The previous literature overview clearly demonstrates that studies mostly indicate positive effects of PL interventions on PA and PF. However, it is important to emphasize certain limitations of the studies performed to date. First, many of the studies did not include a control group of participants, meaning that the changes reported could be a result of growth and development and/or regular PE and sport participation, and not the PL-based intervention [35,37]. Second, studies regularly applied pre- and post-study designs, and to the best of our knowledge, none of the studies have observed retention of the intervention effects [35,37]. Furthermore, there is an evident lack of studies that have evaluated the changes in anthropometric/body composition of children as a result of PL-intervention. However, this information is highly important because body composition status in childhood may indicate later risks for overweight and obesity [45]. Finally, evaluations of PA levels have been conducted primarily using questionnaires and have rarely used direct measurements of PA [33,35,37].

Therefore, with the intention of improving knowledge in the field, this study aimed to evaluate the effects of one specific PL-based intervention on (i) objectively measured PA and (ii) body composition indices in 9- to 11-year-old children from Croatia, observing PA indices as primary, and body composition parameters as secondary outcomes. As a secondary outcome, the eventual changes in body composition indices as a result of the applied intervention were observed, without a priori expectation of significant effects. We hypothesized that a PL intervention would yield positive results in terms of PA indices.

2. Materials and Methods

2.1. Participants

The sample in this quasi-experimental school-based controlled trial consisted of 119 preadolescent children (51 girls) from southern Croatia. The sample size calculation was based on the planned method for assessing effects (analysis of variance), the number of planned groups (two participant groups), statistical power (0.8), and the expected effect size (medium). Using an F-test as the type of effect, the required size for a balanced sample (equal number of participants in both groups) was determined to be a total of 108 students across the two groups, yielding a statistical power of 0.811.

At the time of data collection, the participants were between 9 and 11 years old and were enrolled in either the 3rd ($n = 71$) or 4th grade ($n = 48$) of elementary school. All the children were in good health and attended physical education (PE) classes on a regular basis. Those who had been ill or who had sustained a musculoskeletal injury within two weeks prior to testing were excluded. Before participation, parents or legal guardians were informed about the study objectives and procedures, and parental written consent was obtained. The research protocol was preapproved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb. Most of the participants participated in out-of-school sport activities (78% and 74% in the control and intervention groups, respectively), with no significant difference noted between the groups (Chi square = 1.44, $p > 0.05$). Initially, pubertal timing was estimated for all children using peak height velocity (PHV), as described by Moore et al. ($\text{PHV} = -7.999994 + (0.0036124 \times \text{age (yrs.)} \times \text{height (cm)})$), and no difference was found between the C and E groups ($t\text{-test} = 0.23$, $p > 0.05$), indicating a similar level of maturity status in both study groups [46].

The total sample was divided into a control group (C, $n = 68$) and an experimental group (E, $n = 51$). Owing to the nature of the school setting and the fact that the intervention

was delivered during PE classes (please see later for details), a quasi-experimental design was employed. Specifically, entire classes, rather than individual students, were assigned to either the experimental group (two classes) or the control group (two classes), resulting in nonrandomized allocation of participants. Given the very small number of clusters, the possible confounding effects of non-randomized grouping, multilevel modeling was not applied (please see later for Statistics), as previous school-based studies have found that intra-class correlations (ICCs) for objectively measured physical activity outcomes in this age group are typically low (e.g., $ICC < 0.05$), suggesting a limited influence of clustering on the results [47]. A flow diagram of the study is presented in Figure 1.

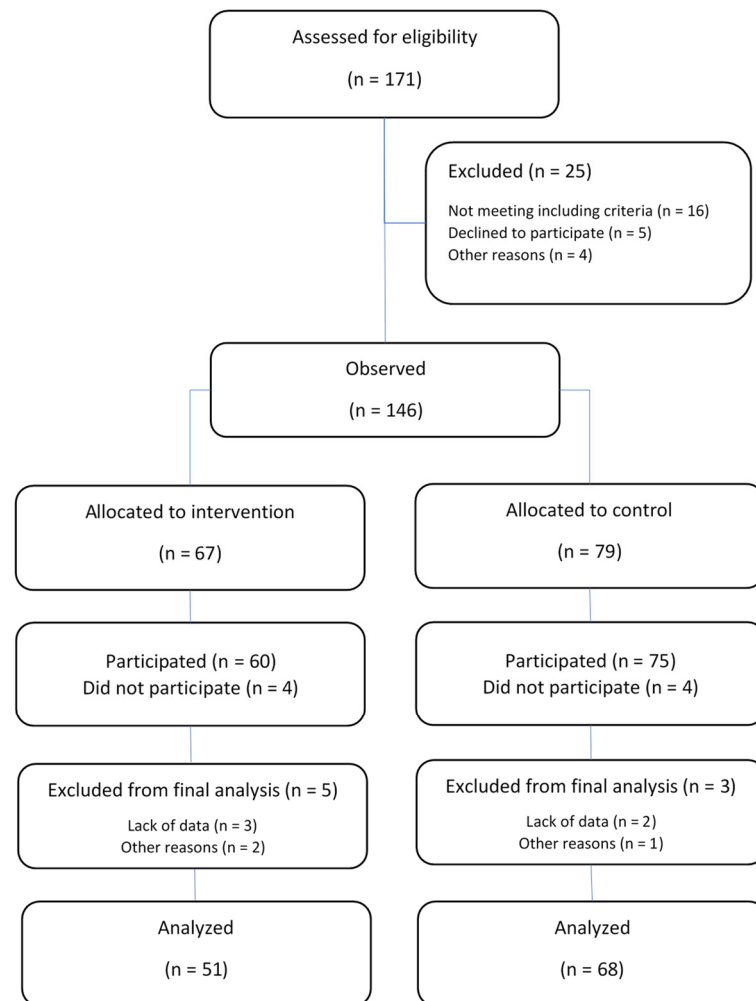


Figure 1. Flow diagram of the study.

2.2. Variables

In addition to age (in years), gender (male vs. female), and school grade (3rd vs. 4th), we directly measured PA and anthropometrics/body composition in this study.

Physical activity was objectively measured using GENEActiv triaxial accelerometers (Activinsights Ltd., Cambridge, UK). This compact (36 mm × 30 mm × 12 mm), lightweight (16 g), waterproof device is equipped with a seismic acceleration sensor and records body temperature, which enhances the accuracy of energy expenditure estimation and the detection of nonwear periods. The GENEActiv accelerometer is widely validated and commonly used for the assessment of physical activity, sedentary behavior, and sleep patterns in both research and clinical settings [48,49].

The participants were instructed to wear the accelerometer continuously on their nondominant wrist for 24 h per day throughout the monitoring period. Raw acceleration data were downloaded using GENEActiv PC software (version 2.2) in .bin format and processed with the GGIR package in R (version 1.2-0). This software automatically detects non-wear time and classifies activity intensities using Euclidean Norm Minus One (ENMO) metrics, following validated acceleration thresholds developed specifically for wrist-worn GENEActiv devices in pediatric populations [50]. The following cut-points were applied by default within the GGIR algorithm: (i) light physical activity (LPA): 35–200 mg, moderate-to-vigorous physical activity (MVPA): >200 mg, vigorous physical activity (VPA): >707 mg. These thresholds were not manually defined by the researchers but were implemented automatically by the GGIR software to ensure consistency and reproducibility. The analysis yielded estimates for total number of steps performed (STEPS; count per week), sedentary time (ST; not including sleep time; min/week), and time spent in light (LPA; min/week), moderate-to-vigorous physical activity (MVPA; min/week), and vigorous physical activity (VPA; min/week). GENEActiv devices record continuous raw triaxial acceleration, eliminating the need for predefined epoch lengths. The GGIR algorithm was used to automatically detect nonwear periods and classify activity intensities on the basis of established GENEActiv-specific thresholds. Participants with insufficient valid wear time were excluded from the final analysis. To be included, individuals were required to have at least four valid days (24 h), including a minimum of two weekdays and two weekend days, in accordance with best practices for measuring habitual PA in children. Later, a weekly average was calculated based on measured data, summarizing weekday and weekend values to represent the entire week. Importantly, activity intensity metrics (LPA, MVPA, and VPA) were derived directly from raw acceleration data using the GGIR algorithm, avoiding the need for user-defined cutoff points.

Anthropometric and body composition measurements were collected in the morning, at least three hours after waking and following normal food and fluid intake. Body height was measured in centimeters with a stadiometer. Body mass and composition were assessed using a bioelectrical impedance analyzer (Tanita TBF-300, Tokyo, Japan) in accordance with established guidelines. A 0.2 kg correction was applied to account for clothing weight. The participants' age, sex, and height were entered prior to measurement. Height was measured using a stadiometer (Seca, Birmingham, UK). During the measurement, the participants stood barefoot, with their hands placed on the designated electrodes. In addition to body height (cm) and mass (kg), the variables obtained included the calculated body mass index (BMI, kg/m²), fat mass (FM, in % of body mass), and skeletal muscle mass (SMM, in % of body mass). All the measurements for all the participants were identical, organized by schools, and conducted by trained personnel. The same measurement protocols, staff, and devices were used at all three time points (see later for details on the study protocol) to ensure measurement reliability. The applied measurement protocols and instruments were already applied to similar samples and checked for validity, and details are available elsewhere [51].

2.3. Intervention and Protocol of the Study

All participants were tested on study variables at pre-test (September 2024), post-test (late December 2024), and retention (May 2025), with the intervention period occurring between pre- and post-measurement. The study protocol is presented in Figure 2.

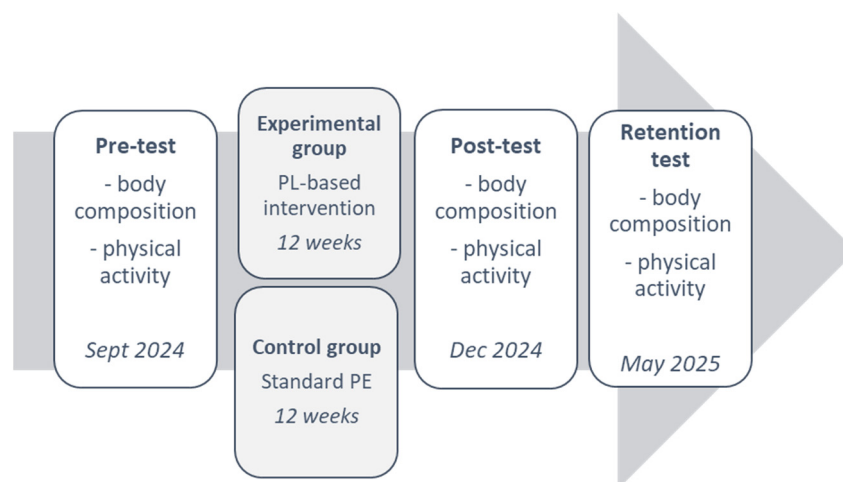


Figure 2. Study protocol.

The PL-focused educational intervention delivered to the E group was embedded within regular PE over a period of three months (12 weeks). During this time, students had three PE lessons per week, resulting in a total of 36 PE lessons across the intervention period. The PL intervention consisted of 12 original educational video materials, each lasting 3–4 min, and addressed different components of PL and PH. Specifically, the PL theme included 2 videos, covering the cognitive domain, focusing on knowledge and understanding, as well as the affective domain, addressing motivation, self-confidence, and self-efficacy. The Cardiovascular Endurance theme was covered by 3 videos. These videos addressed theoretical knowledge of the topic, and provided practical examples (i.e., how to perform cardiovascular activities) and the recommended amount of physical activity necessary to produce positive effects on this capacity. The strength theme was covered by 3 videos, focusing on cognitive and affective learning, along with practical examples that explain how to build strength, the recommended duration and frequency of exercises, and how to use equipment that is commonly available at home. The flexibility theme featured 2 videos, addressing this capacity from the cognitive and affective perspectives, and included specific examples that demonstrate different types of stretching exercises and correct execution techniques. The final topic was named “healthy habits and nutrition” and contained 2 videos, emphasizing the importance of healthy eating and hydration, and their roles in supporting physical activity and overall well-being. In general, these educational videos were designed to support a deeper understanding of PL concepts through both cognitive insights and practical applications. By combining theory with accessible demonstrations, the authors tried to enhance teaching and learning in diverse settings. All videos are freely available, and the authors hope they will assist educators in their efforts to promote physical literacy and healthy lifestyles around the world. Each video was shown three times during the program to support reinforcement and retention of key messages (please see Supplementary Materials for videos).

The main idea was to provide brief yet clear explanations of PL in general, cardiovascular endurance, and each targeted motor ability, highlighting its relevance in daily life. Moreover, the videos emphasized that physical abilities can be developed using simple, self-directed activities that do not require structured environments. Children were given practical guidance on how to use home-available equipment such as ropes, stairs, water-filled bottles, or carpets used as training mats as substitutes for gym equipment, which was backgrounded in previous knowledge that PE curriculum in Croatia could be broadened by incorporating elements that allow students to develop the knowledge and confidence to perform PA and exercise outside of class [52]. By reinforcing the idea that

movement opportunities exist beyond formal PE or sports training, the intervention aimed to empower children to recognize and utilize their own environments to stay active.

We decided to include the video-based instruction because it is increasingly recognized as an effective pedagogical tool for enhancing knowledge acquisition, particularly among children. By combining visual, auditory, and contextual learning cues, videos support multiple learning styles and promote better retention compared to text-based materials alone [53]. Moreover, short and focused educational videos have been shown to maintain attention and facilitate understanding, especially when followed by guided discussion or active reflection [54]. In the context of PE, video content can vividly demonstrate movement concepts and explain their real-life applications. As a result, video education could model desirable behavior and increase physical activity. Indeed, PL-based video instructions were shown to be effective in adolescents during the COVID-19 pandemic period [36]. In this study, brief, thematically structured videos were employed to reinforce the most important PL concepts using minimal resources and within a limited instructional timeframe.

The videos were accompanied by simultaneous explanations and teacher-led discussions, helping students engage with the content in a meaningful way. To maintain instructional balance, each video and discussion substituted approximately 5–7 min of regular PE activity time (within the standard 45 min lesson), allowing the intervention to be seamlessly integrated without compromising the overall structure of the PE curriculum. In brief, in Croatian primary schools, a typical PE lesson is structured into three main parts (i) intro (5–10 min; including light warm-up, dynamic exercises, basic movements, and short games or coordination and attention drills), (ii) main part (30 min; focused on developing motor skills and abilities, technical and tactical elements of sports, and team-based or individual physical activities, and (iii) final part (5–10 min; cool-down activities, breathing exercises, and stretching; short reflection, feedback, or motivational discussion). The educational videos were delivered as the final part of the PE classes, and therefore did not interfere with standard PE themes, meaning that standard motor practices did not differ between study groups. During the study period, the C group participated in the same number of PE lessons (36 total), but their curriculum followed the standard national PE program, which included traditional physical education themes without the PL-educational video content. The intervention summary is presented in Table 1.

Structured procedures were implemented throughout the study period. All teachers involved in the intervention group received standardized training prior to implementation. Initial training sessions were conducted separately at each school by the first authors, who were also the designers of the video materials. These sessions covered the conceptual background of physical literacy (PL), instructional goals for each video, recommended classroom prompts, and clarification strategies. Also, possible questions and answers were covered. Weekly briefings continued throughout the 12-week period to align teaching practices and ensure pedagogical coherence. Fidelity of implementation was monitored via random, non-intrusive classroom observations conducted by the first author and through internal supervision by school officials. Teachers were instructed not to deviate from the established delivery format and to integrate the video content into the final segment of each PE lesson. After viewing each video, students were asked to summarize key concepts, allowing teachers to detect and correct misunderstandings, per initial training instructions. Student adherence to the intervention was monitored using school attendance logs, and only participants who attended at least 80% of the PE sessions were included in the final analysis. The standardization, fidelity monitoring, and protocol details are given in Table S1 (Supplementary Files).

Table 1. Intervention summary.

Component	Description
Duration	3 months (12 weeks)
Frequency	3 PE lessons per week
Total Lessons	36 PE lessons in total
Delivery Format	Short educational videos (3–4 min) integrated into regular PE classes
Number of Videos	12 videos, each repeated 3 times during intervention
Video Themes	2 on PL concepts, 3 on cardiovascular endurance, 5 on motor abilities (strength, power, flexibility, coordination), and 2 on nutrition and healthy habits
Content Focus	Understanding the role of motor abilities in daily life; how to train without structured sport settings
Teaching Tools	Videos, teacher explanations, guided class discussions
Key Practical Strategies	Use of equipment available at home (e.g., ropes, water bottles, carpets); promotion of active transport (e.g., walking, cycling to school)
Control Group Activity	Standard PE curriculum without PL-educational video content

The study protocol was registered at ISCRTN (The UK’s Clinical Study Registry; ISRCTN49955797; 1 September 2024).

2.4. Statistics

All variables were tested for normality using the Kolmogorov–Smirnov test. Descriptive statistics are presented as means and standard deviations for continuous variables and as frequencies for categorical variables (gender and grade).

A $3 \times 2 \times 2$ mixed-design ANOVA was conducted to examine the effects of time (pre-, post-, and retention intervention; within-subjects factor), group (E vs. C), and gender (male vs. female; between-subjects factors) on each dependent variable. Box’s M test was used to assess the homogeneity of covariance matrices, and Levene’s test was used to evaluate the equality of error variances. Cell sizes were assessed to ensure approximate balance across conditions.

Effect sizes were reported using partial eta squared (η^2) for main and interaction effects and interpreted using conventional thresholds as follows: small ($\eta^2 = 0.01$ – 0.06), medium ($\eta^2 = 0.061$ – 0.14), and large ($\eta^2 \geq 0.141$). For significant effects, post hoc analyses were conducted using Scheffé’s test. To reduce the risk of Type I error due to multiple comparisons, a Bonferroni correction was applied where appropriate.

All statistical analyses were performed using Statistica version 14.5 (TIBCO Inc., Palo Alto, CA, USA), with a significance level set at $p < 0.05$.

3. Results

The main and interaction ANOVA effects are presented in Table 2. Significant main effects for “group” were found for STEPS ($\eta^2 = 0.03$, small ES), ST ($\eta^2 = 0.03$, small ES), and VPA ($\eta^2 = 0.03$, small ES). The main effect for “gender” was significant for STEPS ($\eta^2 = 0.15$, large ES) and VPA ($\eta^2 = 0.12$, large ES). When the main effect “time” was observed, statistical significance was reached for height ($\eta^2 = 0.84$, large ES), mass ($\eta^2 = 0.11$, moderate ES), SMM ($\eta^2 = 0.09$, moderate ES), STEPS ($\eta^2 = 0.03$, small ES), and VPA ($\eta^2 = 0.12$, moderate ES). The “time $\times$ group” interaction effect was significant for STEPS ($\eta^2 = 0.03$, small ES), ST ($\eta^2 = 0.03$, small ES), and VPA ($\eta^2 = 0.04$, small ES), indicating differential changes in

the E and C groups over the course of the study. No significant Time $\times$ Group interactions were observed for body composition indices.

Table 2. Main and interaction effects of the repeated-measures factorial ANOVA (F-test) with partial eta squared (η^2). * denotes statistical significance of $p < 0.05$.

		Intercept	Main Effects			Interaction Effects			
			Group	Gender	Time	Group $\times$ Gender	Time $\times$ Group	Time $\times$ Gender	Time $\times$ Group $\times$ Gender
Height	F-test	48,688 *	2.11	1.77	740.20 *	7.97 *	1.21	7.97 *	2.11
	η^2	0.99	0.01	0.01	0.84	0.05	0.01	0.05	0.01
Mass	F-test	1807	3.25	1.36	16.52 *	1.33	0.87	0.77	1.21
	η^2	0.93	0.02	<0.01	0.11	<0.01	<0.01	<0.01	<0.01
BMI	F-test	3113 *	1.80	0.93	9.89 *	1.31	0.35	1.45	0.05
	η^2	0.96	0.01	<0.01	0.07	0.01	<0.01	0.01	<0.01
Body fat	F-test	916 *	1.21	1.54	0.19	0.33	0.36	0.39	0.48
	η^2	0.88	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Skeletal muscle mass	F-test	20,919 *	0.66	6.11 *	12.01 *	2.60	0.79	1.27	1.00
	η^2	0.99	<0.01	0.05	0.09	0.02	<0.01	0.01	<0.01
STEPS	F-test	1214 *	3.30 *	14.05 *	3.57 *	0.07	4.01 *	0.47	0.99
	η^2	0.93	0.03	0.15	0.03	<0.01	0.03	<0.01	<0.01
ST	F-test	2700 *	3.11 *	0.52	1.17	0.53	5.34 *	0.46	0.01
	η^2	0.97	0.03	<0.01	0.02	0.01	0.03	<0.01	<0.01
LPA	F-test	1257 *	0.51	1.17	1.88	0.68	0.59	0.10	0.27
	η^2	0.93	<0.01	0.01	0.02	<0.01	<0.01	<0.01	<0.01
MVPA	F-test	2194 *	0.01	1.52	1.94	2.44	0.15	0.25	0.61
	η^2	0.96	<0.01	0.02	0.02	0.03	<0.01	<0.01	<0.01
VPA	F-test	235 *	3.71 *	28.25 *	10.53 *	1.06	4.09 *	1.52	0.35
	η^2	0.75	0.03	0.25	0.12	0.01	0.04	0.02	<0.01

Legend: STEPS—number of steps per week, ST—sedentary time, LPA—light physical activity, MVPA—moderate-to-vigorous physical activity, VPA—vigorous physical activity.

Descriptive statistics for the total sample and the significance of post hoc differences for the ANOVA main effect “time” are presented in Table 3. Body height and mass increased during the course of the study, with significant differences noted among all three tests. The participants had higher SMM values at retention than at post-measurement. Decreases in the STEPS and VPA were observable during the course of the study, with significant post hoc differences noted between all the measurements.

Descriptive statistics and the significance of post hoc differences for the variables showing significant “time $\times$ group” interaction effects in the ANOVA are presented in Figure 3. The step count (STEPS) decreased during the course of the study in the C group, with significant post hoc differences noted between the pre- and remaining two measurements (Figure 3A). Furthermore, the ST increased only in the C group (significantly different between pre- and retention), with lower values of ST in the E group than in the C group for retention testing (Figure 3B). Finally, the VPA of the C group decreased during the study course (significant post hoc differences between all measurements), with higher VPA in the E group than in the C group for retention testing (Figure 3C).

Table 3. Descriptive statistics for the total sample of participants and ANOVA post hoc differences.

	Pre-	Post-	Retention
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Height (cm)	143.43 $\pm$ 7.4	144.72 $\pm$ 7.26 [¥]	148.65 $\pm$ 7.61 ^{¥,£}
Mass (kg)	37.29 $\pm$ 10.58	38.04 $\pm$ 9.9 [¥]	39.59 $\pm$ 10.2 ^{¥,£}
BMI (kg/m ²)	17.72 $\pm$ 3.37	18.02 $\pm$ 3.59	17.75 $\pm$ 3.39
Body fat (%)	22.98 $\pm$ 5.95	23.6 $\pm$ 6.49	23.66 $\pm$ 7.43
Skeletal muscle mass (%)	43.39 $\pm$ 4.07	43.19 $\pm$ 3.58	43.95 $\pm$ 3.37 [£]
STEPS (count)	91,605.24 $\pm$ 29,755.01	83,511.71 $\pm$ 28,483.71 [¥]	86,681.1 $\pm$ 29,937.73 [¥]
ST (min/week)	3043.47 $\pm$ 720.04	3292.58 $\pm$ 755.94	3313.48 $\pm$ 668.73
LPA (min/week)	2383.58 $\pm$ 726.65	2191.31 $\pm$ 810.83	2237.23 $\pm$ 757.28
MVPA (min/week)	1253.08 $\pm$ 336.36	1257.96 $\pm$ 350.83	1143.27 $\pm$ 329.82
VPA (min/week)	266.41 $\pm$ 192.37	194.69 $\pm$ 143.28 [¥]	200.4 $\pm$ 168.81 [¥]

Legend: STEPS—number of steps per week, ST—sedentary time, LPA—light physical activity, MVPA—moderate-to-vigorous physical activity, VPA—vigorous physical activity, [¥]—significantly different from pre-measurement, [£]—significantly different from post-measurement.

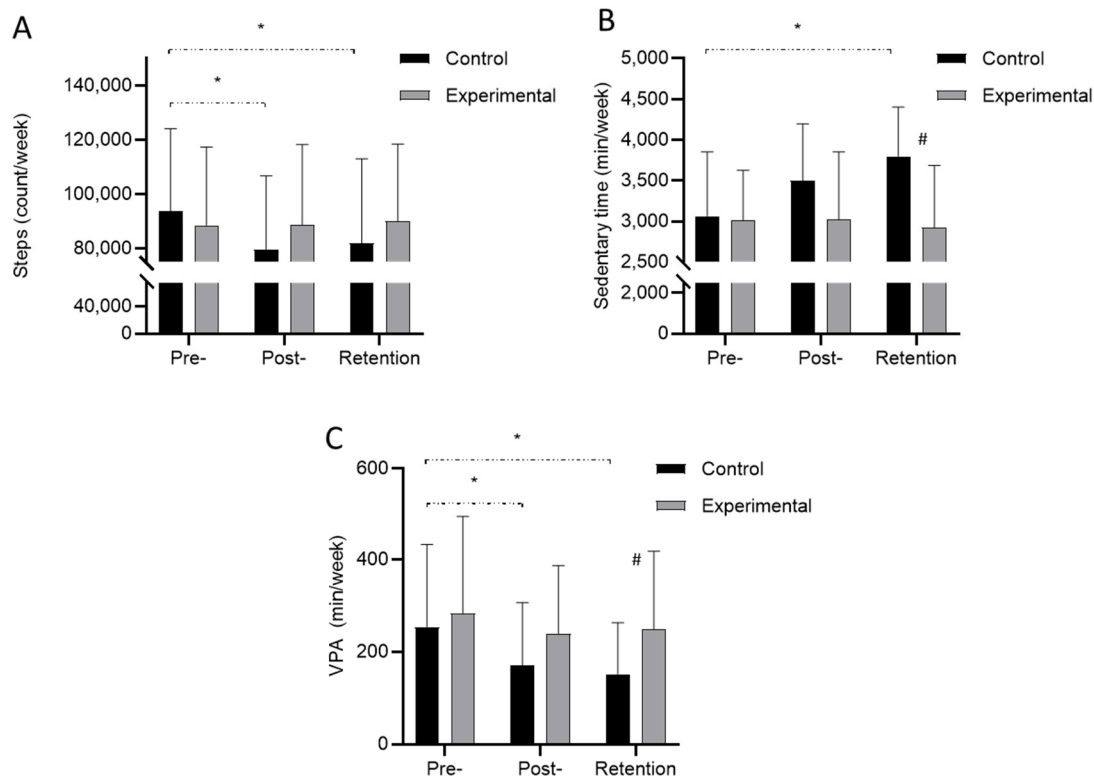


Figure 3. Descriptive statistics (data are presented as means + standard deviations) for study groups ((A)—step counts, (B)—sedentary time, (C)—vigorous physical activity) and significant post hoc differences for variables with significant ANOVA time $\times$ group interaction effects (* indicates significant within-group differences at $p < 0.05$, # indicates significant between-group differences for each measurement at $p < 0.05$).

4. Discussion

With respect to the study aims, several important findings are noted. First, significant positive effects of the PL intervention were found in directly measured indices of PA, specifically, in maintaining the ST, STEPS, and VPA in the E group, with a simultaneous increase in the ST and decreases in the STEP and VPA in the C group. Second, we did not

observe significant effects of the PL intervention on the body composition indices of the studied preadolescents. Therefore, our main study hypothesis can be accepted.

4.1. Positive Effects on Indices of Physical Activity

Sedentary behavior levels in the E group remained unchanged, whereas those in the C group increased over the course of the study. The increase in sedentarism in the C group is likely associated with school-related and seasonal factors, such as increased homework demands, increased winter months, and reduced daylight hours, all of which contribute to a general increase in sedentary behavior. Indeed, it is well documented that shorter days and colder weather during the winter months limit opportunities for outdoor PA and promote more sedentary time, whereas academic pressures further reduce the time available for movement [55–57]. This trend was clearly evident in the C group.

On the other hand, the findings also suggest that well-designed interventions can help mitigate this seasonal decline in PA [56,57]. It seems that this actually occurred in the E group. Most likely, the implemented intervention helped students in the E group develop awareness of the importance of reducing sedentary behavior and provided them with practical strategies to incorporate more PA into their daily lives. As a result, they were able to maintain stable levels of ST despite seasonal and academic factors that typically promote increased sedentariness during the school years. Considering the concept of applied intervention, this outcome highlights the importance of educational approaches that not only increase knowledge but also motivate behavioral change and strengthen children's ability to manage their own habits, representing the core principles of PL.

The intervention had a significant effect on PA, as measured by the step count. Once again, the results revealed that the step count was maintained over the observed school year in the E group, whereas a decrease was evident in the C group. Most likely, education was effective in encouraging children to engage in more active use of their free time, which plays a key role in preventing sedentary lifestyles and associated health risks. This is consistent with the findings of previous studies in which PL-based interventions were effective in maintaining cardiovascular endurance in adolescents during the COVID-19 pandemic [36]. With respect to this specific variable (STEP), it must be highlighted that throughout the intervention, the children were taught a broader understanding of PA, highlighting the fact that PA includes not only sports but also everyday movements such as walking to school, practicing, or engaging in leisure time. In other words, the intervention aimed not only to increase awareness of the importance of daily movement but also to provide children with practical strategies to integrate PA into daily routines, which together resulted in positive outcomes in the E group.

Consistent with the previous discussions on sedentary behavior and step count, the results indicated that VPA levels in the E group were maintained, whereas a significant decline in VPA was observed in the C group over the course of the study. Although the intervention did not result in an increase in VPA in the E group, considering the previously described (negative) seasonal and school-year effects on PA in children, the observed maintenance of VPA can still be regarded as a positive effect of the intervention [58,59]. The discussed factors that negatively influence PA likely contributed to the decline in VPA in the C group. However, it appears that the PL-based intervention helped maintain levels of VPA over the course of the study in the E group. Therefore, although the intervention did not produce a measurable increase in PA indices, the retention of VPA and step count in the experimental group, compared to the notable declines observed in the control group, represents a meaningful outcome, particularly during a school year period marked by seasonal declines in PA. From an ecological perspective, maintaining baseline levels of

VPA and daily steps aligns with public health goals, as even the prevention of decline can support long-term adherence to PA guidelines in children.

One could question the lack of effects in MVPA, but this is probably a result of the classification of accelerometer-measured data. Specifically, the lack of significant effect in MVPA, despite observed differences in VPA and step count, may be partially explained by the way physical activity intensities are classified in accelerometry-based analysis [60]. In brief, MVPA encompasses a broad range of intensities, and it is possible that changes within the upper end (i.e., VPA) were not substantial enough to shift overall MVPA values. Additionally, small fluctuations in light or moderate activity may have offset gains in VPA, resulting in a net neutral effect on the MVPA category.

Collectively, one of the goals of the PL educational content was to highlight that physical activity does not require access to specialized equipment, organized sports, or formal training facilities (please see Materials and Methods for details). As professionals in sport and exercise but also parents themselves, the authors of the educational materials were well aware that the absence of structured physical exercise programs, equipment, and facilities is often overstated as a barrier to PA in all age groups, particularly among children. Indeed, this problem is also highlighted in the literature [61,62]. To address this misconception, the educational video materials and accompanying instructions consistently encouraged children to engage in simple, self-directed forms of movement, such as active play, running, jumping, or stair climbing, activities that can be performed in a variety of environments, including at home or outdoors. Using this approach, the intervention aimed to “demystify” exercise and promote the idea that PA is both accessible and adaptable.

A similar approach was previously found to be effective in adolescents, where the authors confirmed the effects of PL online education on cardiovascular endurance during the COVID-19 pandemic [36]. Furthermore, an 8-week intervention study based on self-determination theory and focused on developing knowledge, motivation, and physical competence (a model closely aligned with our PL-based intervention) resulted in increased VPA levels in children aged 11–13 years [63]. In general, it aligns closely with the foundational concept of PL as defined by Whitehead, who described it as “the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life” [64]. Taken together, these findings suggest that PL-based education likely enhanced children’s confidence and perceived autonomy in remaining active, which ultimately led to the results we presented and discussed thus far.

4.2. No Significant Effect on Body Composition

As body composition was evaluated as a secondary, exploratory outcome in this study, the lack of significant changes was not unexpected. Several factors may explain this outcome. First, and perhaps most importantly, this result can be attributed to the fact that diet plays a dominant role in regulating body composition in the pediatric population. PA alone, especially when not accompanied by changes in dietary habits, is often insufficient to produce noticeable alterations in body composition [65]. Moreover, it is important to highlight that at this age, children typically do not have autonomy over food choices and intake, relying instead on parental dietary practices, household food availability, and school meal offerings [66–68]. Meanwhile, in our study, only two videos addressed nutrition, without direct parental involvement or changes in food environment.

Specifically, a study involving 596 children aged 3–12 years and their parents revealed that parental factors (e.g., parental BMI, dietary styles, and the overall family environment) were significantly associated with children’s BMI and nutritional status [67]. Similarly, a systematic review demonstrated that healthier parenting styles and structured, controlled

dietary practices can substantially contribute to improved body composition outcomes in children aged 4–12 years [68]. Similarly, in their systematic review of nutrition and physical activity interventions, Tomayko and colleagues (2021) emphasized that parental involvement is a key factor in improving body weight and preventing obesity in children within this age group [69]. Therefore, although the educational component of our intervention included some nutritional information and evidently positively influenced PA, its impact on body composition was limited simply because of the lack of actual changes in children's eating behavior.

The second probable reason for the absence of significant effects on children's body composition may be the insufficient duration of the intervention. For example, a recent systematic review and meta-analysis involving a sample of 20,462 children aged 5–10 years reported that interventions longer than 12 weeks (3 months) generally yield better and more sustainable outcomes in reducing BMI and improving body composition than shorter interventions do [70]. Finally, we should not underestimate the natural variability and dynamic changes in anthropometric measures that occur in children aged 9–11 years. This period is characterized by rapid growth and prepubertal development. During this stage, increases in both fat mass and lean mass are typical and can vary widely among individuals, influenced by genetics, maturation rates, and hormonal changes [71]. As a result, normal growth-related changes may override or mask the effects of short-term interventions. Together, these factors could influence the effects of the PL intervention as well, simply by making it more difficult to detect significant shifts in body composition attributable to the intervention alone.

4.3. Limitations and Strengths

This study has several limitations that should be acknowledged. First, although the intervention was standardized across all participants in the E group, it was delivered by different teachers who taught PE for different classes. Next, because of the specifics of the school curriculum, classes and not children were divided into E and C groups. This may have introduced variability in delivery quality and engagement (among PE teachers and children), potentially influencing the study outcomes. However, due to the very limited number of classes (four in total), cluster effects could not be modeled and standard errors may therefore be underestimated. A limitation of the study is the use of BIA equations (Tanita TBF-300), which are not specifically validated for children aged 9–11, and for whom region- and ethnicity-specific standards are still lacking. However, since our focus was on within-subject changes rather than absolute comparisons, the impact on our findings is likely limited. Additionally, the study did not include certain important sociocultural variables (i.e., parental control, neighborhood safety, and the home environment) that could potentially moderate children's PA behaviors and influence the final results. Also, this study was performed in a specific geographic region with a mild climate, which may limit the generalizability of the findings to areas with unfavorable weather conditions. Additionally, we cannot ignore the fact that teachers were not strictly formally educated and trained on applied interventions, and that limited fidelity monitoring may have introduced variability in intervention delivery across classes. Furthermore, the quasi-experimental group allocation without randomization reduces internal validity and limits the generalizability of the findings. Further studies should simultaneously follow eventual changes in PL facets and their influence on changes in health indices in children. From our perspective, the most significant limitation is the study's time frame, which covered only one school year rather than a full calendar year. This design excluded important seasonal variations, particularly summer months, which are known to influence PA in children, particularly those living in Mediterranean regions.

Despite these limitations, this study also has several notable strengths. First, this study is among the first to examine a PL-focused educational intervention in early school-aged children via a pre/post/retention design. This allowed us to assess the immediate and sustained effects. Second, PA was measured directly, providing objective and reliable data rather than relying on subjective reports, which are prone to bias. Third, all assessments were conducted by the same group of trained examiners, ensuring consistency in testing procedures and reducing measurement error across time points.

5. Conclusions

This study demonstrates that a PL intervention, when embedded within standard PE, can effectively help stabilize sedentary behavior and maintain indices of PA in children during the school year. These findings are particularly relevant given that seasonal and school-related factors often contribute to declining activity levels. It is of particular importance to note that the applied intervention used low-cost, scalable, and curriculum-aligned strategies, making it a potentially practical approach for real-world educational settings.

No specific effects were evidenced in body composition. This may be due to several factors: the absence of a structured nutritional component, the relatively short intervention duration, and the natural variability associated with growth and development in this age group. Additionally, the lack of significant changes may reflect limitations in the precision of body composition measurement tools used in this population.

Importantly, the study's conclusions are constrained by certain limitations. These include variability in intervention delivery due to differences in teacher training and fidelity, the quasi-experimental design without randomization, and the small number of clusters (classes). These factors could reduce the internal validity and limit the generalizability of the findings to other populations and educational contexts.

Despite these limitations, the study contributes original evidence supporting the behavioral impact of PL-based educational interventions on maintaining children's PA. Future research should employ randomized controlled designs, include formal fidelity monitoring procedures, and extend intervention duration to account for seasonal variation. Moreover, incorporating broader contextual and sociocultural variables (i.e., parental influence and environmental factors) could provide a more comprehensive understanding of how PL interventions interact with children's health and development. Also, studies examining the effects of similar interventions on different fitness indicators are warranted.

Supplementary Materials: The video materials of the applied intervention are available here: <https://www.youtube.com/playlist?list=PLJ15G3CvzEJ2VHOqFhp2mZreNJrb5XMRv> (accessed on 10 January 2026). Supplementary Table S1, including Standardization, Fidelity Monitoring, and Intervention Protocol Details, is available here: <https://www.dropbox.com/scl/fi/kongf8klv92g8bul2jmvvg/Table-S1-Standardization.docx?rlkey=fl9y9va6r1psnefqz4pcl23ya&dl=0> (accessed on 10 January 2026).

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethical Committee of the Faculty of Kinesiology, University of Zagreb (approval number 93/2004, issued on 9 September 2024).

Informed Consent Statement: Informed consent was obtained from the parents or legal guardians of all subjects involved in the study.

Data Availability Statement: The data are available to all interested parties upon reasonable request.

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Abbreviations

The following abbreviations are used in this manuscript:

PA	Physical activity
PL	Physical literacy
PE	Physical education
PF	Physical fitness
LPA	Light physical activity
MVPA	Moderate-to-vigorous physical activity
VPA	Vigorous physical activity

References

1. Siedentop, D.; Van der Mars, H. *Introduction to Physical Education, Fitness, and Sport*; Human Kinetics: Champaign, IL, USA, 2022.
2. García-Hermoso, A.; Izquierdo, M.; Ramírez-Vélez, R. Tracking of physical fitness levels from childhood and adolescence to adulthood: A systematic review and meta-analysis. *Transl. Pediatr.* **2022**, *11*, 474–486. [\[CrossRef\]](#)
3. Moliner-Urdiales, D.; Ruiz, J.R.; Ortega, F.B.; Jiménez-Pavón, D.; Vicente-Rodriguez, G.; Rey-López, J.P.; Martínez-Gómez, D.; Casajús, J.A.; Mesana, M.I.; Marcos, A.; et al. Secular trends in health-related physical fitness in Spanish adolescents The AVENA and HELENA Studies. *J. Sci. Med. Sport* **2010**, *13*, 584–588. [\[CrossRef\]](#)
4. Silventoinen, K.; Maia, J.; Jelenkovic, A.; Pereira, S.; Gouveia, É.; Antunes, A.; Thomis, M.; Lefevre, J.; Kaprio, J.; Freitas, D. Genetics of somatotype and physical fitness in children and adolescents. *Am. J. Hum. Biol.* **2021**, *33*, e23470. [\[CrossRef\]](#)
5. Souilla, L.; Larsen, A.C.; Juhl, C.B.; Skou, S.T.; Bricca, A. Childhood and adolescence physical activity and multimorbidity later in life: A systematic review. *J. Multimorb. Comorbidity* **2024**, *14*, 26335565241231403. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Dwyer, T.; Magnusson, C.G.; Schmidt, M.D.; Ukoumunne, O.C.; Ponsonby, A.L.; Raitakari, O.T.; Zimmet, P.Z.; Blair, S.N.; Thomson, R.; Cleland, V.J.; et al. Decline in Physical Fitness from Childhood to Adulthood Associated with Increased Obesity and Insulin Resistance in Adults. *Diabetes Care* **2009**, *32*, 683–687. [\[CrossRef\]](#)
7. Hills, A.P.; Andersen, L.B.; Byrne, N.M. Physical activity and obesity in children. *Br. J. Sports Med.* **2011**, *45*, 866–870. [\[CrossRef\]](#)
8. Smith, J.J.; Eather, N.; Morgan, P.J.; Plotnikoff, R.C.; Faigenbaum, A.D.; Lubans, D.R. The Health Benefits of Muscular Fitness for Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Med.* **2014**, *44*, 1209–1223. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Bermejo-Cantarero, A.; Alvarez-Bueno, C.; Martínez-Vizcaino, V.; Redondo-Tébar, A.; Pozuelo-Carrascosa, D.P.; Sánchez-López, M. Relationship between both cardiorespiratory and muscular fitness and health-related quality of life in children and adolescents: A systematic review and meta-analysis of observational studies. *Health Qual. Life Outcomes* **2021**, *19*, 127. [\[CrossRef\]](#)
10. Cadenas-Sanchez, C.; Mena-Molina, A.; Torres-Lopez, L.V.; Migueles, J.H.; Rodriguez-Ayllon, M.; Lubans, D.R.; Ortega, F.B. Healthier Minds in Fitter Bodies: A Systematic Review and Meta-Analysis of the Association between Physical Fitness and Mental Health in Youth. *Sports Med.* **2021**, *51*, 2571–2605. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Dambel, L.; Del Sordo, G.; Saidi, O.; Duché, P. Exploring the Effects of Lifestyle Disruptions on Physical Fitness in Children and Adolescents: A Systematic Scoping Review. *Sports Med.-Open* **2025**, *11*, 65. [\[CrossRef\]](#)
12. Fuhner, T.; Kliegl, R.; Arntz, F.; Kriemler, S.; Granacher, U. An Update on Secular Trends in Physical Fitness of Children and Adolescents from 1972 to 2015: A Systematic Review. *Sports Med.* **2021**, *51*, 303–320. [\[CrossRef\]](#)
13. Uzicanin, E.; Gilic, B.; Babajic, F.; Huremovic, T.; Hodzic, S.; Bilalic, J.; Sajber, D. The international study of movement behaviours in the early years: A pilot study from Bosnia and Herzegovina. *Montenegrin J. Sports Sci. Med.* **2024**, *20*, 5–12. [\[CrossRef\]](#)
14. Zhou, X.X.; Li, J.Y.; Jiang, X.P. Effects of different types of exercise intensity on improving health-related physical fitness in children and adolescents: A systematic review. *Sci Rep.* **2024**, *14*, 14301. [\[CrossRef\]](#)
15. Burden, S.J.; Weedon, B.D.; Turner, A.; Whaymand, L.; Meaney, A.; Dawes, H.; Jones, A. Intensity and Duration of Physical Activity and Cardiorespiratory Fitness. *Pediatrics* **2022**, *150*, e2021056003. [\[CrossRef\]](#) [\[PubMed\]](#)

16. Jaekel, J. The role of physical activity and fitness for children's wellbeing and academic achievement. *Pediatr. Res.* **2024**, *96*, 1550–1551. [\[CrossRef\]](#)
17. Chen, W.Y.; Hammond-Bennett, A.; Hypnar, A.; Mason, S. Health-related physical fitness and physical activity in elementary school students. *BMC Public Health* **2018**, *18*, 195. [\[CrossRef\]](#) [\[PubMed\]](#)
18. Haapala, E.A.; Leppänen, M.H.; Skog, H.; Lubans, D.R.; Viitasalo, A.; Lintu, N.; Jalanko, P.; Maeaettae, S.; Lakka, T.A. Childhood Physical Fitness as a Predictor of Cognition and Mental Health in Adolescence: The PANIC Study. *Sports Med.* **2025**, *55*, 487–497. [\[CrossRef\]](#)
19. Kumar, B.; Robinson, R.; Till, S. Physical activity and health in adolescence. *Clin. Med.* **2015**, *15*, 267–272. [\[CrossRef\]](#)
20. Melby, P.S.; Elsborg, P.; Nielsen, G.; Lima, R.A.; Bentsen, P.; Andersen, L.B. Exploring the importance of diversified physical activities in early childhood for later motor competence and physical activity level: A seven-year longitudinal study. *BMC Public Health* **2021**, *21*, 1492. [\[CrossRef\]](#)
21. Gu, X.L.; Chang, M.; Solmon, M.A. Physical Activity, Physical Fitness, and Health-Related Quality of Life in School-Aged Children. *J. Teach. Phys. Educ.* **2016**, *35*, 117–126. [\[CrossRef\]](#)
22. Guillamón, A.R.; García-Cantó, E.; García, P.L.R.; Soto, J.J.P.; Marcos, M.L.T.; López, P.J.T. Physical activity, physical fitness and quality of diet in schoolchildren from 8 to 12 years. *Nutr. Hosp.* **2017**, *34*, 1292–1298. [\[CrossRef\]](#)
23. Larsen, M.N.; Nielsen, C.M.; Orntoft, C.O.; Randers, M.B.; Manniche, V.; Hansen, L.; Hansen, P.R.; Bangsbo, J.; Krstrup, P. Physical Fitness and Body Composition in 8-10-Year-Old Danish Children Are Associated with Sports Club Participation. *J. Strength Cond. Res.* **2017**, *31*, 3425–3434. [\[CrossRef\]](#)
24. Padulo, J.; Bragazzi, N.L.; De Giorgio, A.; Grgantov, Z.; Prato, S.; Ardigò, L.P. The Effect of Physical Activity on Cognitive Performance in an Italian Elementary School: Insights From a Pilot Study Using Structural Equation Modeling. *Front. Physiol.* **2019**, *10*, 202. [\[CrossRef\]](#)
25. Jarvamaa, M.; Riso, E.M.; Reisberg, K.; Jurimae, J. Development of Cardiorespiratory Fitness in Children in the Transition From Kindergarten to Basic School According to Participation in Organized Sports. *Front. Physiol.* **2022**, *13*, 881364. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Ługowska, K.; Kolanowski, W.; Trafialek, J. Increasing physical activity at school improves physical fitness of early adolescents. *Int. J. Environ. Res. Public Health* **2023**, *20*, 2348. [\[CrossRef\]](#)
27. Dumuid, D.; Wake, M.; Clifford, S.; Burgner, D.; Carlin, J.B.; Mensah, F.K.; Frayssse, F.; Lycett, K.; Baur, L.; Olds, T. The association of the body composition of children with 24-hour activity composition. *J. Pediatr.* **2019**, *208*, 43–49.e49. [\[CrossRef\]](#)
28. Poitras, V.J.; Gray, C.E.; Borghese, M.M.; Carson, V.; Chaput, J.-P.; Janssen, I.; Katzmarzyk, P.T.; Pate, R.R.; Connor Gorber, S.; Kho, M.E. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl. Physiol. Nutr. Metab.* **2016**, *41*, S197–S239. [\[CrossRef\]](#)
29. García-Artero, E.; Ortega, F.B.; Ruiz, J.R.; Mesa, J.L.; Delgado, M.; González-Gross, M.; García-Fuentes, M.; Vicente-Rodríguez, G.; Gutiérrez, Á.; Castillo, M.J. El perfil lipídico-metabólico en los adolescentes está más influido por la condición física que por la actividad física (estudio AVENA). *Rev. Española Cardiol.* **2007**, *60*, 581–588. [\[CrossRef\]](#)
30. Martínez-Vizcaino, V.; Sánchez-López, M. Relación entre actividad física y condición física en niños y adolescentes. *Rev. Española De Cardiol.* **2008**, *61*, 108–111. [\[CrossRef\]](#)
31. Twisk, J.W.R.; Kemper, H.C.G.; van Mechelen, W. The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age. The Amsterdam Growth and Health Longitudinal Study. *Int. J. Sports Med.* **2002**, *23*, S8–S14. [\[CrossRef\]](#) [\[PubMed\]](#)
32. Whitehead, M. Definition of physical literacy and clarification of related issues. *ICSSPE Bull.* **2013**, *65*, 29–34.
33. Rajkovic Vuletic, P.; Gilic, B.; Zenic, N.; Pavlinovic, V.; Kesic, M.G.; Idrizovic, K.; Sunda, M.; Manojlovic, M.; Sekulic, D. Analyzing the associations between facets of physical literacy, physical fitness, and physical activity levels: Gender-and age-specific cross-sectional study in preadolescent children. *Educ. Sci.* **2024**, *14*, 391. [\[CrossRef\]](#)
34. Vuletic, P.R.; Kesic, M.G.; Gilic, B.; Pehar, M.; Uzicanin, E.; Idrizovic, K.; Sekulic, D. Evaluation of physical literacy in 9-to 11-Year-Old children: Reliability and validity of two measurement tools in three southeastern European countries. *Children* **2023**, *10*, 1722. [\[CrossRef\]](#)
35. Graudusius, M.; Koch, L.; Wessely, S.; Joisten, C. School-based promotion of physical literacy: A scoping review. *Front. Public Health* **2024**, *12*, 1322075. [\[CrossRef\]](#) [\[PubMed\]](#)
36. Gilic, B.; Sunda, M.; Versic, S.; Modric, T.; Olujic, D.; Sekulic, D. Effectiveness of Physical-Literacy-Based Online Education on Indices of Physical Fitness in High-School Adolescents: Intervention Study during the COVID-19 Pandemic Period. *Children* **2023**, *10*, 1666. [\[CrossRef\]](#)
37. Carl, J.; Barratt, J.; Wanner, P.; Topfer, C.; Cairney, J.; Pfeifer, K. The Effectiveness of Physical Literacy Interventions: A Systematic Review with Meta-Analysis. *Sports Med.* **2022**, *52*, 2965–2999. [\[CrossRef\]](#)
38. Johnstone, A.; Hughes, A.R.; Janssen, X.; Reilly, J.J. Pragmatic evaluation of the Go2Play active play intervention on physical activity and fundamental movement skills in children. *Prev. Med. Rep.* **2017**, *7*, 58–63. [\[CrossRef\]](#)

39. Mandigo, J.; Lodewyk, K.; Tredway, J. Examining the Impact of a Teaching Games for Understanding Approach on the Development of Physical Literacy Using the Passport for Life Assessment Tool. *J. Teach. Phys. Educ.* **2019**, *38*, 136–145. [\[CrossRef\]](#)
40. Crozier, M.; Wasenius, N.S.; Denize, K.M.; da Silva, D.F.; Nagpal, T.S.; Adamo, K.B. Evaluation of Afterschool Activity Programs' (ASAP) Effect on Children's Physical Activity, Physical Health, and Fundamental Movement Skills. *Health Educ. Behav.* **2022**, *49*, 87–96. [\[CrossRef\]](#)
41. Invernizzi, P.L.; Crotti, M.; Bosio, A.; Cavaggioni, L.; Alberti, G.; Scurati, R. Multi-Teaching Styles Approach and Active Reflection: Effectiveness in Improving Fitness Level, Motor Competence, Enjoyment, Amount of Physical Activity, and Effects on the Perception of Physical Education Lessons in Primary School Children. *Sustainability* **2019**, *11*, 405. [\[CrossRef\]](#)
42. Stoddart, A.L.; Humbert, M.L.; Kerpan, S.; Cameron, N.; Kriellaars, D. PLitPE: An intervention for physical literacy enriched pedagogy in Canadian elementary school physical education classes. *Phys. Educ. Sport Pedagog.* **2023**, *28*, 675–691. [\[CrossRef\]](#)
43. Nezondet, C.; Gandrieau, J.; Bourrelie, J.; Nguyen, P.; Zunquin, G. The Effectiveness of a Physical Literacy-Based Intervention for Increasing Physical Activity Levels and Improving Health Indicators in Overweight and Obese Adolescents (CAPACITES 64). *Children* **2023**, *10*, 956. [\[CrossRef\]](#) [\[PubMed\]](#)
44. Santos, S.; Jimenez, S.; Sampaio, J.; Leite, N. Effects of the Skills4Genius sports-based training program in creative behavior. *PLoS ONE* **2017**, *12*, e0172520. [\[CrossRef\]](#) [\[PubMed\]](#)
45. Bander, A.; Murphy-Alford, A.J.; Owino, V.O.; Loechl, C.U.; Wells, J.C.; Gluning, I.; Kerac, M. Childhood BMI and other measures of body composition as a predictor of cardiometabolic non-communicable diseases in adulthood: A systematic review. *Public Health Nutr.* **2023**, *26*, 323–350. [\[CrossRef\]](#)
46. Moore, S.A.; McKay, H.A.; Macdonald, H.; Nettlefold, L.; Baxter-Jones, A.D.; Cameron, N.; Brasher, P.M. Enhancing a Somatic Maturity Prediction Model. *Med. Sci. Sports Exerc.* **2015**, *47*, 1755–1764. [\[CrossRef\]](#)
47. Van Sluijs, E.M.; McMinn, A.M.; Griffin, S.J. Effectiveness of interventions to promote physical activity in children and adolescents: Systematic review of controlled trials. *BMJ* **2007**, *335*, 703. [\[CrossRef\]](#)
48. Clark, C.C.T.; Nobre, G.C.; Fernandes, J.F.T.; Moran, J.; Drury, B.; Mannini, A.; Gronek, P.; Podstawski, R. Physical activity characterization: Does one site fit all? *Physiol. Meas.* **2018**, *39*, 09TR02. [\[CrossRef\]](#)
49. Esliger, D.W.; Rowlands, A.V.; Hurst, T.L.; Catt, M.; Murray, P.; Eston, R.G. Validation of the GENE Accelerometer. *Med. Sci. Sports Exerc.* **2011**, *43*, 1085–1093. [\[CrossRef\]](#)
50. Hildebrand, M.; Hansen, B.H.; van Hees, V.T.; Ekelund, U. Evaluation of raw acceleration sedentary thresholds in children and adults. *Scand. J. Med. Sci. Sports* **2017**, *27*, 1814–1823. [\[CrossRef\]](#)
51. Khan, I.; Hawkesworth, A.; Hawlader, S.M.D.H.; El Arifeen, S.; Moore, S.; Hills, A.P.; Wells, J.C.; Persson, L.-Å.; Kabir, I. Body composition of Bangladeshi children: Comparison and development of leg-to-leg bioelectrical impedance equation. *J. Health Popul. Nutr.* **2012**, *30*, 281–290. [\[CrossRef\]](#)
52. Sunda, M.; Gilic, B.; Sekulic, D.; Matic, R.; Drid, P.; Alexe, D.I.; Cucui, G.G.; Lupu, G.S. Out-of-School Sports Participation Is Positively Associated with Physical Literacy, but What about Physical Education? A Cross-Sectional Gender-Stratified Analysis during the COVID-19 Pandemic among High-School Adolescents. *Children* **2022**, *9*, 753. [\[CrossRef\]](#)
53. Mayer, R.E. *Multimedia Learning*; Cambridge University Press: Cambridge, UK, 2001.
54. Kay, R.H. Exploring the use of video podcasts in education: A comprehensive review of the literature. *Comput. Hum. Behav.* **2012**, *28*, 820–831. [\[CrossRef\]](#)
55. Atkin, A.J.; Sharp, S.J.; Harrison, F.; Brage, S.; Van Sluijs, E.M.F. Seasonal Variation in Children's Physical Activity and Sedentary Time. *Med. Sci. Sports Exerc.* **2016**, *48*, 449–456. [\[CrossRef\]](#)
56. Janssen, X.; Basterfield, L.; Parkinson, K.; Pearce, M.; Reilly, J.; Adamson, A.; Reilly, J. Determinants of changes in sedentary time and breaks in sedentary time among 9 and 12 year old children. *Prev. Med. Rep.* **2015**, *2*, 880–885. [\[CrossRef\]](#) [\[PubMed\]](#)
57. Weaver, R.G.; Hensing, C.; Armstrong, B.; Adams, E.L.; Beets, M. Seasonal Shifts in Children's Sedentary Behaviors, Physical Activity, and Sleep A Systematic Review and meta-Analysis. *Pediatr. Clin. N. Am.* **2022**, *69*, 671–693. [\[CrossRef\]](#)
58. Khawaja, I.; Woodfield, L.; Collins, P.; Benkwitz, A.; Nevill, A. Tracking Children's Physical Activity Patterns across the School Year: A Mixed-Methods Longitudinal Case Study. *Children* **2020**, *7*, 178. [\[CrossRef\]](#) [\[PubMed\]](#)
59. Belanger, M.; Gray-Donald, K.; O'Loughlin, J.; Paradis, G.; Hanley, J. Influence of weather conditions and season on physical activity in adolescents. *Ann. Epidemiol.* **2009**, *19*, 180–186. [\[CrossRef\]](#)
60. Migueles, J.H.; Cadenas-Sanchez, C.; Ekelund, U.; Delisle Nyström, C.; Mora-Gonzalez, J.; Löf, M.; Labayen, I.; Ruiz, J.R.; Ortega, F.B. Accelerometer data collection and processing criteria to assess physical activity and other outcomes: A systematic review and practical considerations. *Sports Med.* **2017**, *47*, 1821–1845. [\[CrossRef\]](#) [\[PubMed\]](#)
61. Dwyer, J.J.; Allison, K.R.; Barrera, M.; Hansen, B.; Goldenberg, E.; Boutilier, M.A. Teachers' perspective on barriers to implementing physical activity curriculum guidelines for school children in Toronto. *Can. J. Public Health* **2003**, *94*, 448–452. [\[CrossRef\]](#)
62. Finkelstein, D.M.; Petersen, D.M.; Schottenfeld, L.S. Promoting Children's Physical Activity in Low-Income Communities in Colorado: What Are the Barriers and Opportunities? *Prev. Chronic Dis.* **2017**, *14*, E134. [\[CrossRef\]](#)

63. Liu, Y.; Chen, S.L. Characterizing Middle School Students' Physical Literacy Development: A Self-Determination Theory-Based Pilot Intervention in Physical Education. *Front. Sports Act. Living* **2022**, *3*, 809447. [[CrossRef](#)] [[PubMed](#)]
64. Whitehead, M. *Physical Literacy: Throughout the Lifecourse*; Routledge: Abington, UK, 2010.
65. Williams, A.J.; Henley, W.E.; Williams, C.A.; Hurst, A.J.; Logan, S.; Wyatt, K.M. Systematic review and meta-analysis of the association between childhood overweight and obesity and primary school diet and physical activity policies. *Int. J. Behav. Nutr. Phys. Act.* **2013**, *10*, 101. [[CrossRef](#)]
66. Khan, D.S.A.; Das, J.K.; Zareen, S.; Lassi, Z.S.; Salman, A.; Raashid, M.; Dero, A.A.; Khanzada, A.; Bhutta, Z.A. Nutritional status and dietary intake of school-age children and early adolescents: Systematic review in a developing country and lessons for the global perspective. *Front. Nutr.* **2022**, *8*, 739447. [[CrossRef](#)] [[PubMed](#)]
67. Kocaadam-Bozkurt, B.; Sözlü, S.; Macit-Çelebi, M.S. Exploring the understanding of how parenting influences the children's nutritional status, physical activity, and BMI. *Front. Nutr.* **2023**, *9*, 1096182. [[CrossRef](#)]
68. Shloim, N.; Edelson, L.R.; Martin, N.; Hetherington, M.M. Parenting Styles, Feeding Styles, Feeding Practices, and Weight Status in 4-12 Year-Old Children: A Systematic Review of the Literature. *Front. Psychol.* **2015**, *6*, 1849. [[CrossRef](#)] [[PubMed](#)]
69. Tomayko, E.J.; Tovar, A.; Fitzgerald, N.; Howe, C.L.; Hingle, M.D.; Murphy, M.P.; Muzaffar, H.; Going, S.B.; Hubbs-Tait, L. Parent involvement in diet or physical activity interventions to treat or prevent childhood obesity: An umbrella review. *Nutrients* **2021**, *13*, 3227. [[CrossRef](#)]
70. Tanous, D.R.; Ruedl, G.; Motevalli, M.; Drenowatz, C.; Cocca, A.; Schauer, M.; Kirschner, W.; Rosemann, T.; Wirnitzer, K.C. Randomized controlled trials on physical activity, diet, or both for public health through body weight management in 5-to 10-year-old pupils: A systematic review and meta-analysis. *Eur. J. Public Health* **2025**, *35*, 555–562. [[CrossRef](#)]
71. Rowland, T.W. *Children's Exercise Physiology*; Human Kinetics: Champaign, IL, USA, 2005.

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Article

Physical Literacy-Focused Education Improves Fitness Markers in Preadolescents: Implications for School-Based Health Promotion

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Highlights

What are the main findings?

- A physical literacy-based intervention led to small, but significant, improvements in specific fitness domains among preadolescent children, particularly jumping power and abdominal strength.
- The intervention was successfully implemented within regular physical education classes, requiring no additional resources or time, making it a real-world, scalable model for schools.

What are the implications of the main findings?

- Enhancing physical fitness in preadolescents can lay a foundation for lifelong physical activity, potentially reducing the future burden of chronic non-communicable diseases.
- The applied model is suitable for public health programs in schools, especially in low-resource settings.

Abstract

Background/Objectives: Physical literacy (PL) is globally recognized as a foundational determinant of health status in children, but the effects of interventions based on PL were rarely studied in preadolescent children. The aim of this quasi-experimental, school-based study was to evaluate the potential effects of a PL intervention delivered during regular school hours on physical fitness (PF), physical literacy (PL), and physical activity (PA) in children aged 9 to 11 years from southern Croatia. **Methods:** Participants were 125 preadolescents (57 girls), and were grouped into a control group (C = 70), and an experimental group (E, n = 55). The E group participated in a specific PL-focused education, integrated into regular physical education (PE) lessons as a 5–6 min substitute for standard PE content, over 12 weeks (36 PE classes in total). The C group participated in the standard PE curriculum. A pre–post–retention design was used, and the observed variables included anthropometrics (height, weight, BMI), PF (jumping power, abdominal strength, upper body strength, flexibility, mobility, and cardiovascular endurance), PL (evaluated by the PLAYself questionnaire), and indirectly measured PA (estimated via the PAQ-C questionnaire). Multivariate (MANOVA) and univariate (ANOVA) analyses of variance for repeated measurements were used with time, gender, and group as the main effects, including their interactions. **Results:** MANOVA calculated for a set of PF variables revealed significant



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main effects for time ($F = 1361, p < 0.001$) and a significant time $\times$ group interaction ($F = 2.98, p < 0.05$). Univariate ANOVA indicated specific intervention effects for jumping power and abdominal strength, favoring the E group. No significant differential effects were observed for PL or PA. Conclusions: The study demonstrated small, but statistically significant, improvements in PF indicators among children exposed to the PL-based intervention. Notably, the intervention was conducted in authentic school settings using standard resources, supporting the ecological validity and real-world applicability of the findings.

Keywords: motor activity; pediatrics; quasi-experimental studies; health promotion

1. Introduction

It is widely accepted that physical fitness (PF) serves as one of the main indicators of health in children and adolescents [1–4]. In brief, optimal PF during childhood and adolescence represents a fundamental basis for the adoption of healthy lifestyle habits and is an important factor reflecting the health status of the individual [2,5]. Supportively, studies indicate a strong association between high levels of PF in youth and better health status in adulthood [2,5]. Furthermore, maintaining adequate PF in youth significantly reduces the risks of overweight/obesity, various cardiovascular diseases, and type II diabetes [6,7]. Findings from research on mental health suggest a positive relationship between PF and general mental well-being in children and youth [8]. Finally, studies repeatedly reported better quality of life in children with better PF, with extensive evidence also highlighting a significant relationship between PF and academic performance [9,10]. Among the components of PF, cardiorespiratory fitness and muscular strength have been identified as key factors with a strong and consistent impact on health [11]. However, despite the robust body of evidence supporting the importance of PF, there are significant indicators of a continued decline in PF levels among children and adolescents [12,13].

Regular physical activity (PA) is a fundamental prerequisite for achieving and maintaining optimal levels of PF and is therefore considered a key factor in preserving and improving the health of children and adolescents [14]. Studies conducted on youth populations confirm that PA is the primary driver for the development of essential PF components, such as aerobic endurance and muscular strength, with significant effects particularly evident in high-intensity physical activities [15]. At the same time, higher levels of PF enable individuals to engage in more intense and prolonged PA, as they exhibit greater load tolerance [15–18]. Therefore, it is widely accepted that encouraging diverse forms of PA throughout development is crucial for fostering overall PF and ensuring long-term health maintenance [19]. However, existing research indicates that childhood and adolescence represent critical periods for establishing these positive interrelations [14,20,21]. Therefore, in order to achieve optimal health benefits, programs and interventions targeting children should simultaneously promote both PA and PF.

Due to the previously outlined challenges, research increasingly focuses on identifying effective methods to enhance levels of PA and improve PF [22–24]. In general, there is a general consensus that increasing PA positively influences various dimensions of PF [25–27]. For instance, a US study reported a positive correlation between PA levels and all measures of PF among children aged 9 to 11 years [25]. Likewise, research on Spanish children aged 8 to 12 years also confirmed that higher PA levels are associated with better PF outcomes [26]. Furthermore, Danish authors studied children aged 8 to 10 years and demonstrated that those children who engage in sports and exhibit higher PA levels show superior cardiorespiratory function, sprint times, motor coordination, and better body composition compared to peers

with lower PA levels [27]. A longitudinal study conducted in Estonia, which followed children from preschool through the end of grade five (up to 11.5 years of age), also confirmed the positive effects of regular participation in sports activities on health and PF [28]. More accurately, the study revealed that 73% of children who remained physically active achieved optimal PF levels, compared to only 24% among inactive peers [28]. Additionally, a recent study from Poland highlighted the positive effects of increasing PE class hours (and consequently increasing PA levels) on PF in children aged 11 to 12 years [29]. However, growing evidence suggests that merely increasing PA does not necessarily lead to improvements in PF among children. Therefore, it is recommended to focus on promoting those forms and intensities of PA that directly contribute to enhancing PF levels [15,30–32]. With regard to all that has been said, the concept of physical literacy has gained significant attention over the past decade as an integrative and comprehensive framework for understanding and promoting their development.

Physical literacy (PL) can be defined as an individual's ability to demonstrate the physical competence, confidence and motivation to engage in PA, along with an understanding of its health benefits, in order to develop lifelong habits of active living [33,34]. Studies confirmed that interventions aimed at developing PL result in significant improvements in components of PF and simultaneously increase levels of PA among children and adolescents, thereby supporting their overall developmental goals [35,36]. For instance, pedagogical intervention demonstrated significant improvements in various fitness capacities in children aged 8 to 12 years [37]. Further, a six-month program targeting PL development showed substantial gains in PF among children aged 5 to 12 years [38]. Moreover, a twelve-week intervention designed to enhance PL resulted in significant increases in both PA and PF levels among children aged 9 to 11 years [39]. A five-month program based on structured and active play reduced sedentary behavior, and increased PA levels among children aged 6 to 9 years [40]. In contrast, an extracurricular intervention focused on creativity, conducted over five months, did not yield statistically significant changes in PF among children aged 8 to 11 years [41]. However, the intervention integrating various dimensions of PL in children aged 8 to 11 years demonstrated statistically significant improvements in PF [42].

Collectively, it is widely accepted that PL deserves particular attention in global efforts aiming at simultaneous improvement of PF and PA in children. Specifically, most of the studies which targeted improvement of PL as a way of improving PF and PA reported positive effects [35]. Nevertheless, it is crucial to highlight several limitations of previous studies. First, the majority of previous studies did not include a control group (i.e., the improvements observed may result from external factors such as maturation and/or seasonal effects). Second, it seems that none of the studies done so far have conducted follow-up assessments, which prevents evaluation of the long-term sustainability of effects, making it unclear whether observed changes persist beyond the immediate post-intervention period [35,36]. Furthermore, the assessment of PF in most studies relied on a limited number of tests, often focusing predominantly on cardiorespiratory fitness indices, which may not comprehensively capture the multifaceted nature of PF [35,36]. Therefore, this study aimed to evaluate the effects of a PL intervention on changes in PL, indirectly measured PA and various components of physical PF in Croatian preadolescents, aged 9 to 11 years. The hypothesis posits that the PL intervention incorporated in the regular PE curriculum will lead to increased PA, better PL, and positive changes in PF components in preadolescent children.

2. Materials and Methods

2.1. Participants

A total of 125 preadolescents (68 boys and 57 girls) from southern Croatia participated in this study. At the time of assessment, they were 9–11 years old, and were enrolled in the 3rd ($n = 74$) or 4th ($n = 51$) grade of elementary school, healthy, and regularly attending physical education (PE) classes. Exclusion criteria included illness or locomotor injury. Written informed consent was obtained from parents/guardians after they were briefed on the study's aims and procedures by the research team. The study protocol was approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb.

Figure 1 presents a flow diagram of the study.

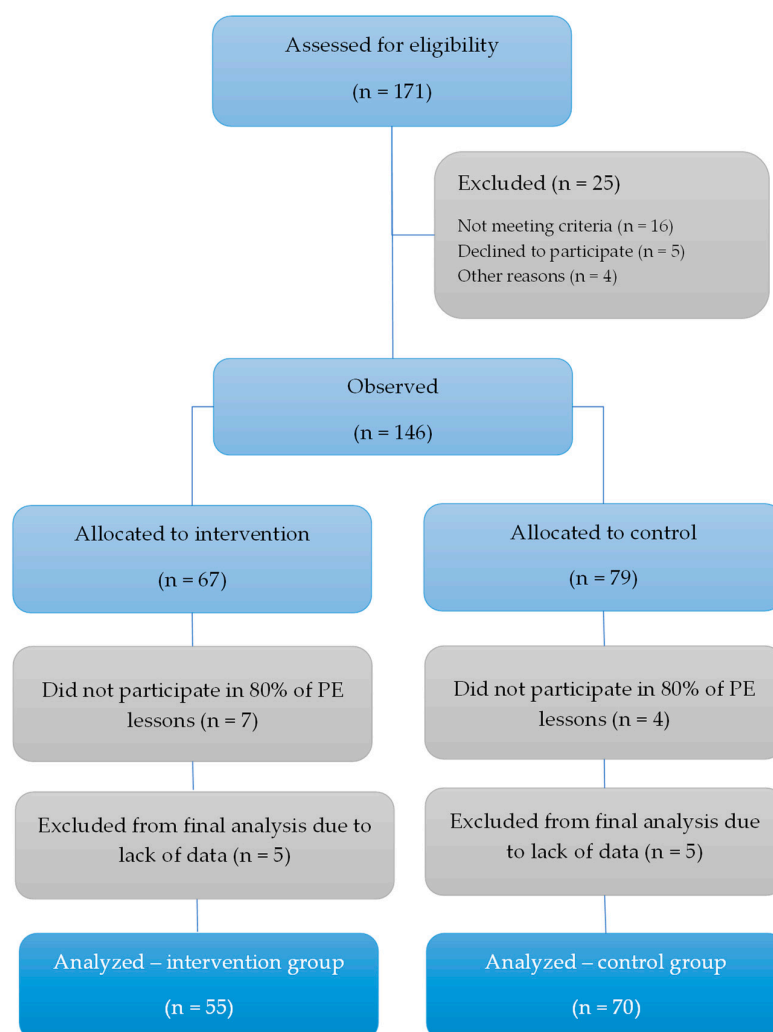


Figure 1. Flow diagram of the investigation.

The participants were grouped into an experimental/intervention group (E, $n = 55$) and a control group (C, $n = 70$). Since intervention was delivered as a part of PE, we applied a quasi-experimental design. In particular, intact classes (rather than individual students) were assigned to either the E (two classes) or the C (two classes). Because participants were nested within classes, intraclass correlation coefficients (ICCs) were calculated for the primary outcome variables to estimate the magnitude of clustering. The observed ICC values for fitness variables were low ($ICC = 0.01$ – 0.04), suggesting that only 2–4% of the total variance was attributable to class-level differences. This magnitude is below commonly

cited thresholds indicating meaningful clustering effects in school-based research (e.g., $ICC \geq 0.05$) [43]. Therefore, multilevel modeling was not deemed necessary.

2.2. Variables

Besides gender (female/male), and age (years), key outcomes included anthropometric variables (body height, body mass, and calculated body mass index), PF, PL, and indirectly estimated PA. An experienced technician with substantial expertise in assessments performed the anthropometric measurements. PF tests were performed by PE teachers, with five examiners each evaluating an entire group simultaneously. All assessors were experienced, had undergone study-specific training, and were familiar with the protocols, which align with routine Croatian PE fitness testing practices.

The PL was measured using the Croatian version of the PLAYself questionnaire, a component of the PLAY tools (PLAYfun, PLAYbasic, PLAYself, PLAYparent, PLAYcoach, PLAYinventory [44]. Based on self-evaluation protocol, it comprises four subdomains: (i) environment, evaluating confidence in movement across various settings (e.g., gym activities, water, snow, and ice); (ii) self-report of PL, measuring affective and cognitive aspects (e.g., motivation, confidence, self-esteem) that influence self-efficacy and PA participation (i.e., “It does not take me long to learn new skills, sports or activities”); (iii) relative ranking of literacy (including literacy, numeracy, and physical literacy subdomains), assessing literacy valuation in contexts like school, home, and peers; and (iv) fitness status, determined by the question “My fitness level is good enough to allow me to participate in all the activities I choose” (excluded from the final score). The overall score is calculated as the average from the first three subdomains across 27 items, with a maximum of 100 indicating strong self-perception.

In order to evaluate the PA, we used the Croatian version of the “Physical Activity Questionnaire for Older Children” (PAQ-C) [45]. This 9-item instrument uses a 5-point scale to compute a mean score reflecting habitual activity (range: 1 = minimal; 5 = maximal), with sample items including “What did you do during long breaks last week (excluding snacks)?” and “Daily physical activity frequency last week.” Questionnaires were completed online in classroom groups of ≤ 10 children, with an examiner available for support but positioned to prevent viewing responses, thereby maintaining confidentiality.

Body height (BH) was measured using a stadiometer, with participants standing barefoot on a firm, level surface in an upright posture and the head aligned to the Frankfurt horizontal plane (gaze straight ahead). Measurements were recorded to 0.1 cm precision. Body mass (BM) was assessed via a digital scale, wearing shorts and a sports shirt, and results reported in kilograms to 0.1 kg accuracy. Body mass index (BMI) was calculated by dividing participants’ body mass (in kg) by their squared body height (in meters).

PF was assessed using tests from the FitnessGram battery (body height and mass, aerobic (cardiovascular) endurance, flexibility, torso extensor strength, abdominal and upper body strength), and standing broad jump [46]. Aerobic endurance was evaluated using the 15 m multistage fitness test (beep test). The test comprises running between 15 m divided lines. Participants have to step on the line on each beep and turn promptly, continuing until they are unable to reach the line before the second beep; scores reflect completed levels. Abdominal strength/endurance was measured by the sit-up test (sit-ups), where participants performed maximal torso lifts (up to 75), scored as correctly executed repetitions. Torso extensor strength/flexibility was assessed via the torso lift test: Participants raised the cervical/thoracic spine controllably to maximum extension, maintaining neutral head alignment with the spine. Upper body strength/endurance used the push-up test: From a plank position (palms under shoulders, legs extended), participants lowered until elbows reached 90° (upper arms parallel to floor) then extended

fully, keeping the body straight; maximum correct repetitions were recorded. Lower back/hamstring flexibility was tested with the sit-and-reach: Seated with legs extended against a box, participants reached maximally forward (palms down), holding 2+ seconds; the best average of three trials was used. Jumping power (explosive strength) was assessed by the standing long jump (broad jump): Barefoot from a starting line, participants jumped maximally forward onto a standardized mat (ELAN, Begunje, Slovenia); the best of three attempts in cm was used as a final result.

2.3. Intervention and Protocol of the Study

An overview of the study timeline is presented in Figure 2.

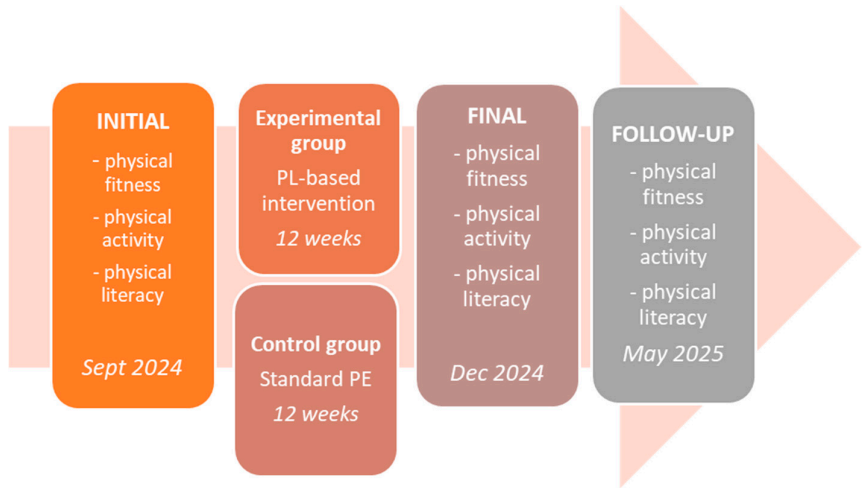


Figure 2. Study protocol.

The educational intervention, focused on PL, was implemented within the existing PE schedule for the experimental group over a 12-week period. During this time, students received three PE sessions weekly (36 lessons in total). The intervention incorporated 12 short, original educational videos (3–4 min each), each addressing a key topic related to PL or physical health. The video content was organized into the following themes: two videos covered core PL principles (e.g., movement motivation, confidence, and understanding), three focused on cardiorespiratory fitness, five targeted motor abilities (strength, power, coordination, flexibility), and two addressed general health habits, including nutrition. Each video was shown three times to reinforce learning and ensure knowledge retention (please see Supplementary Materials for video education, Video S1). A short overview of the video contents is presented in Table 1.

Table 1. Main characteristics of the video contents.

Theme	Number of Videos	Key Topics Covered
Physical Literacy	2	Cognitive domain; affective domain
Cardiovascular Endurance	3	Cognitive and affective domains + practical examples
Strength	3	Cognitive and affective domains + practical examples
Flexibility	2	Cognitive and affective domains + specific examples
Healthy Habits and Nutrition	2	The significance of balanced nutrition and hydration (with regard to physical activity and health)

Concise, focused videos are known to be especially effective for maintaining children’s attention and promoting engagement, especially in the situations when videos are followed by guided discussions, such as the one we applied in the study [47]. The development

of the video content was carried out in consultation with both PE specialists and medical professionals to ensure accuracy, relevance, and age-appropriateness. This collaborative approach helped align the content with curricular goals while also addressing key health promotion messages. As a result, the videos reflected evidence-based practices from both educational and health perspectives. Notably, similar approaches were found to be successful among adolescents during COVID-19 disruptions to traditional schooling [48]. Also, this PL-educational program has recently shown promising results in the context of maintaining PA levels during the school year in early school age children, and the authors noted the necessity of evaluating its effectiveness for other important health related indices, particularly PF status [49].

With regard to differences between the experimental and control group, it should be stated that the Croatian PE practices (45 min in total) typically consist of a warm-up (5–10 min), main activity block (30 min), and a closing section (5–10 min). The experimental educational content was delivered during the final segment of each class. As such, the motor content of PE lessons remained consistent across both study groups. To integrate the intervention without disrupting the core PE structure, PL-education replaced <7 min of standard activity. The control group also received 36 PE lessons over the same period, but followed the national curriculum without additional PL-based content. Intervention structure is provided in Table 2, emphasizing the most important differences between the control and experimental group.

Table 2. Main characteristics of the program applied in experimental and control group.

Aspect	Experimental Group	Control Group
Number of PE Lessons	36 lessons over 12 weeks	36 lessons over 12 weeks
Curriculum Content	Standard PE + PL-focused educational content	Standard national PE curriculum
Educational Video Integration	12 videos shown 3 times each, with teacher-led discussion	No video content
Focus on Physical Literacy	Yes, emphasized throughout intervention	No targeted PL education
Use of Supplementary Materials	Yes, videos and practical tips provided	No Supplementary Materials
Instructional Time Adjustment	5–7 min per lesson substituted standard PL education	No instructional time reallocation
Assessment	Yes (initial–final–follow-up)	Yes (initial–final–follow-up)

This research is a continuation of the previous research in the field [48,49]. However, this study extends previous works conducted within the same educational framework (PL-based intervention) but differs in several important methodological and conceptual aspects [49]. Whereas recent research investigated the effects of the PL intervention on PA and body composition, the current study focuses specifically on PF outcomes, including muscular strength, explosive power, flexibility, and aerobic endurance. Next, this study included younger participants, and/or observed a larger sample than previous ones [48,49]. Finally, previous studies used univariate analysis exclusively, while herein, multivariate statistical procedures were applied (please see Statistics below) [48,49].

2.4. Statistics

The Kolmogorov–Smirnov test was applied to evaluate the normality of distributions for all variables. Descriptive statistics included the calculation of means and standard deviations (for continuous variables), and counts and percentages (for categorical variables).

To control for potential inflation of Type I error due to multiple outcomes, a hierarchical analytical strategy was applied. Specifically, a multivariate repeated measures analysis of variance (MANOVA) was first conducted for the full set of PF variables to test for overall time and interaction effects while accounting for intercorrelations among dependent variables. Since the multivariate test reached statistical significance in the next phase, we

applied a 2 (Group: experimental vs. control) $\times$ 2 (Gender: boys vs. girls) $\times$ 3 (Time: pre-, post-, and retention-test) mixed-design analysis of variance (ANOVA) with repeated measures on the time factor for each dependent variable. Post hoc comparisons were conducted for variables showing significant ANOVA effects. Additionally, Bonferroni correction was applied to post hoc comparisons where appropriate. This stepwise approach reduces the likelihood of Type I error inflation by limiting secondary analyses to statistically justified cases. Homogeneity of covariance matrices was tested using Box's M test, and Levene's test was used to assess the equality of error variances. Cell sizes were reviewed to ensure approximate balance across conditions.

Initially, pubertal timing was estimated for all children using peak height velocity (PHV), as described by Moore et al. ($\text{PHV} = -7.999994 + (0.0036124 \times \text{age (yrs.)} \times \text{height (cm)})$) [50]. In order to control for the possible influence of maturity status on changes which occurred during the study course, the PHV was included as a covariate in ANOVA and MANOVA calculations.

Effect sizes for ANOVA main and interaction effects are reported as partial eta squared (η^2), interpreted as follows: small (0.01–0.06), medium (0.061–0.14), and large (≥ 0.141). When significant effects were found, post hoc analyses were performed using Scheffé's test.

To reduce the risk of Type I error due to multiple comparisons, Bonferroni correction was applied as appropriate.

All statistical analyses were conducted using Statistica v14.5 (TIBCO Inc., Palo Alto, CA, USA), with the level of statistical significance set at $p < 0.05$.

3. Results

MANOVA calculated for PF variables indicated significant main effects for time (large ES). Also, significant interaction effects were found for “time $\times$ group” (medium ES), indicating differential changes in physical fitness variables in study groups over the study course (Table 3).

Table 3. Main and interaction effects for the factorial multivariate analysis of variance for repeated measurements calculated for the set of physical fitness variables (F-test) with partial eta squared (η^2).

	Intercept		Main Effects			Interaction Effects		
		Time	Gender	Group	Time $\times$ Gender	Time $\times$ Group	Group $\times$ Gender	Time $\times$ Gender $\times$ Group
F-test	2615 *	1391 *	1.06	1.78	2.44	2.98 *	2.23	2.21
η^2	0.98	0.98	0.02	0.04	0.09	0.12	0.05	0.05

* denotes statistical significance of $p < 0.05$.

Table 4 presents the results of the ANOVA, with corresponding effect size values. Significant main effects for “time” were found for all variables, specifically: body height (large ES), body mass (medium ES), BMI (medium ES), all PF tests broad jump (medium ES), push-ups (medium ES), sit-ups (large ES), torso lift (medium ES), sit-and-reach (large ES), multistage fitness test (small ES), physical literacy (medium ES), and PA (small ES). When observing the main effect for “gender”, the F-test reached statistical significance for sit-and-reach (large ES), multistage fitness test (medium ES), and PA (medium ES). With regard to the “time $\times$ gender” interaction effect, the F-test was significant only for body height (small ES). The interaction effect for “time $\times$ group” was significant for broad jump (small ES) and sit-ups (small ES), indicating differential changes in the control and experimental group during the study course.

Table 4. Main and interaction effects of the repeated measures factorial ANOVA (F-test) with partial eta squared (η^2).

		Intercept	Main Effects				Interaction Effects		
			Time	Gender	Group	Time $\times$ Gender	Time $\times$ Group	Group $\times$ Gender	Time $\times$ Gender $\times$ Group
Body height	F-test	4868 *	740.2 *	1.77	3.2	7.97 *	2.90	0.01	2.81
	η^2	0.99	0.84	0.01	0.02	0.06	0.02	<0.01	0.02
Body mass	F-test	1807 *	16.52 *	1.36	3.25	0.77	0.87	1.33	1.21
	η^2	0.93	0.10	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
BMI	F-test	3113 *	9.89 *	0.93	1.81	1.45	0.35	1.31	0.05
	η^2	0.96	0.07	<0.01	0.01	0.01	<0.01	0.01	<0.01
Broad jump	F-test	6202 *	19.07 *	0.85	0.01	1.12	3.26 *	2.13	1.25
	η^2	0.97	0.12	<0.01	<0.01	<0.01	0.02	0.01	<0.01
Push-ups	F-test	211 *	11.24 *	3.35	2.93	0.86	2.91	0.08	5.04 *
	η^2	0.6	0.07	0.02	0.02	<0.01	0.02	<0.01	0.04
Sit-ups	F-test	409.21 *	48.34 *	0.38	0.11	2.77	5.92 *	0.24	1.86
	η^2	0.75	0.26	<0.01	<0.01	0.02	0.04	<0.01	0.01
Torso lift	F-test	2341 *	11.19 *	1.97	1.13	0.39	0.91	0.45	0.25
	η^2	0.94	0.07	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sit-and-reach	F-test	3206 *	28.29 *	41.25 *	0.02	1.94	2.23	0.67	0.91
	η^2	0.95	0.17	0.24	<0.01	0.01	0.01	<0.01	<0.01
Multistage fitness test	F-test	1184 *	4.81 *	15.39 *	0.02	0.39	1.01	0.33	0.37
	η^2	0.89	0.04	0.1	<0.01	<0.01	<0.01	<0.01	<0.01
Physical literacy	F-test	6244 *	21.22 *	0.01	1.9	0.15	0.21	0.16	2.01
	η^2	0.97	0.13	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Physical activity	F-test	4547 *	3.87 *	10.85 *	1.04	0.11	0.39	2.47	2.12
	η^2	0.97	0.03	0.07	<0.01	<0.01	<0.01	0.01	0.02

* denotes statistical significance of $p < 0.05$.

Table 5 presents descriptive statistics for the total sample of participants at initial, final- and follow-up testing, with the significance of the ANOVA post hoc differences. Specifically, analyses indicated an increase in the body height and body mass throughout the study course, with significant post hoc ($p < 0.05$) differences between all three measurements (initial-, final, and follow-up testing). The BMI values increased from initial to final, and decreased until follow-up measurement, with significant post hoc differences between the first two measurements. The performance in broad jump and sit-ups improved throughout the study course, with significant post hoc differences between initial and follow-up measurement. Changes in the push-ups test varied, with a decrease from the initial to final measurement and an increase from final to follow-up testing (significant post hoc differences between final and follow-up). On the other hand, children improved their performance in the torso lift between initial and final testing, but results were worsened between final and follow-up (significant post hoc differences between initial and final measurement). Sit-and-reach performance slightly improved in the first part of the study (significant post hoc differences between the initial and remaining two measurements). The results of the multistage fitness test improved during the study course, with significant post hoc differences between initial and follow-up testing. The PL improved during the study course (significant post hoc differences between initial and follow-up measurement). Finally, results showed significantly higher PA at the follow-up measurement than in the initial testing. Relative changes which occurred during the study course for the total sample, as well as for the control and experimental groups, are presented in the Supplementary Figure S1.

Table 5. Descriptive statistics for the total sample of participants and ANOVA post hoc differences.

	Initial	Final	Follow-up
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Body height (cm)	143.47 $\pm$ 7.31	144.79 $\pm$ 7.36 [¥]	149.01 $\pm$ 8.11 ^{¥,£}
Body mass (kg)	37.33 $\pm$ 10.48	38.14 $\pm$ 10.11 [¥]	40.01 $\pm$ 10.6 ^{¥,£}
BMI (kg/m ²)	17.74 $\pm$ 3.41	19.01 $\pm$ 3.77 [¥]	17.76 $\pm$ 4.02
Broad jump (cm)	140.64 $\pm$ 21.09	143.39 $\pm$ 21.14	146.28 $\pm$ 21.58 [¥]
Push-ups (reps)	11.61 $\pm$ 9.51	10.41 $\pm$ 11.69	12.55 $\pm$ 11.21 [£]
Sit-ups (reps)	15.8 $\pm$ 12.41	17.74 $\pm$ 12.34	24.61 $\pm$ 14.14 [¥]
Torso lift (cm)	15.88 $\pm$ 4.51	17.78 $\pm$ 4.64 [¥]	16.41 $\pm$ 5.29
Sit-and-reach (cm)	44.17 $\pm$ 11.42	48.27 $\pm$ 12.22 [¥]	49.35 $\pm$ 11.82 [¥]
Multistage fitness test (levels)	7.68 $\pm$ 2.62	8.99 $\pm$ 8.08	10.14 $\pm$ 11.58 [¥]
Physical literacy (score)	67.24 $\pm$ 11.63	71.98 $\pm$ 11.6	72.23 $\pm$ 11.24 [¥]
Physical activity (score)	3.41 $\pm$ 0.72	3.42 $\pm$ 0.72	3.55 $\pm$ 0.68 [¥]

[¥]—significantly different from initial measurement, [£]—significantly different from final measurement.

Figure 3 presents the descriptive statistics and significance of the post hoc differences, for those variables where ANOVA evidenced a significant “time $\times$ group” interaction effect, and consequently indicated differential changes in studied variables in the control and experimental group. For the broad jump, the experimental group significantly improved performance, with significant differences between initial and final measurement, and initial and follow-up measurement. Simultaneously, no significant changes were evidenced in the control group for the same performance (Figure 3A). When analyzing for sit-ups (Figure 3B), both groups improved their achievement during the study course, with significant differences between initial and follow-up measurement. However, the improvement was more evident in the experimental group than in the control group.

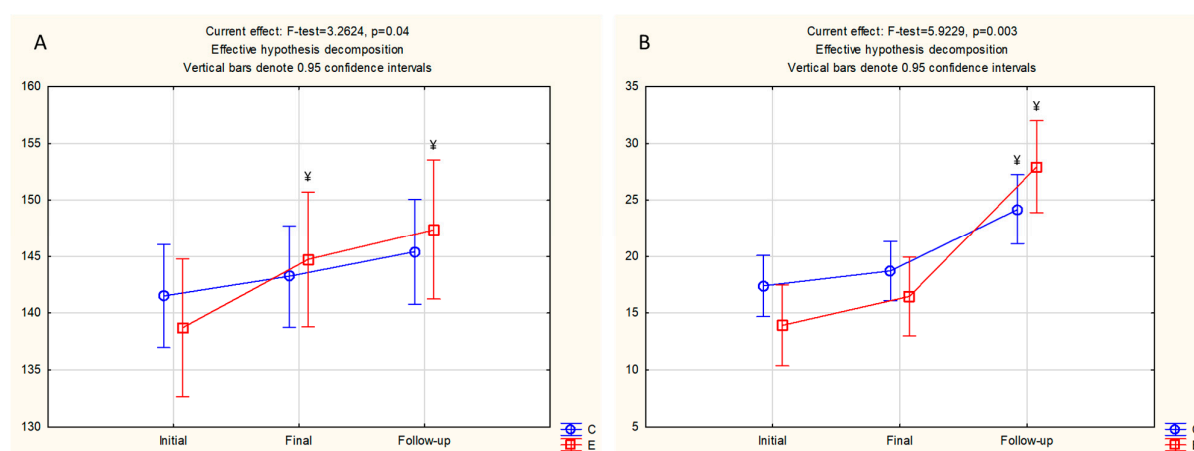


Figure 3. Descriptive statistics (data are presented as means + 95% confidence intervals) for study control (C), and experimental (E) group ((A)—broad jump, (B)—sit-ups) and significant post hoc differences for variables with significant ANOVA time $\times$ group interaction effects ([¥] significantly different from initial measurement).

4. Discussion

Following are the most important findings indicated by the results. First, PL intervention resulted in small but statistically significant improvements in certain dimensions of PF, specifically power and strength capacities. Second, there was no significant effect of PL intervention on indirectly measured PA and affective and cognitive domains of the PL. Therefore, our initial study hypothesis can be partially accepted.

4.1. Effects of Physical Literacy-Based Intervention on Physical Fitness

Our study demonstrated the benefits of PL-based intervention in improving children's PF, specifically lower-body explosive strength (jumping power capacity) and the dynamic muscle strength of abdominal muscles. In exploring the potential reasons for this improvement, several factors emerge as the most plausible. First, it is likely that the intervention, which included brief, clearly structured educational content on PL, contributed to bettering participants' knowledge about physical fitness and training, which resulted in positive attitudes and stronger intentions to engage in PA. Specifically, the educational video contents, such as "What is strength and how do we train it?", likely stimulated greater engagement in strength-related tasks (e.g., squats, sit-ups, core exercises) during PE classes, but also in free time. This likely resulted in a greater accumulation of effective repetitions in the experimental group, compared to the control group.

It is important to highlight that both the standing broad jump and sit-up tests are tasks where improvements can be achieved relatively quickly through increased effort (in the case of sit-ups) and minor technical adjustments (e.g., improved arm swing, take-off preparation, execution rhythm in the case of the broad jump), without requiring long-term, sport-specific training [51,52]. Encouragingly, this pattern of effects aligns with findings from a meta-analysis that included 48 intervention studies conducted with children and adolescents aged approximately 6 to 18 years, all focused on the development of PL [35]. In general, it was found that interventions similar to the one applied in our study produce statistically significant effects in PF and motor skills [35]. Additionally, a study implementing PL interventions in children aged 7 to 9 years also reported significant improvements in PF components, further supporting the findings of our research [53].

Another possible explanation of the achieved positive effects deserves attention. Namely, it is possible that interventions incorporating education based on PL significantly enhances children's sense of self-efficacy, fostering beliefs such as "I can do this" and "I know how to do this." This contributes to greater effort, persistence, and improved performance in motor tasks [54–57]. Specifically, when high cognitive load occurs during physical exercising, it often reduces perceived self-efficacy. Altogether, it partially mediates declines in performance, and reduces the participation in physical exercising itself [55]. As a result, children with high self-efficacy are more likely to engage in PA [56]. Therefore, it can be said that high physical self-efficacy encourages engagement, greater effort, and improved outcomes in fitness tests by enhancing understanding, perceived competence, enjoyment, and intrinsic motivation [54,58,59]. Taken together, all these factors (e.g., enhanced self-efficacy, reduced cognitive load, and improved technique) could lead to the obtained positive PF outcomes evidenced in the experimental group.

Although the PL-educational content included topics related to the importance of flexibility and aerobic (cardiovascular) endurance, as well as strategies for their development, no significant effects were observed in these components of PF. The authors believe this may be explained by several factors. First, we cannot neglect the simple fact that, during the period of intervention, participants did not have a sufficient volume of continuous, moderate-to-vigorous-intensity activities necessary to stimulate cardiovascular adaptations that typically lead to improvements in aerobic endurance [60]. Most specifically, the intervention was applied in the period of three months, in unfavorable weather conditions (autumn and winter period). As a result, it was hard to expect participants to participate in activities which would be suitable for the development of aerobic endurance, such as prolonged running, hiking, bicycling, and similar. Therefore, environmental conditions may have attenuated the potential impact of the intervention on cardiorespiratory fitness outcomes. It is important to note that existing research suggests that aerobic endurance improvements require a longer, structurally adapted, and sufficiently intense intervention,

often involving several weeks of systematic training, while purely informational interventions, without a clear increase in training volume or load, frequently fail to produce measurable outcomes [61].

It is important to note that other studies examining the effects of interventions focused on PL, where authors also reported limited impact on aerobic endurance, often attributed to the short duration or educational emphasis of the programs [35]. Specifically, an afterschool PL intervention involving 15 min of fundamental motor skills (FMSs) and games over an 8-week period in children aged 5 to 12 years did not lead to improvements in aerobic endurance [62]. Similarly, a 12-week afterschool PL program incorporating games and skill-based activities in children aged 5 to 12 years showed no significant improvements in cardiorespiratory endurance [38]. Also, a 10-week PL program combining track and field games with functional movement skill exercises for children aged 8 to 12 years did not result in changes in aerobic endurance indicators [63].

Similar to our findings, previous studies focused on PL have also failed to demonstrate significant effects on flexibility. For example, the previously cited study by Chinese authors did not report any intervention-related improvements in flexibility measures [53]. Additionally, in a study comparing a sports-oriented elementary school with a traditional school, no effects on flexibility were found despite the higher volume of organized PA in the sports school [64]. This suggests that neither a more intensive nor a sport-enriched curriculum alone guarantees improvements in flexibility unless flexibility-specific content is systematically and purposefully included in the program [64]. There are several possible explanations for this. First, the pronounced longitudinal bone growth during this developmental period may partially obscure actual flexibility achievements, as most flexibility tests, including the one we have applied here (e.g., sit-and-reach), do not account for changes in skeletal proportions [65]. Second, flexibility as a component of PF is generally less appealing to children of this age group. In other words, it is unlikely that children will engage seriously in training activities aimed at improving flexibility.

4.2. Lack of Effects in Indirectly Measured Physical Activity

The PL intervention did not produce a significant effect on indirectly assessed PA. The first possible explanation for the absence of a significant effect on PA lies in the timing of the study itself (September–December–May). During the initial measurement period, children had not yet encountered intense academic obligations and had more free time available for spontaneous PA, such as outdoor play. The final measurement was conducted in December, during the winter months, when days are shorter and weather conditions colder, factors well-known to reduce overall PA in children by limiting opportunities for outdoor activities [66–68]. The follow-up measurement was conducted near the end of the school year, a period typically associated with heightened academic demands [66–68]. Supportively, a recent meta-analysis involving children aged 3 to 18 years confirms that winter is associated with a significant decline in PA and an increase in sedentary behavior [67]. Collectively, these factors likely equalized PA levels across groups and masked any specific effects of the intervention on PAQ-C scores.

Second, the lack of effects in PA can also be attributed to the limitations of indirect assessment using self-report questionnaires. Specifically, the PAQ-C, as a self-administered tool, assesses general levels of PA over the past seven days, focusing primarily on moderate-to-vigorous PA during daily routines, leisure time, and sports participation. This makes it a subjective measure, prone to recall bias [69,70]. Additionally, we cannot overlook the potential influence of social desirability bias. In self-report instruments such as the PAQ-C, where participants are asked about socially acceptable and expected behaviors (i.e., being engaged in higher levels of PA), children may tend to report more favorable behaviors

than those actually performed (i.e., in our case, they will probably report higher PA). This tendency may lead to the overestimation of PA and may reduce the sensitivity of the questionnaire [71]. Studies have already shown that the PAQ-C may have weak correlations with objective measures of PA and may not be sensitive to changes resulting from specific types of physical training or fitness improvements [71,72]. This implies that an intervention which enhances specific motor abilities does not necessarily lead to detectable changes in the overall pattern or frequency of PA typically performed by children, which is what the PAQ-C is designed to measure. Indeed, a recent study evidenced favorable changes in PA as a result of PL intervention, when PA was objectively measured by accelerometers [49]. Collectively, the lack of significant effects in PA can be interpreted as a consequence of both the limitations of the measurement instrument and the influence of seasonal factors, rather than as evidence of the intervention's failure to enhance overall PA in children.

4.3. Lack of Effects in Physical Literacy Facets

Although PL in children generally increased (see Results for details), the intervention did not result in significant differential effects on PL, specifically in the affective domain (motivation and confidence) and the cognitive domain (knowledge and understanding), as assessed by the PLAYself questionnaire. The most probable explanation for this outcome is that children in their self-assessments of PL primarily compared themselves to peers within their own group (i.e., children in the experimental group compared themselves to other children in the same group, and similarly in the control group). In this context, their perceived physical competence may not have changed in relative terms. A previous study assessing PL in children aged 9 to 11 years showed that the PLAYself questionnaire demonstrates good reliability and validity, but also revealed that children's self-perceptions of PL are largely shaped through peer comparisons within the same social context, potentially "stabilizing" their responses in the absence of external reference points [44]. Under such circumstances, children rarely perceive personal progress unless they have the opportunity to compare themselves with other groups or against objective standards. A similar pattern of effects was reported in a recent experiment where authors analyzed the effects of the 8–9-week enriched PE intervention for children aged 9 to 11 years, and reported no statistically significant changes in the affective and cognitive domains as measured by the PLAYself questionnaire [42].

On the other hand, a 10-week PL program involving track and field games and fundamental motor skill exercises in children aged 8 to 12 years, assessed using another measurement tool (e.g., CAPL-2 questionnaire), led to significant improvements in the cognitive domain of PL [63]. Similarly, a study that implemented a 13-week PL intervention in children aged 9 to 12 years, combining classroom instruction with digital content during the regular school day and assessed using CAPL-2, also demonstrated statistically significant improvements in the cognitive domain [73]. Also, positive findings were found in a pilot study on active recess in preadolescents (8–12 years), which involved four weeks of short, structured, and content-focused activities, and reported significant improvements in both the affective and cognitive domains, also assessed by the CAPL-2 questionnaire [74].

Taken together, it seems that intervention studies that used the PLAYself questionnaire (the one we used herein) did not report significant changes in the affective and cognitive domains of PL following the intervention questionnaire [42]. In contrast, studies reporting improvements in these domains predominantly regularly used the CAPL-2 assessment tool [63,74]. This pattern raises the possibility that CAPL-2 may be more sensitive or better suited to capturing changes in motivation, confidence, knowledge, and understanding among children, particularly in the context of short-term interventions.

In addition to all that has been discussed, we must note that, although the PLAYself questionnaire has shown good reliability and validity in previous studies, it is generally known that self-assessment tools in children can be influenced by social desirability bias [44]. This means that children may answer in a way they think is expected by teachers or researchers, instead of reporting their true thoughts or abilities. Such responses may reduce the sensitivity of the questionnaire to detect small changes after an intervention. Nevertheless, in the present study, PLAYself was intentionally used due to its previously established psychometric robustness in Croatian children, including cultural and linguistic adaptation, and its feasibility for use in a school-based setting [44]. However, given the previously discussed improvements in PF, it seems reasonable to conclude that the PL intervention did lead to actual gains in PL, but that these changes were not adequately captured by the chosen measurement tool.

4.4. Implications of Results for School-Based Strategies and Health Promotions

Although the effects of the intervention were not large, they are still important when considered in the real school setting in which the program was carried out. For example, improvements in lower-body explosive strength are important because this type of strength supports everyday activities such as running, jumping, climbing stairs, and active play. Improvements in abdominal strength are also meaningful, as core muscles help maintain good posture, stabilize the body during movement, and may reduce the risk of injury. Importantly, these improvements were achieved without adding extra class time, increasing training intensity, or requiring additional equipment. Instead, they resulted from small changes within regular PE lessons.

The findings of this study reinforce the potential of school-based PL interventions as practical and effective strategies for promoting children's PF. By embedding short, structured, PL-focused educational content into regular PE classes, the intervention led to significant improvements in certain components of PF. These outcomes highlight that even minimal, well-targeted modifications to existing PE curricula can yield measurable benefits. Importantly, the intervention required no additional resources or scheduling, making it highly feasible and scalable within standard school environments. From a public health perspective, integrating PL principles into schools may help establish the foundation for healthy movement habits, which are essential for the prevention of pediatric obesity, musculoskeletal issues, and cardiometabolic risk factors [75].

Moreover, the study underscores the ecological validity and real-world applicability of PL-based health promotion within the school setting. Conducted during regular school hours with regular PE teachers, the intervention mirrors the actual conditions under which health promotion strategies must operate, ensuring greater translational relevance. Therefore, our results actually underscore the opinion that schools should be considered vital platforms for preventive health measures, and that PL-based content represents a promising, cost-effective approach to improving children's physical and mental well-being [76].

4.5. Limitations and Strengths

This study has several limitations that should be acknowledged. First, the allocation to intervention and control groups was done at the class level rather than through individual randomization. Although this approach is generally consistent with established practices in school-based cluster randomized trials designed to minimize contamination effects and preserve natural classroom structures, such an approach may result in residual bias, thereby potentially influencing effect estimates. Next, the study was conducted in a geographically specific area with a mild Mediterranean climate. It potentially facilitated more outdoor

activity (despite the period of the study) and therefore limits the generalizability of findings. Additionally, PA was assessed using subjective reporting, which may be prone to recall bias or social desirability effects. Finally, PL was evaluated using a single self-report instrument (PLAYself), which may not fully capture the multidimensional nature of the construct. Therefore, further studies should apply different measurement tools in evidencing changes in PL in early school-age children. Also, a potential limitation of the present study is the increased risk of Type I error associated with the analysis of multiple outcomes, which may elevate the probability of false-positive findings. Finally, we did not examine individual responsiveness to the intervention. While previous research has shown that considerable inter-individual variability exists in training adaptations [77,78], future studies should consider analyzing responder profiles to better understand variability in PF outcomes.

Despite these limitations, the study also possesses some strengths. First, a wide range of PF tests we have used allowed a comprehensive evaluation of participants' capacities, evidencing specific effects in different facets of PF. Second, the longitudinal design, incorporating baseline, post-intervention, and follow-up measurements, enabled the assessment of both immediate and retained effects of the intervention. Next, testing was conducted by experienced evaluators following standardized protocols, ensuring the consistency and reliability of data collection. Most importantly, the intervention was implemented in a real-world school setting, providing ecologically valid insights into the practical impact of PL-based education within the regular PE curriculum.

5. Conclusions

This study suggests small, but significant, improvements in specific PF indicators among children who participated in the PL-based intervention, specifically in abdominal strength and jumping power. These effects are likely due to the combination of structured and non-structured activities, empowered by PL-educational content that emphasized the importance, benefits, and accessibility of PA. The integration of video-based education and simple training strategies probably helped children to understand and apply fitness-related concepts in everyday contexts, which resulted in improvements of PF status.

In terms of PL, the study did not evidence substantial changes in the cognitive or affective domains, possibly due to the limitations of the measurement tool used (PLAYself). While PLAYself has demonstrated reliability, it may lack sensitivity to detect subtle gains in self-perceived competence and knowledge. In other words, it is possible that the lack of effects of the applied intervention on PA is actually a consequence of the applied measurement tool. This raises the need to explore more responsive instruments, such as CAPL-2, in future PL evaluations.

It is important to note that the applied intervention was “educational”, and not “training-based” in nature. It did not increase exercise volume or intensity, but focused on improving children's knowledge, understanding, and awareness of PA and PF. The observed improvements suggest that even brief, structured educational content integrated into regular physical education classes can positively influence PF outcomes. These findings highlight the value of pedagogical strategies in promoting children's health without the need for additional training time or resources.

Future research should consider longer interventions, more diverse assessment tools, and designs that account for classroom-level clustering. Including direct measures of motivation, knowledge, and environmental influences (e.g., family or community support) could provide a fuller understanding of PL's impact. Multi-site trials would also strengthen generalizability and identify which children benefit most from these programs.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/healthcare14050695/s1>, Figure S1: Percentage of changes in study variables during the study course for total sample (A), control group (B), and experimental group (C); The video materials of the applied intervention are available here: Video S1: <https://tinyurl.com/videosPL> (accessed on 8 January 2026).

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Abbreviations

The following abbreviations are used in this manuscript:

PF	Physical Fitness
PA	Physical Activity
PL	Physical Literacy
PE	Physical Education

References

- Demchenko, I.; Prince, S.A.; Merucci, K.; Cadenas-Sanchez, C.; Chaput, J.P.; Fraser, B.J.; Manyanga, T.; Mcgrath, R.; Ortega, F.B.; Singh, B.; et al. Cardiorespiratory fitness and health in children and adolescents: An overview of systematic reviews with meta-analyses representing over 125 000 observations covering 33 health-related outcomes. *Br. J. Sports Med.* **2025**, *59*, 856–865. [\[CrossRef\]](#)
- Ortega, F.B.; Ruiz, J.R.; Castillo, M.J.; Sjöström, M. Physical fitness in childhood and adolescence: A powerful marker of health. *Int. J. Obes.* **2008**, *32*, 1–11. [\[CrossRef\]](#)
- Wei, L.; Li, Z.; Sun, Y. Types and Frequencies of Physical Activity Associated with Physical Fitness in Chinese Children and Adolescents: A National Cross-Sectional Study. *Healthcare* **2025**, *13*, 2400. [\[CrossRef\]](#)
- Maicas-Pérez, L.; Hernández-Lougedo, J.; Maté-Muñoz, J.L.; Villagra-Astudillo, A.; García-Fernández, P.; Suárez-Villadat, B.; Jiménez-Rojo, B. Effect of Physical Activity Interventions on Health Parameters in Children and Adolescents with Intellectual Disabilities: A Systematic Review. *Healthcare* **2024**, *12*, 2434. [\[CrossRef\]](#)
- Aly, M.; El-Gyar, N.; Shalaby, A.M.; Abdelkarim, O. Health-related physical fitness in children among five Mediterranean countries: A cross-cultural study from the DELICIOUS project. *Front. Public Health* **2025**, *12*, 1520096. [\[CrossRef\]](#)
- Hills, A.P.; Andersen, L.B.; Byrne, N.M. Physical activity and obesity in children. *Br. J. Sports Med.* **2011**, *45*, 866–870. [\[CrossRef\]](#) [\[PubMed\]](#)
- Smith, J.J.; Eather, N.; Morgan, P.J.; Plotnikoff, R.C.; Faigenbaum, A.D.; Lubans, D.R. The Health Benefits of Muscular Fitness for Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Med.* **2014**, *44*, 1209–1223. [\[CrossRef\]](#) [\[PubMed\]](#)

8. Cadenas-Sanchez, C.; Mena-Molina, A.; Torres-Lopez, L.V.; Migueles, J.H.; Rodriguez-Ayllon, M.; Lubans, D.R.; Ortega, F.B. Healthier Minds in Fitter Bodies: A Systematic Review and Meta-Analysis of the Association between Physical Fitness and Mental Health in Youth. *Sports Med.* **2021**, *51*, 2571–2605. [\[CrossRef\]](#)
9. Bermejo-Cantarero, A.; Álvarez-Bueno, C.; Martínez-Vizcaino, V.; Redondo-Tébar, A.; Pozuelo-Carrascosa, D.P.; Sánchez-López, M. Relationship between both cardiorespiratory and muscular fitness and health-related quality of life in children and adolescents: A systematic review and meta-analysis of observational studies. *Health Qual. Life Outcomes* **2021**, *19*, 127. [\[CrossRef\]](#) [\[PubMed\]](#)
10. Rodriguez, C.C.; de Camargo, E.M.; Rodriguez-Añez, C.R.; Reis, R.S. Physical Activity, Physical Fitness and Academic Achievement in Adolescents: A Systematic Review. *Rev. Bras. Med. Esporte* **2020**, *26*, 441–448. [\[CrossRef\]](#)
11. García-Hermoso, A.; Ramírez-Vélez, R.; Saavedra, J.M. Exercise, health outcomes, and paediatric obesity: A systematic review of meta-analyses. *J. Sci. Med. Sport* **2019**, *22*, 76–84. [\[CrossRef\]](#)
12. Dambel, L.; Del Sordo, G.; Saidi, O.; Duché, P. Exploring the Effects of Lifestyle Disruptions on Physical Fitness in Children and Adolescents: A Systematic Scoping Review. *Sports Med. Open* **2025**, *11*, 65. [\[CrossRef\]](#)
13. Fuhner, T.; Kliegl, R.; Arntz, F.; Kriemler, S.; Granacher, U. An Update on Secular Trends in Physical Fitness of Children and Adolescents from 1972 to 2015: A Systematic Review. *Sports Med.* **2021**, *51*, 303–320. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Kumar, B.; Robinson, R.; Till, S. Physical activity and health in adolescence. *Clin. Med.* **2015**, *15*, 267–272. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Zhou, X.; Li, J.; Jiang, X. Effects of different types of exercise intensity on improving health-related physical fitness in children and adolescents: A systematic review. *Sci. Rep.* **2024**, *14*, 14301. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Burden, S.J.; Weedon, B.D.; Turner, A.; Whaymand, L.; Meaney, A.; Dawes, H.; Jones, A. Intensity and Duration of Physical Activity and Cardiorespiratory Fitness. *Pediatrics* **2022**, *150*, e2021056003. [\[CrossRef\]](#)
17. Chen, W.Y.; Hammond-Bennett, A.; Hypnar, A.; Mason, S. Health-related physical fitness and physical activity in elementary school students. *BMC Public Health* **2018**, *18*, 195. [\[CrossRef\]](#)
18. Jaekel, J. The role of physical activity and fitness for children’s wellbeing and academic achievement. *Pediatr. Res.* **2024**, *96*, 1550–1551. [\[CrossRef\]](#)
19. Janssen, I.; LeBlanc, A.G. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int. J. Behav. Nutr. Phys. Act.* **2010**, *7*, 40. [\[CrossRef\]](#)
20. Haapala, E.A.; Leppänen, M.H.; Skog, H.; Lubans, D.R.; Viitasalo, A.; Lintu, N.; Jalanko, P.; Maeaetae, S.; Lakka, T.A. Childhood Physical Fitness as a Predictor of Cognition and Mental Health in Adolescence: The PANIC Study. *Sports Med.* **2025**, *55*, 487–497. [\[CrossRef\]](#)
21. Melby, P.S.; Elsborg, P.; Nielsen, G.; Lima, R.A.; Bentsen, P.; Andersen, L.B. Exploring the importance of diversified physical activities in early childhood for later motor competence and physical activity level: A seven-year longitudinal study. *BMC Public Health* **2021**, *21*, 1492. [\[CrossRef\]](#)
22. Calcaterra, V.; Marin, L.; Vandoni, M.; Rossi, V.; Pirazzi, A.; Grazi, R.; Patane, P.; Silvestro, G.S.; Carnevale Pellino, V.; Albanese, I.; et al. Childhood Obesity and Incorrect Body Posture: Impact on Physical Activity and the Therapeutic Role of Exercise. *Int. J. Environ. Res. Public Health* **2022**, *19*, 16728. [\[CrossRef\]](#)
23. Escapite, A.O.; Lopez-Alonzo, S.J.; Barron-Lujan, J.C.; Guedea-Delgado, J.C.; Balderrama, C.V.V. Physical education, motor development and physical activity in preschool children: A systematic review. *VIREF Rev. Educ. Fis.* **2022**, *11*, 28–41.
24. Goodyear, V.A.; Skinner, B.; McKeever, J.; Griffiths, M. The influence of online physical activity interventions on children and young people’s engagement with physical activity: A systematic review. *Phys. Educ. Sport Pedagog.* **2023**, *28*, 94–108. [\[CrossRef\]](#)
25. Gu, X.L.; Chang, M.; Solmon, M.A. Physical Activity, Physical Fitness, and Health-Related Quality of Life in School-Aged Children. *J. Teach. Phys. Educ.* **2016**, *35*, 117–126. [\[CrossRef\]](#)
26. Guillamón, A.R.; García-Cantó, E.; García, P.L.R.; Soto, J.J.P.; Marcos, M.L.T.; López, P.J.T. Physical activity, physical fitness and quality of diet in schoolchildren from 8 to 12 years. *Nutr. Hosp.* **2017**, *34*, 1292–1298. [\[CrossRef\]](#)
27. Larsen, M.N.; Nielsen, C.M.; Orntoft, C.O.; Randers, M.B.; Manniche, V.; Hansen, L.; Hansen, P.R.; Bangsbo, J.; Krustrup, P. Physical Fitness and Body Composition in 8-10-Year-Old Danish Children Are Associated with Sports Club Participation. *J. Strength Cond. Res.* **2017**, *31*, 3425–3434. [\[CrossRef\]](#)
28. Jarvamaa, M.; Riso, E.M.; Reisberg, K.; Jurimae, J. Development of Cardiorespiratory Fitness in Children in the Transition From Kindergarten to Basic School According to Participation in Organized Sports. *Front. Physiol.* **2022**, *13*, 881364. [\[CrossRef\]](#)
29. Ługowska, K.; Kolanowski, W.; Trafialek, J. Increasing physical activity at school improves physical fitness of early adolescents. *Int. J. Environ. Res. Public Health* **2023**, *20*, 2348. [\[CrossRef\]](#) [\[PubMed\]](#)
30. García-Artero, E.; Ortega, F.B.; Ruiz, J.R.; Mesa, J.L.; Delgado, M.; González-Gross, M.; García-Fuentes, M.; Vicente-Rodríguez, G.; Gutiérrez, Á.; Castillo, M.J. El perfil lipídico-metabólico en los adolescentes está más influido por la condición física que por la actividad física (estudio AVENA). *Rev. Española Cardiol.* **2007**, *60*, 581–588. [\[CrossRef\]](#) [\[PubMed\]](#)
31. Martínez-Vizcaino, V.; Sánchez-López, M. Relación entre actividad física y condición física en niños y adolescentes. *Rev. Española Cardiol.* **2008**, *61*, 108–111. [\[CrossRef\]](#)

32. Twisk, J.W.R.; Kemper, H.C.G.; van Mechelen, W. The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age. The Amsterdam Growth and Health Longitudinal Study. *Int. J. Sports Med.* **2002**, *23*, S8–S14. [\[CrossRef\]](#)
33. Whitehead, M. Definition of physical literacy and clarification of related issues. In *International Council of Sport Science and Physical Education Bulletin Journal of Sport Science and Physical Education*; International Council of Sport Science and Physical Education: Berlin, Germany, 2013; Volume 65.
34. Carl, J.; Bryant, A.S.; Edwards, L.C.; Bartle, G.; Birch, J.E.; Christodoulides, E.; Emeljanovas, A.; Froberg, A.; Gandrieau, J.; Gilic, B.; et al. Physical literacy in Europe: The current state of implementation in research, practice, and policy. *J. Exerc. Sci. Fit.* **2023**, *21*, 165–176. [\[CrossRef\]](#)
35. Carl, J.; Barratt, J.; Wanner, P.; Topfer, C.; Cairney, J.; Pfeifer, K. The Effectiveness of Physical Literacy Interventions: A Systematic Review with Meta-Analysis. *Sports Med.* **2022**, *52*, 2965–2999. [\[CrossRef\]](#) [\[PubMed\]](#)
36. Grauduszus, M.; Koch, L.; Wessely, S.; Joisten, C. School-based promotion of physical literacy: A scoping review. *Front. Public Health* **2024**, *12*, 1322075. [\[CrossRef\]](#)
37. Mandigo, J.; Lodewyk, K.; Tredway, J. Examining the Impact of a Teaching Games for Understanding Approach on the Development of Physical Literacy Using the Passport for Life Assessment Tool. *J. Teach. Phys. Educ.* **2019**, *38*, 136–145. [\[CrossRef\]](#)
38. Crozier, M.; Wasenius, N.S.; Denize, K.M.; da Silva, D.F.; Nagpal, T.S.; Adamo, K.B. Evaluation of Afterschool Activity Programs' (ASAP) Effect on Children's Physical Activity, Physical Health, and Fundamental Movement Skills. *Health Educ. Behav.* **2022**, *49*, 87–96. [\[CrossRef\]](#)
39. Invernizzi, P.L.; Crotti, M.; Bosio, A.; Cavaggioni, L.; Alberti, G.; Scurati, R. Multi-Teaching Styles Approach and Active Reflection: Effectiveness in Improving Fitness Level, Motor Competence, Enjoyment, Amount of Physical Activity, and Effects on the Perception of Physical Education Lessons in Primary School Children. *Sustainability* **2019**, *11*, 405. [\[CrossRef\]](#)
40. Johnstone, A.; Hughes, A.R.; Janssen, X.; Reilly, J.J. Pragmatic evaluation of the Go2Play active play intervention on physical activity and fundamental movement skills in children. *Prev. Med. Rep.* **2017**, *7*, 58–63. [\[CrossRef\]](#) [\[PubMed\]](#)
41. Santos, S.; Jimenez, S.; Sampaio, J.; Leite, N. Effects of the Skills4Genius sports-based training program in creative behavior. *PLoS ONE* **2017**, *12*, e0172520. [\[CrossRef\]](#)
42. Stoddart, A.L.; Humbert, M.L.; Kerpan, S.; Cameron, N.; Kriellaars, D. PLitPE: An intervention for physical literacy enriched pedagogy in Canadian elementary school physical education classes. *Phys. Educ. Sport Pedagog.* **2023**, *28*, 675–691. [\[CrossRef\]](#)
43. Van Sluijs, E.M.; McMinn, A.M.; Griffin, S.J. Effectiveness of interventions to promote physical activity in children and adolescents: Systematic review of controlled trials. *BMJ* **2007**, *335*, 703. [\[CrossRef\]](#)
44. Vuletic, P.R.; Kesic, M.G.; Gilic, B.; Pehar, M.; Uzicanin, E.; Idrizovic, K.; Sekulic, D. Evaluation of Physical Literacy in 9- to 11-Year-Old Children: Reliability and Validity of Two Measurement Tools in Three Southeastern European Countries. *Children* **2023**, *10*, 1722. [\[CrossRef\]](#) [\[PubMed\]](#)
45. Vuletic, P.R.; Matijasevic, P.; Pavlinovic, V. Is the PAQ-C a Valid Measurement Tool for Evaluating Physical Activity Levels in Rural Children? Cross-Sectional Study in Southern Croatia. *Sport Mont* **2025**, *23*, 85–91. [\[CrossRef\]](#)
46. Welk, G.; Meredith, M.D. *Fitnessgram and Activitygram Test Administration Manual*, 4th ed.; Human Kinetics: Champaign, IL, USA, 2010.
47. Kay, R.H. Exploring the use of video podcasts in education: A comprehensive review of the literature. *Comput. Hum. Behav.* **2012**, *28*, 820–831. [\[CrossRef\]](#)
48. Gilic, B.; Sunda, M.; Versic, S.; Modric, T.; Olujic, D.; Sekulic, D. Effectiveness of Physical-Literacy-Based Online Education on Indices of Physical Fitness in High-School Adolescents: Intervention Study during the COVID-19 Pandemic Period. *Children* **2023**, *10*, 1666. [\[CrossRef\]](#)
49. Rajkovic Vuletic, P.; Gilic, B.; Pavlinovic, V.; Matijasevic, P.; Sekulic, D. Effects of a Physical-Literacy-Based Educational Intervention on Physical Activity and Body Composition in Preadolescent Children: A School-Based Controlled Trial. *Sports* **2026**, *14*, 77. [\[CrossRef\]](#)
50. Moore, S.A.; McKay, H.A.; Macdonald, H.; Nettlefold, L.; Baxter-Jones, A.D.; Cameron, N.; Brasher, P.M. Enhancing a Somatic Maturity Prediction Model. *Med. Sci. Sports Exerc.* **2015**, *47*, 1755–1764. [\[CrossRef\]](#) [\[PubMed\]](#)
51. Zhou, H.; Yu, P.; Thirupathi, A.; Liang, M. How to Improve the Standing Long Jump Performance? A Mininarrative Review. *Appl. Bionics Biomech.* **2020**, *2020*, 8829036. [\[CrossRef\]](#)
52. Baxter, R.E.; Moore, J.H.; Pendergrass, T.L.; Crowder, T.A.; Lynch, S. Improvement in sit-up performance associated with 2 different training regimens. *J. Orthop. Sports Phys. Ther.* **2003**, *33*, 40–47. [\[CrossRef\]](#)
53. Zhang, D.; Shi, L.; Zhu, X.; Chen, S.; Liu, Y. Effects of intervention integrating physical literacy into active school recesses on physical fitness and academic achievement in Chinese children. *J. Exerc. Sci. Fit.* **2023**, *21*, 376–384. [\[CrossRef\]](#) [\[PubMed\]](#)
54. Morano, M.; Bortoli, L.; Ruiz, M.C.; Vitali, F.; Robazza, C. Self-efficacy and enjoyment of physical activity in children: Factorial validity of two pictorial scales. *PeerJ* **2019**, *7*, e7402. [\[CrossRef\]](#)

55. Graham, J.D.; Li, Y.-C.; Bray, S.R.; Cairney, J. Effects of cognitive control exertion and motor coordination on task self-efficacy and muscular endurance performance in children. *Front. Hum. Neurosci.* **2018**, *12*, 379. [\[CrossRef\]](#) [\[PubMed\]](#)
56. Ning, W.; Gao, Z.; Lodewyk, K. Associations between Socio-Motivational Factors, Physical Education Activity Levels and Physical Activity Behavior among Youth. *ICHPER-SD J. Res.* **2012**, *7*, 3–10.
57. Signorini, G.; Scurati, R.; Bosio, A.; Pizzoli, M.; Pagano, A.; Raiola, G.; Invernizzi, P.L. The Perception of Effort as a Basis for Improving Physical Efficacy and Efficiency in Italian Military School Students. *Sports* **2025**, *13*, 128. [\[CrossRef\]](#)
58. de Bruijn, A.G.M.; Brocken, J.E.A. Motor and prosocial skills relate to enjoyment and physical activity levels during primary school recess. *J. Sports Sci.* **2025**, *43*, 1532–1546. [\[CrossRef\]](#)
59. Russo, G.; De Matteis, F.; Oparina, E.; Ceciliani, A.; Bigliassi, M. Exploring the relationship between physical activity behavior, sport modality, and higher-order psychosocial skills in children. *Heliyon* **2025**, *11*, e43739. [\[CrossRef\]](#)
60. Cao, M.; Quan, M.; Zhuang, J. Effect of High-Intensity Interval Training versus Moderate-Intensity Continuous Training on Cardiorespiratory Fitness in Children and Adolescents: A Meta-Analysis. *Int. J. Environ. Res. Public Health* **2019**, *16*, 1533. [\[CrossRef\]](#) [\[PubMed\]](#)
61. Warneke, K.; Wirth, K.; Keiner, M.; Schiemann, S. Improvements in Flexibility Depend on Stretching Duration. *Int. J. Exerc. Sci.* **2023**, *16*, 83–94. [\[CrossRef\]](#)
62. Bremer, E.; Graham, J.D.; Cairney, J. Outcomes and Feasibility of a 12-Week Physical Literacy Intervention for Children in an Afterschool Program. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3129. [\[CrossRef\]](#)
63. Coyne, P.; Vandeborn, E.; Santarossa, S.; Milne, M.M.; Milne, K.J.; Woodruff, S.J. Physical literacy improves with the Run Jump Throw Wheel program among students in grades 4–6 in southwestern Ontario. *Appl. Physiol. Nutr. Metab.* **2019**, *44*, 645–649. [\[CrossRef\]](#) [\[PubMed\]](#)
64. Demetriou, Y.; Bachner, J.; Reimers, A.K.; Göhner, W. Effects of a Sports-Oriented Primary School on Students' Physical Literacy and Cognitive Performance. *J. Funct. Morphol. Kinesiol.* **2018**, *3*, 37. [\[CrossRef\]](#)
65. Alter, M.J. *Science of Flexibility*; Human Kinetics: Champaign, IL, USA, 2004.
66. Atkin, A.J.; Sharp, S.J.; Harrison, F.; Brage, S.; Van Sluijs, E.M. Seasonal Variation in Children's Physical Activity and Sedentary Time. *Med. Sci. Sports Exerc.* **2016**, *48*, 449–456. [\[CrossRef\]](#)
67. Weaver, R.G.; Hensing, C.; Armstrong, B.; Adams, E.L.; Beets, M. Seasonal Shifts in Children's Sedentary Behaviors, Physical Activity, and Sleep A Systematic Review and meta-Analysis. *Pediatr. Clin. N. Am.* **2022**, *69*, 671–693. [\[CrossRef\]](#)
68. Janssen, X.; Basterfield, L.; Parkinson, K.N.; Pearce, M.; Reilly, J.K.; Adamson, A.J.; Reilly, J.J. Determinants of changes in sedentary time and breaks in sedentary time among 9 and 12 year old children. *Prev. Med. Rep.* **2015**, *2*, 880–885. [\[CrossRef\]](#) [\[PubMed\]](#)
69. Benítez-Porres, J.; López-Fernández, I.; Raya, J.F.; Álvarez Carnero, S.; Alvero-Cruz, J.R.; Álvarez Carnero, E. Reliability and Validity of the PAQ-C Questionnaire to Assess Physical Activity in Children. *J. Sch. Health* **2016**, *86*, 677–685. [\[CrossRef\]](#)
70. Makai, A.; Prémusz, V.; Dózsa-Juhász, O.; Fodor-Mazzag, K.; Melczer, C.; Ács, P. Examination of Physical Activity Patterns of Children, Reliability and Structural Validity Testing of the Hungarian Version of the PAQ-C Questionnaire. *Children* **2023**, *10*, 1547. [\[CrossRef\]](#)
71. Voss, C.; Dean, P.H.; Gardner, R.F.; Duncombe, S.L.; Harris, K.C. Validity and reliability of the Physical Activity Questionnaire for Children (PAQ-C) and Adolescents (PAQ-A) in individuals with congenital heart disease. *PLoS ONE* **2017**, *12*, e0175806. [\[CrossRef\]](#)
72. Podnar, H.; Kunješić, M.; Radman, I. Internal Consistency and Retest Reliability of the Croatian Version of PAQ-C/Interna konzistencija i retest pouzdanost hrvatske inačice PAQ-C upitnika. *Croat. J. Educ. Hrvatski Časopis Odgoj Obrazovanje* **2017**, *19*, 45–62. [\[CrossRef\]](#)
73. Li, M.H.; Rudd, J.; Chow, J.Y.; Sit, C.H.P.; Wong, S.H.S.; Sum, R.K.W. A Randomized Controlled Trial of a Blended Physical Literacy Intervention to Support Physical Activity and Health of Primary School Children. *Sports Med. Open* **2022**, *8*, 55. [\[CrossRef\]](#) [\[PubMed\]](#)
74. Mendoza-Muñoz, M.; Calle-Guisado, V.; Pastor-Cisneros, R.; Barrios-Fernandez, S.; Rojo-Ramos, J.; Vega-Muñoz, A.; Contreras-Barraza, N.; Carlos-Vivas, J. Effects of Active Breaks on Physical Literacy: A Cross-Sectional Pilot Study in a Region of Spain. *Int. J. Environ. Res. Public Health* **2022**, *19*, 7597. [\[CrossRef\]](#) [\[PubMed\]](#)
75. Wyszynska, J.; Ring-Dimitriou, S.; Thivel, D.; Weghuber, D.; Hadjipanayis, A.; Grossman, Z.; Ross-Russell, R.; Dereń, K.; Mazur, A. Physical activity in the prevention of childhood obesity: The position of the European childhood obesity group and the European academy of pediatrics. *Front. Pediatr.* **2020**, *8*, 535705. [\[CrossRef\]](#) [\[PubMed\]](#)
76. Vaivada, T.; Sharma, N.; Das, J.K.; Salam, R.A.; Lassi, Z.S.; Bhutta, Z.A. Interventions for health and well-being in school-aged children and adolescents: A way forward. *Pediatrics* **2022**, *149*, e2021053852M. [\[CrossRef\]](#)

77. Astorino, T.A.; Schubert, M.M. Individual responses to completion of short-term and chronic interval training: A retrospective study. *PLoS ONE* **2014**, *9*, e97638. [[CrossRef](#)]
78. Alvarez, C.; Ramirez-Campillo, R.; Ramirez-Velez, R.; Izquierdo, M. Effects and prevalence of nonresponders after 12 weeks of high-intensity interval or resistance training in women with insulin resistance: A randomized trial. *J. Appl. Physiol.* **2017**, *122*, 985–996. [[CrossRef](#)] [[PubMed](#)]

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Examining Qualitative Changes in Physical Fitness and Body Composition in a School-Based Physical Literacy Intervention: Methodological and Practical Considerations

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Abstract

Studying qualitative changes is important in sport and exercise sciences because it reveals how different physical traits interact and develop together over time. This study aimed to explore how a physical literacy-based intervention (PL-intervention) affects the relationships between body composition and fitness indicators in preadolescent children. The participants were 112 children (9 to 11 years old, 50 girls), divided into a control group (C group, $n=61$) and an experimental intervention group (E group, $n=51$). They were tested in anthropometrics/body composition (height, mass, body fat, and skeletal muscle mass) and fitness indicators (assessing jumping power, abdominal and upper body strengths, mobility, flexibility, and cardiovascular endurance) at initial (September), final (December), and retention measurements (May). Between the initial and final measurements, the E-group participated in a structured physical literacy-based intervention (PL-intervention) delivered as a part of their regular physical education classes (PE), while the C-group participated in standard PE. To examine changes in the intervariable associations over time, correlation matrices were computed, while factor loading matrices were compared across measurement phases using Tucker's coefficient of congruence for each study group. During the course of the study, the C-group experienced certain qualitative changes, showing early signs of structural divergence. On the other hand, factor structures and correlations among variables for the E-group were similar across measurements, suggesting that the intervention helped maintain stable relationships between body composition and physical fitness variables. The results suggest that the applied intervention program supported coordinated and balanced physical development and showed that such programs may help children develop lasting and organized patterns of physical functioning.

Keywords: curriculum, anthropometry, motor abilities, physical education, program evaluation

Introduction

Preadolescence is a critical developmental period marked by rapid physical, cognitive, and social changes (Rowland, 2005). During this stage, monitoring physical fitness and body composition is essential, as it provides valuable insight into children's overall health trajectories and poten-

tial risk factors for chronic diseases (Rajković Vuletić et al., 2024). Global trends continue to show a rising prevalence of overweight and obesity in children, often linked to sedentary behavior, insufficient physical activity, and poor dietary habits (Masanović et al., 2020). These issues are associated with serious physical health outcomes, including insulin resistance,

increased cardiovascular risk, and orthopedic complications. Additionally, there is growing evidence that excess weight and low physical fitness are related to psychosocial difficulties, such as low self-esteem and reduced academic performance (Santana et al., 2017).

Low levels of physical fitness are recognized as strong predictors of future health, independent of body weight. Meanwhile, among children and adolescents, physical activity is the most important determinant of physical fitness (Lohman et al., 2008). Given that both physical activity and fitness levels tend to track from childhood into adolescence and adulthood, early identification and timely intervention are crucial. Schools and sports programs have therefore been recognized as key environments for promoting healthy behaviors and monitoring fitness trends (Marinho et al., 2022). As a result, many studies have examined fitness trends and the effectiveness of various school-based or sport-related fitness programs in pediatric populations (Rauner, Mess, & Woll, 2013). However, most of these studies focus primarily on quantitative changes evidencing improvements in absolute values of body composition or fitness indices (e.g., cardiorespiratory endurance, strength, power, flexibility) (Errisuriz, Golaszewski, Born, & Bartholomew, 2018; Kriemler et al., 2011).

While such metrics are fundamental for evaluating intervention effects and understanding growth patterns, they represent only one side of the adaptation process. In contrast, qualitative changes refer to shifts in the internal structure of relationships between variables (i.e., how fitness and body composition measures interact and reorganize over time). For example, two children may both show improved results in a beep test (commonly used to assess aerobic capacity), yet the underlying factors driving this improvement could differ, such as increased step length from growth, gains in muscular power, or enhanced cardiovascular function (Rowland, 2005). Qualitative analysis seeks to uncover these interactions and reveal how and why performance changes occur by examining the evolving relationships among the contributing variables. From the developmental perspective, this is highly important because functional improvements may take place without major changes in variable structure — and vice versa. Therefore, a research focus on qualitative structure could provide a more comprehensive understanding of adaptation and physical development.

In other words, analyzing qualitative changes allows researchers and practitioners to “look beyond outcome measures” and investigate how a system as a whole adapts. In this context, it involves evaluating whether specific fitness and body composition variables become more or less connected over time, whether associations between variables strengthen or weaken, and whether new relationships emerge. These structural changes may reflect underlying shifts in motor control, neuromuscular coordination, or metabolic function, all of which are important for long-term health and physical competence. For instance, if improved aerobic capacity becomes increasingly related to lean muscle mass rather than just reduced fat mass, it may indicate a more efficient or robust physiological adaptation. Methodologically, such insights can be gained by comparing correlation matrices or factor struc-

tures of selected variables across different time points (e.g., before and after the intervention). These methods can also detect delayed or latent effects that may not be visible through performance outcomes alone. Ultimately, qualitative analysis offers a deeper understanding of adaptation mechanisms, durability of change, and individual variability in response to physical education and training.

In recent years, physical literacy has emerged as a promising framework for promoting lifelong engagement in physical activity and, in turn, supporting fitness development (Carl et al., 2023; Gilic, Sekulic, Munoz, Jaunig, & Carl, 2025; Lilic et al., 2024; Rajkovic Vuletic et al. 2026). In general, physical literacy goes beyond physical competence alone; it incorporates motivation, confidence, knowledge, and understanding of movement, encouraging children to value and maintain active lifestyles (Kesic et al., 2022; Sunda et al., 2022; Whitehead, 2013). Because childhood is a sensitive period for both motor development and behavior formation, physical literacy-based interventions can play a key role. Unlike traditional programs that often target isolated physical capacities, physical literacy emphasizes the development of coordinated, adaptable movement patterns that may help sustain long-term functional balance. As such, physical literacy interventions have the potential to support not only measurable performance gains but also the stability and reorganization of deeper structural dimensions related to body composition and fitness.

Studies have frequently examined the quantitative effects of physical literacy interventions and have shown promising results (Carl et al., 2022; Rajkovic Vuletic et al., 2026). However, there is an evident lack of studies that have evidenced structural/qualitative changes in specific variables as a result of physical literacy intervention in children. Therefore, the aim of this study was to investigate how a physical literacy-based intervention influences the relationships between body composition and physical fitness in preadolescent children. Specifically, the study explored whether the intervention led to qualitative changes by comparing structural relationships over time between an experimental group and a control group. Through this approach, we aimed to assess whether physical literacy education supports more coordinated and enduring physical development.

Methods

Participants

The sample of participants consisted of 112 preadolescent children (50 girls) from southern Croatia. At the time of data collection, the participants were between 9 and 11 years old and were enrolled in either the 3rd ($n=71$) or 4th grade ($n=48$) of elementary school (two schools in total). All the children were in good health and attended physical education (PE) classes on a regular basis. Those who had been ill or who had sustained a musculoskeletal injury within two weeks prior to testing were excluded. Before participation, parents or legal guardians were informed about the study objectives and procedures, and parental written consent was obtained. The research protocol was preapproved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb. The total

sample was divided into a control group (n=60) and an experimental group (n=52) similarly across both schools included in the study.

Variables

Variables included a set of anthropometric/body composition indices and a set of physical fitness tests.

Anthropometrics included body height (measured by stadiometer in 0.5 cm) and body mass (measured in 0.1 kg by Tanita measuring scale). Body composition measures included body fat and skeletal muscle mass (both in % of body mass) by a bio-electrical impedance analyzer (Tanita TBF-300, Tokyo, Japan).

Physical fitness (PF) was assessed using selected tests evaluating aerobic endurance, muscular strength and endurance (abdominal and upper body), torso extensor strength and flexibility, overall flexibility, and jumping power. Aerobic endurance was measured using the 15-meter multistage fitness test (Beep test), which includes 21+ levels, each consisting of multiple 15-meter running intervals. Participants ran between two cones, turning and touching the line at each beep. The test ended when they could no longer reach the line in time; the final score reflected the highest level completed. Upper body strength and endurance were evaluated using the push-up test (Push-ups). From a plank position, participants lowered themselves until elbows reached a 90° angle and then returned to full extension while maintaining a straight body

line. The number of correctly performed repetitions was recorded. Abdominal strength and endurance were assessed using the sit-up test (Sit-ups), where participants performed as many correct sit-ups as possible (up to a maximum of 75). Each correctly executed repetition was scored. Torso extensor strength and flexibility were measured with the torso lift test (Torso lift), in which participants raised their upper back (cervical and thoracic spine) from the floor to the maximum controllable height, keeping the head aligned with the spine. Flexibility of the lower back and hamstrings was assessed using the sit-and-reach test (Sit-reach). Seated with legs extended, participants reached forward along a measuring box, holding the position for at least two seconds. The best of three trials was used. The explosive strength was measured with the standing long jump test (broad jump). Participants jumped forward barefoot from a standing position onto a standardized mat (ELAN, Begunje, Slovenia), and the best of three jumps (in centimeters) was recorded.

Intervention

Participants were assessed at three time points: initial measurement (September 2024), final measurement (late December 2024), and retention measurement (May 2025). The intervention was conducted between the initial and final assessments. An overview of the study timeline is presented in Figure 1.

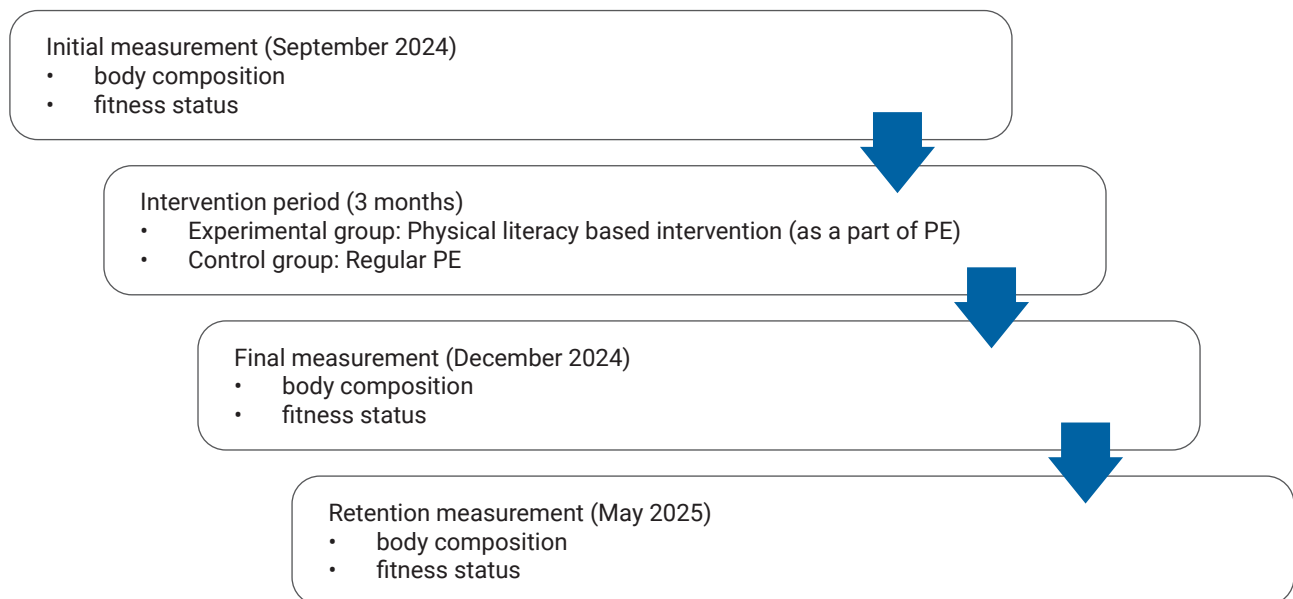


Figure 1. Timeline of the study

The educational intervention, focused on physical literacy (PL), was implemented within the existing PE schedule for the experimental group over a 12-week period. During this time, students received three PE sessions weekly, amounting to a total of 36 lessons. The intervention incorporated 12 short, original educational videos (3–4 minutes each), each addressing a key topic related to PL or physical health. The video content was organized into the following themes: two videos covered core PL principles (e.g., movement motiva-

tion, confidence, and understanding), three focused on cardiorespiratory fitness, five targeted motor abilities (strength, power, coordination, flexibility), and two addressed general health habits, including nutrition. Each video was shown three times to reinforce learning and ensure knowledge retention. More details on educational intervention and video materials are available elsewhere (please see supplementary materials in published study of Rajkovic Vuletic et al., 2026).

Statistics

To examine changes in the intervariable relationships over time, correlation matrices were computed for each measurement phase within both the control and experimental groups. Jennrich's test was used to statistically assess differences between correlation matrices obtained from repeated measurements on the same participants (Jennrich, 1970; Steiger, 1980).

To assess the stability and reorganization of latent factor structures, exploratory factor analysis was performed using the Varimax rotation method and the Guttman–Kaiser criterion for factor extraction (Kaiser, 1958). Factor loading matrices were compared across measurement phases using Tucker's coefficient of congruence (Lorenzo-Seva & Ten Berge, 2006). Congruence values above 0.85 were interpreted as reflecting

good structural similarity, while values above 0.95 indicated near-identity. In comparisons involving a different number of factors across phases (e.g., 3 vs. 2), only the leading shared number of factors was compared to ensure interpretability. All matrix and factor comparisons were conducted separately for the control and experimental groups to determine the extent to which the intervention influenced structural stability or reorganization.

Results

Table 1 presents the Pearson's correlation coefficients calculated between study variables in the initial, final and retention measurements for the control group. Meanwhile, correlations between study variables for the experimental group are shown in Table 2.

Table 1. Correlations between study variables in the initial, final, and retention measurements for the control group (*denotes significance of $p < 0.05$)

		1	2	3	4	5	6	7	8	9
Broad jump (1)	Initial	-								
	Final	-								
	Retention	-								
Push-ups (2)	Initial	0.47*								
	Final	0.41*								
	Retention	0.44*								
Sit-ups (3)	Initial	0.32*	0.28*							
	Final	0.42*	0.47*							
	Retention	0.32*	0.33*							
Trunk lift (4)	Initial	0.04	0.04	0.11						
	Final	0.18	-0.05	-0.12						
	Retention	0.13	0.05	0.14						
Sit-reach (5)	Initial	0.08	0.05	0.33*	0.15					
	Final	0.16	0.11	0.13	0.31*					
	Retention	0.14	0.03	0.18	0.29*					
Beep test (6)	Initial	0.51*	0.51*	0.17	0.13	-0.16				
	Final	0.23*	0.17	0.10	0.00	-0.10				
	Retention	0.10	0.05	-0.08	-0.22*	-0.05				
Height (7)	Initial	0.06	-0.41*	0.13	0.02	0.16	-0.23*			
	Final	0.12	-0.35*	-0.05	0.24*	0.20	0.04			
	Retention	-0.03	-0.41*	-0.01	-0.04	0.10	0.11			
Mass (8)	Initial	-0.37*	-0.42*	-0.18	0.05	-0.07	-0.28*	0.43*		
	Final	-0.36*	-0.45*	-0.35*	0.18	0.05	-0.15	0.64*		
	Retention	-0.41*	-0.48*	-0.28*	0.01	0.05	-0.03	0.65*		
Body fat (9)	Initial	-0.70*	-0.52*	-0.26*	0.10	0.10	-0.52*	0.19	0.64*	
	Final	-0.63*	-0.44*	-0.41*	0.12	0.08	-0.24*	0.23*	0.81*	
	Retention	-0.17	-0.09	-0.09	0.03	0.02	-0.06	0.12	0.26*	
Muscle mass (10)	Initial	0.70*	0.52*	0.26*	-0.10	-0.10	0.51*	-0.19	-0.64*	-0.98*
	Final	0.63*	0.44*	0.41*	-0.12	-0.09	0.24*	-0.23*	-0.81*	-0.98*
	Retention	0.65*	0.45*	0.29*	-0.09	-0.21*	0.12	-0.19	-0.75*	-0.33*

Table 2. Correlations between study variables in the initial, final, and retention measurements for the experimental group (*denotes significance of $p < 0.05$)

		1	2	3	4	5	6	7	8	9
Broad jump (1)	Initial	-								
	Final	-								
	Retention	-								
Push-ups (2)	Initial	0.54*								
	Final	0.31*								
	Retention	0.60*								
Sit-ups (3)	Initial	0.30*	0.39*							
	Final	0.46*	0.25							
	Retention	0.48*	0.26							
Trunk lift (4)	Initial	0.36*	0.11	0.23						
	Final	0.08	0.07	0.02						
	Retention	0.19	-0.05	0.26						
Sit-reach (5)	Initial	0.16	0.04	0.20	0.42*					
	Final	0.18	-0.12	0.20	0.37*					
	Retention	0.24	-0.10	0.36*	0.46*					
Beep test (6)	Initial	0.55*	0.47*	0.25	0.20	-0.09				
	Final	0.60*	0.34*	0.37*	-0.03	-0.02				
	Retention	0.57*	0.71*	0.41*	0.04	-0.17				
Height (7)	Initial	-0.19	-0.41*	0.26	0.28	0.29	-0.10			
	Final	-0.28*	-0.12	0.17	0.26	0.24	-0.27*			
	Retention	-0.31*	-0.46*	0.07	0.28	0.24	-0.46*			
Mass (8)	Initial	-0.36*	-0.45*	0.16	0.07	0.16	-0.34*	0.78*		
	Final	-0.44*	-0.13	-0.01	0.33	0.09	-0.44*	0.83*		
	Retention	-0.44*	-0.43*	-0.17	0.19	0.07	-0.55*	0.80*		
Body fat (9)	Initial	-0.49*	-0.60*	-0.07	-0.07	0.12	-0.54*	0.45*	0.82*	
	Final	-0.65*	-0.21	-0.29*	0.33*	0.18	-0.61*	0.62*	0.82*	
	Retention	-0.48*	-0.56*	-0.25	0.13	0.16	-0.65*	0.58*	0.85*	
Muscle mass (10)	Initial	0.22	0.40*	-0.05	-0.29*	-0.27*	0.37*	-0.40*	-0.48*	-0.55*
	Final	0.62*	0.20	0.22	-0.34*	-0.11	0.63*	-0.63*	-0.86*	-0.96*
	Retention	0.48*	0.55*	0.25	-0.13	-0.16	0.65*	-0.58*	-0.85*	-0.98*

In the control group, the comparison between the initial and final correlation matrices revealed no significant change in the structure of intervariable relationships. Jennrich's test result was $\chi^2(45)=29.82$, $p=0.960$, indicating a very high similarity in the pattern of correlations before and after the study period. This suggests that the control group, which did not receive an intervention, maintained stable relationships among body composition and performance variables. The most notable individual changes occurred in correlations involving the Beep test, such as with Push-ups (+0.33), Broad jump (+0.28), and Body fat (+0.28). Despite these fluctuations, the overall matrix structure remained intact. For the experimental group, the initial-to-final comparison showed signs of reorganization, although it did not reach statistical significance. Jennrich's test yielded $\chi^2(45)=55.45$, $p=0.137$. The largest changes

occurred in key physiological relationships, especially body fat vs muscle mass (+0.41), trunk lift vs body fat (+0.41), and broad jump vs muscle mass (+0.40). These shifts point to the intervention's impact on how variables interact structurally, even if not yet confirmed statistically at the matrix level.

From final test to retention, the control group showed a statistically significant restructuring of intervariable relationships. Jennrich's test yielded $\chi^2(45)=72.61$, $p=0.0056$, confirming that the correlation structure changed meaningfully. This was especially evident in changes involving body fat, which shifted strongly in its correlation with muscle mass (+0.67), mass (+0.55), and broad jump (+0.46). In contrast, the experimental group showed no significant matrix-wide change from the final test to retention. Jennrich's test resulted in $\chi^2(45)=42.57$, $p=0.575$. Nonetheless, some moderate pair-

wise shifts were observed — particularly involving push-ups, whose correlations with the Beep test (+0.36), muscle mass (+0.35), and height (cm) (+0.34) increased.

Over the longer period from initial testing to retention, the control group experienced a clear and statistically significant alteration in its correlation structure. Jennrich's test yielded $\chi^2(45)=72.61$, $p=0.0056$ which was practically identical to the Final–Retention comparison. The strongest pairwise changes again involved body fat, especially its links to muscle mass (+0.67), broad jump (+0.53), and push-ups (+0.43). The experimental group maintained statistical stability in its intervariable relationships over the full study period. Jennrich's test yielded $\chi^2(45)=42.57$, $p=0.575$, indicating no significant deviation from the initial correlation structure. Nevertheless, notable pairwise changes included body fat (%) vs muscle

mass (+0.45), mass vs muscle mass (+0.37), and height (cm) vs Beep test (+0.36).

The results of the factor analyses calculated in the initial, final and retention measurements for the control group are presented in Table 3. Jennrich's test comparison shows no significant change in the control group's factor structure between the initial and final measurements. However, Tucker's coefficient of congruence indicates partial similarity. Notably, Initial F3 vs Final F2=0.977, and Initial F2 vs Final F3=0.954. One factor (Initial F1) showed lower similarity (~0.72), suggesting partial restructuring. Strong similarity was observed between final and retention factor structures in the control group. Final F2 vs Retention F2=0.977 and Final F3 vs Retention F3=0.955, indicating good preservation of structure.

Table 3. Factor analysis calculated for the initial, final and retention measurements for the control group (F – factor structure)

	Initial measurement				Final measurement			Retention measurement		
	F1	F2	F3	F4	F1	F2	F3	F1	F2	F3
Broad jump	-0.85	0.11	0.15	0.14	-0.77	0.31	0.27	0.83	0.18	0.06
Push-ups	-0.57	0.15	-0.49	0.25	-0.58	-0.33	0.32	0.58	0.14	-0.42
Sit-ups	-0.37	0.66	0.14	0.16	-0.56	-0.11	0.32	0.53	0.43	0.02
Trunk lift	0.10	0.14	0.00	0.88	0.05	0.44	0.51	-0.02	0.74	-0.08
Sit-reach	0.11	0.88	0.03	0.05	0.02	0.11	0.83	0.08	0.68	0.25
Beep test	-0.65	-0.23	-0.16	0.46	-0.43	0.42	-0.37	0.32	-0.48	0.38
Height	0.04	0.14	0.93	-0.04	0.19	0.85	0.13	-0.08	0.02	0.91
Mass	0.55	-0.22	0.58	0.19	0.75	0.53	0.06	-0.62	0.06	0.67
Body fat	0.94	0.01	0.17	0.11	0.93	0.12	0.09	-0.39	0.17	0.08
Muscle mass	-0.94	0.00	-0.16	-0.11	-0.93	-0.12	-0.09	0.84	-0.21	-0.25
Explained Variance	3.69	1.39	1.57	1.15	3.79	1.64	1.40	2.66	1.56	1.75
Proportion Total	0.37	0.14	0.16	0.11	0.38	0.16	0.14	0.27	0.16	0.17

The results of the factor analysis calculated for the experimental group are shown in Table 4. The factor structure remained very stable in the experimental group from the initial to final measurements. Tucker's coefficient showed initial F1 vs final F1=0.986 and F3 vs F2=0.883. Only one dimension had a weaker match, suggesting minimal structural change postintervention. Moderate-to-strong similarity was

observed in the experimental group between the initial and retention phases. F2 matched well (≈ 0.883), and F1 showed fair congruence (~ 0.754), supporting structural consistency. Final and retention factor structures were highly congruent in the experimental group. Tucker's coefficients: F2 ≈ 0.883 and F1 ≈ 0.754 , indicating strong consistency across phases.

Table 4. Factor analysis calculated for the initial, final and retention measurements for the experimental group (F – factor structure)

	Initial measurement			Final measurement			Retention measurement	
	F1	F2	F3	F1	F2	F3	F1	F2
Broad jump	-0.38	0.37	0.63	-0.55	0.60	0.33	-0.61	0.56

(continued from previous page)

Table 4. Factor analysis calculated for the initial, final and retention measurements for the control group (F – factor structure)

	Initial measurement			Final measurement			Retention measurement	
	F1	F2	F3	F1	F2	F3	F1	F2
Push-ups	-0.46	0.06	0.68	-0.04	0.71	-0.29	-0.73	0.19
Sit-ups	0.36	0.13	0.75	-0.04	0.75	0.22	-0.28	0.73
Trunk lift	0.06	0.81	0.23	0.35	0.15	0.60	0.19	0.72
Sit-reach	0.14	0.79	0.00	0.08	0.01	0.89	0.21	0.74
Beep test	-0.28	-0.01	0.74	-0.52	0.61	0.05	-0.79	0.23
Height	0.85	0.22	0.10	0.82	0.18	0.19	0.76	0.31
Mass	0.94	0.04	-0.12	0.95	0.02	0.05	0.88	0.09
Body fat	0.76	0.01	-0.47	0.90	-0.31	0.09	0.92	0.01
Muscle mass	-0.51	-0.49	0.36	-0.92	0.26	-0.05	-0.92	0.00
Explained Variance	3.03	1.72	2.39	3.96	2.03	1.45	4.75	2.09
Proportion Total	0.30	0.17	0.24	0.40	0.20	0.14	0.48	0.21

Discussion

This study aimed to evaluate eventual qualitative changes in studied anthropometric/body composition and physical fitness indices in preadolescent children as a result of physical literacy-based education (intervention). The results indicated several important findings. First, the control group, which did not participate in physical literacy-based educational intervention, experienced certain qualitative changes, showing early signs of structural divergence. Meanwhile, factor structure and correlations among variables in the experimental group were negligible, indicating that the applied intervention supported foundations for sustainable, self-directed physical development.

Qualitative changes in the control group

As stated previously, the control group showed early signs of structural divergence. Specifically, from the initial to the final measurement, no statistically significant changes in the correlation matrix were observed, but several subtle shifts pointed to early disorganization in intervariable relationships. These changes likely reflect natural developmental variability, including growth, hormonal changes, and differences in unstructured activity levels. In explaining the background for these results, the context of the research should be briefly presented.

The study was performed during one school year, with initial testing performed in September, final testing in December, and retention testing in May. It is well known that during this period, a significant decrease in physical activity regularly occurs due to unfavorable weather conditions and

increased academic pressure (Frömel, Šafář, Jakubec, Groffik, & Žatka, 2020; Kibbe et al., 2011). Therefore, it is reasonable to expect that without the support of a specifically designed and applied structured program oriented toward increasing (or at least maintaining) the level of physical activity, internal physiological relationships may evolve inconsistently. Of particular note were shifts involving fat mass and muscular performance variables, where previously aligned patterns became weaker or more inconsistent, which almost certainly indicate fragmentation of physiological properties. It is important to note that such early signs of disintegration suggest that, even in relatively short periods, physiological systems may become less cohesive when not intentionally supported.

This trend continued and even increased in the control group during the retention phase. These dynamics were actually logical knowing the longer period between final and retention testing (five months) in comparison to the period between initial and final measurement (three months). Specifically, between the final and retention measurements, the group exhibited statistically significant changes in the correlation matrix. This clearly signals a substantial reorganization of internal relationships between anthropometric/body composition and physical fitness indices. In other words, it seems that without ongoing stimulus, previously established functional linkages between body composition and fitness began to deteriorate. The breakdown of these patterns, especially among fat mass, muscle mass, and fitness indicators, reflects a loss of physiological coordination and coherence. Such structural disorganization is not unexpected in growing children without consistent physical activity, and this is particularly possible in the winter period where previously specified fac-

tors of negative influence on physical activity are practically unavoidable (Carson & Spence, 2010).

(Lack of) qualitative changes in the experimental group

The experimental group demonstrated a markedly different pattern than the control group across all phases. First, between the initial and final measurements, no significant changes in the internal correlation structure were detected. Generally, differences between the corresponding correlation coefficients calculated for the initial and final measurements were negligible, indicating similar structures in both testing phases (e.g., September and December). Therefore, it can be said that due to exposure to a targeted PL-based intervention, the relationships among key variables remained highly stable and internally coherent. This suggests that the educational program helped to reinforce existing physiological linkages. If we consider that the 2nd study phase (from final to retention measurement) lasted longer than the previous phase (five months in comparison to three months) and that during the 2nd phase, the experimental group did not receive any intervention, it is of particular importance that in this period, structural coherence was maintained, with no evidence of regression or fragmentation. This enduring alignment among body composition and performance variables implies that the benefits of the intervention extended beyond its active duration, resulting in lasting physiological organization. These findings align with the goals of PL which emphasize autonomy, competence, and sustainable movement patterns rather than short-term gains.

Indeed, by fostering a deeper understanding of movement and encouraging consistent engagement, the PL-intervention applied here aimed to build durable motor patterns and internal motivation that support long-term physical development. In this context, the structural stability observed in our study reflects the formation of resilient, self-sustaining systems rooted in meaningful and developmentally appropriate activity. In other words, the observed “lack” of qualitative changes in the experimental group between the final and retention measurements suggests that the intervention supported the development of coordinated, transferable movement skills and physiological efficiency that remained intact even without continued instruction. Collectively, this suggests that by focusing on meaningful engagement, movement understanding, and confidence, the applied intervention may have enabled participants to internalize key aspects of physical functioning, leading to self-sustained physical adaptation. In this way, physical literacy acts not only as a pedagogical framework but also as a mechanism for stabilizing internal systems, allowing children to maintain balanced development across body composition and fitness domains.

The calculated factor analyses further support previous interpretations. In brief, the control group exhibited notable instability in factor structure across study phases, especially between the initial and retention measurements. Shifts in factor loadings and lower Tucker congruence coefficients suggest that the relationships among latent constructs became increasingly unstable without structured support. In

contrast, the experimental group displayed high factorial stability throughout. Tucker's coefficients reflected strong to near-identical alignment across all three measurement phases. This is particularly evident from the initial to final measurements. Variables related to body composition and functional performance consistently loaded on the same factors, reflecting a well-integrated and resilient internal structure. These findings illustrate that the intervention actually preserved and reinforced the latent architecture of physical development.

Final considerations

One could find surprising that the experimental group, despite participating in a structured intervention, showed relatively few changes in the internal structure of fitness and body composition variables. However, this stability of structure should not be seen as a lack of adaptation but rather as a positive indicator of functional consolidation. In a developmental stage characterized by rapid physical changes and natural variability, maintaining consistent intervariable relationships suggests that the system has adapted in a stable and organized manner. Structural stability, in this case, reflects efficiency and resilience, the body's ability to improve or maintain performance without disrupting underlying physiological mechanisms. In this context, the underlying physiological mechanisms refers to the natural and functional relationships between body composition (such as muscle mass, fat mass, and overall body size) and performance in physical fitness tasks. For example, higher skeletal muscle mass typically supports better outcomes in strength- and power-based tests such as push-ups or broad jumps, while excessive fat mass may negatively affect most of the fitness components. These relationships reflect how the body's structural components contribute to movement efficiency, force production, and energy expenditure. When these interactions remain consistent over time, the body adapts in an organized and balanced way by maintaining a logical and efficient link between body dimensions and fitness performance. Such outcomes are especially valuable in youth, where coherent development across systems is a key marker of long-term physical and functional health. Therefore, the absence of significant structural change may be interpreted not as resistance to the intervention but as a desirable outcome.

This interpretation is further supported by the nature of the applied intervention, which was grounded in the concept of PL. Rather than focusing narrowly on fitness gains, the intervention emphasized movement competence, motivation, and the understanding of physical activity as a lifelong practice. Suggested activities were designed to be developmentally appropriate, engaging, and varied while encouraging children to explore, refine, and connect movement patterns across domains. This broad and inclusive approach likely contributed to the preservation of systemic organization, helping the experimental group internalize stable relationships between body composition and performance. In line with the philosophy of PL, the observed structural consistency suggests that the intervention supported not only immediate outcomes but also the foundations for sustainable, self-directed physical development.

Limitations and strengths

This study has several limitations that should be considered. First, the assessment of physical fitness was conducted using field-based tests only. These tests are known to be practical and widely used in school settings but may lack the precision of laboratory-based measures. Second, the analysis was not stratified by gender, which may have masked sex-specific patterns in physiological development and response to the intervention. Third, the study was conducted over a relatively short duration of one academic year, which limits the ability to observe longer-term structural adaptations or delayed effects of the intervention.

Meanwhile, this is one of the rare studies to explore qualitative structural changes in fitness and body composition variables in response to a PL-based intervention, offering a novel perspective in the field. The intervention was specifically designed around physical literacy principles, ensuring developmental relevance and educational value. Furthermore, all assessments were performed using standardized protocols, with the same trained experts conducting all measurements, which enhances reliability and reduces inter-rater variability.

Conclusion

Although rarely used in sport and exercise sciences, analyses of qualitative changes offer valuable insights into how physiological systems adapt and organize over time, revealing deeper patterns of functional development. This study supports the potential of applying analyses of qualitative changes as induced by intervention protocol in physical education settings, and showed that a PL-based intervention helped maintain stable relationships between body composition and physical fitness variables. This suggests that the program supported coordinated and balanced physical development.

From a practical view, results highlight the value of using well-planned and age-appropriate activities in schools. Such programs can improve not only fitness levels but also how different physical abilities work together. Future studies should follow children for a longer time to see how stable these changes are. It would also be useful to look at differences in structural changes between boys and girls or to compare different effects among age-groups.

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Conflict of interest

The authors declare no conflicts of interest.

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References

- Carl, J., Barratt, J., Wanner, P., Toepfer, C., Cairney, J., & Pfeifer, K. (2022). The effectiveness of physical literacy interventions: a systematic review with meta-analysis. *Sports Medicine*, 52(12), 2965-2999. <https://doi.org/10.1007/s40279-022-01738-4>
- Carl, J., Bryant, A. S., Edwards, L. C., Bartle, G., Birch, J. E., Christodoulides, E., . . . Gilic, B. (2023). Physical literacy in Europe: The current state of implementation in research, practice, and policy. *Journal of Exercise Science & Fitness*, 21(1), 165-176. <https://doi.org/10.1016/j.jesf.2022.12.003>
- Carson, V., & Spence, J. C. (2010). Seasonal variation in physical activity among children and adolescents: a review. *Pediatric Exercise Science*, 22(1), 81-92. <https://doi.org/10.1123/pes.22.1.81>
- Errisuriz, V., Golaszewski, N., Born, K., & Bartholomew, J. (2018). Systematic review of physical education-based physical activity interventions among elementary school children. *The Journal of Primary Prevention*, 39(3), 303-327. <https://doi.org/10.1007/s10935-018-0507-x>
- Frömel, K., Šafář, M., Jakubec, L., Groffik, D., & Žatka, R. (2020). Academic stress and physical activity in adolescents. *BioMed Research International*, 2020(1), 4696592. <https://doi.org/10.1155/2020/4696592>
- Gilic, B., Sekulic, D., Munoz, M. M., Jaunig, J., & Carl, J. (2025). Translation, cultural adaptation, and psychometric properties of the Perceived Physical Literacy Questionnaire (PPLQ) for adults in Southeastern Europe. *Journal of Public Health*, 1-11. <https://doi.org/10.1007/s10389-025-02428-x>
- Jennrich, R. I. (1970). An asymptotic χ^2 test for the equality of two correlation matrices. *Journal of the American Statistical Association*, 65(330), 904-912.
- Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. *Psychometrika*, 23(3), 187-200.
- Kesic, M. G., Peric, M., Gilic, B., Manojlovic, M., Drid, P., Modric, T., . . . Pajtler, A. (2022). Are Health Literacy and Physical Literacy Independent Concepts? A Gender-Stratified Analysis in Medical School Students from Croatia. *Children*, 9(8), 1231. <https://doi.org/10.3390/children9081231>
- Kibbe, D. L., Hackett, J., Hurley, M., McFarland, A., Schubert, K. G., Schultz, A., & Harris, S. (2011). Ten Years of TAKE 10!®: Integrating physical activity with academic concepts in elementary school classrooms. *Preventive Medicine*, 52, S43-S50. <https://doi.org/10.1016/j.ypmed.2011.01.025>
- Kriemler, S., Meyer, U., Martin, E., van Sluijs, E. M., Andersen, L. B., & Martin, B. W. (2011). Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *British Journal of Sports Medicine*, 45(11), 923-930. <https://doi.org/10.1136/bjsports-2011-090186>
- Lilic, A. S., Vuletic, P. R., Pehar, M., Uzicanin, E., Zovko, I. C., Bujakovic, B., & Zenic, N. (2024). Analyzing the Associations between Physical Literacy, Physical Activity Levels, and Sedentary Behavior: Cross-sectional Study in Preadolescent Children. *Sport Mont*, 22(2). <https://doi.org/10.26773/smj.240708>
- Lohman, T. G., Ring, K., Pfeiffer, K., Camhi, S., Arredondo, E., Pratt, C., . . . Webber, L. S. (2008). Relationships among fitness, body composition, and physical activity. *Medicine and Science in Sports and Exercise*, 40(6), 1163. <https://doi.org/10.1249/MSS.0b013e318165c86b>
- Lorenzo-Seva, U., & Ten Berge, J. M. (2006). Tucker's congruence coefficient as a meaningful index of factor similarity. *Methodology*, 2(2), 57-64. <https://doi.org/10.1027/1614-2241.2.2.57>
- Marinho, D. A., Neiva, H. P., Marques, L., Lopes, V. P., & Morais, J. E. (2022). The influence of a specific high intensity circuit training during physical education classes in children's physical activity and body composition markers. *Montenegrin Journal of Sports Science & Medicine*, 11(2). <https://doi.org/10.26773/mjssm.220904>
- Masanovic, B., Gardasevic, J., Marques, A., Peralta, M., Demetriou, Y., Sturm, D. J., & Popovic, S. (2020). Trends in physical fitness among school-aged children and adolescents: a systematic review. *Frontiers in Pediatrics*, 8, 627529. <https://doi.org/10.3389/fped.2020.627529>
- Rajkovic Vuletic, P., Gilic, B., Zenic, N., Pavlinovic, V., Kesic, M. G., Idrizovic, K., . . . Sekulic, D. (2024). Analyzing the associations be-

- tween facets of physical literacy, physical fitness, and physical activity levels: Gender-and age-specific cross-sectional study in preadolescent children. *Education Sciences*, 14(4), 391. <https://doi.org/10.3390/educsci14040391>
- Rajkovic Vuletic, P., Gilic, B., Pavlinovic, V., Matijasevic, P., & Sekulic, D. (2026). Effects of a Physical-Literacy-Based Educational Intervention on Physical Activity and Body Composition in Preadolescent Children: A School-Based Controlled Trial. *Sports*, 14(2), 77. <https://doi.org/10.3390/sports14020077>
- Rauner, A., Mess, F., & Woll, A. (2013). The relationship between physical activity, physical fitness and overweight in adolescents: a systematic review of studies published in or after 2000. *BMC Pediatrics*, 13(1), 19. <https://doi.org/10.1186/1471-2431-13-19>
- Rowland, T. W. (2005). *Children's Exercise Physiology*: Human Kinetics.
- Santana, C. D. A., Azevedo, L. D., Cattuzzo, M. T., Hill, J. O., Andrade, L. P., & Prado, W. D. (2017). Physical fitness and academic performance in youth: A systematic review. *Scandinavian Journal of Medicine & Science in Sports*, 27(6), 579-603. <https://doi.org/10.1111/sms.12773>
- Steiger, J. H. (1980). Tests for comparing elements of a correlation matrix. *Psychological Bulletin*, 87(2), 245. <https://doi.org/>
- Sunda, M., Gilic, B., Sekulic, D., Matic, R., Drid, P., Alexe, D. I., . . . Lupu, G. S. (2022). Out-of-School Sports Participation Is Positively Associated with Physical Literacy, but What about Physical Education? A Cross-Sectional Gender-Stratified Analysis during the COVID-19 Pandemic among High-School Adolescents. *Children (Basel)*, 9(5). <https://doi.org/10.3390/children9050753>
- Whitehead, M. (2013). Definition of physical literacy and clarification of related issues. *Icsspe Bulletin*, 65(1.2).

6 Discussion

The studies that were published as part of the dissertation, and which were previously presented in their original form, generally dealt with individual issues related to the dissertation. In this regard, they also contain a discussion on individual topics. However, each study went through the review process, the corrections of the papers that were made were often based on the answers to the reviewers' questions and suggestions. Therefore, the published papers sometimes strayed from the dissertation topic itself. For this reason, this chapter directly refers to the objectives of the dissertation and discusses the obtained results accordingly. The following subsections discuss:

- applicability and measurement characteristics of tools for assessing physical literacy
- impact of the applied intervention on physical activity
- impact of the applied intervention on physical fitness
- impact of the applied intervention on physical literacy
- the qualitative changes

6.1 Applicability and metrics of physical literacy assessment tools

One of the aims of the doctoral thesis was to determine the validity and reliability of the Croatian versions of the questionnaire for assessing PL in pre-adolescents, with an emphasis on the affective and cognitive domains. The affective domain encompasses motivation and self-confidence and refers to feelings and emotions towards movement and physical activity (PA), including the development of self-esteem, self-confidence and motivation, and the understanding of emotional reactions related to movement and PA (Keegan, Barnett, & Dudley, 2019). The cognitive domain includes knowledge and understanding, i.e. the development of knowledge about how, when and why to move, as well as awareness of the importance and benefits of movement and TA for improving health (Keegan et al., 2019). In general, the questionnaires included in the CAPL-2 and PLAY tools for assessing PL are most often used in research for these two domains (Caldwell, Di Cristofaro, Cairney, Bray, & Timmons, 2021; Jean de Dieu & Zhou, 2021; Longmuir, Gunnell, et al., 2018).

Specifically, the CAPL-2 questionnaire covers the cognitive domain of PL (knowledge and understanding) through questions aimed at: (i) understanding of recommendations on PA and sedentary behavior, (ii) knowledge of basic parameters of physical fitness and movement and ways to improve them, and (iii) different perceptions of health. (Francis et al., 2016; Longmuir, Woodruff, Boyer, Lloyd, & Tremblay, 2018). In contrast, the PLAYself questionnaire contains items focused on: (i) self-confidence and motivation for PA, (ii) knowledge and understanding, and (iii) perceived ability to participate in different PA settings (Jefferies, Bremer, Kozera, Cairney, & Kriellaars, 2021). Both measurement tools have been confirmed in previous research as reliable and valid in measuring PL for different populations, including early school-age children, but their reliability and validity in South-eastern European countries was rarely investigated (Dania, Kaioglou, & Venetsanou, 2020; Elsborg et al., 2021; Jefferies et al., 2021; Longmuir, Woodruff, et al., 2018; Pastor-Cisneros et al., 2022). To the

best of the authro's knowledge only one study evaluated the measurement properties of these tools in adolescents in Croatia (Sunda, Gilic, Sekulic, et al., 2022).

Consequently, as a part of this dissertation original study was conducted to assess the reliability and validity of translated versions of the CAPL-2 and PLAYself questionnaires in children aged 9-11 from Croatia, Bosnia and Herzegovina and Montenegro(Vuletic et al., 2023). It was hypothesized that both questionnaires would demonstrate appropriate reliability and validity in assessing PL in preadolescents. The study included 303 children (141 girls) aged 9-11 years from regular primary schools in Croatia (n=71), Bosnia and Herzegovina (n=162) and Montenegro (n=70). During class, children completed two translated and culturally adapted questionnaires to assess PL: the shorter version of the Canadian Assessment of Physical Literacy (CAPL-2) and PLAYself. To assess reliability, a test-retest protocol with a 5-7-day interval was applied. The questionnaires were posted on an online platform (SurveyMonkey) participants responded anonymously, and test-retest analysis was ensured using codes. Test-retest reliability (ICC, Kappa, percentage agreement), internal consistency (Cronbach's alpha), and criterion/convergent validity were analyzed by examining the association between results and characteristics of sports participation (playing sports, frequency) (Vuletic et al., 2023).

The results showed that PLAYself achieved good test-retest reliability (ICC for individual subscales of 0.70-0.80, for the total score 0.84) and satisfactory internal consistency. On the other hand, CAPL-2 showed low Kappa values (0.11-0.23) and a relatively low percentage of test-retest absolute agreement (< 62%), which points to insufficient reliability of the CAPL-2 questionnaire for this age group and cultural context. With regard to validity, children involved in organized sports achieved significantly higher scores on the PLAYself questionnaire, especially on the environment and self-description subscales, compared to their peers who do not play sports, confirming the criterion validity of PLAYself among children ages 9-11 (Vuletic et al., 2023). Based on these findings, it was decided to use the PLAYself questionnaire as the primary instrument for assessing the affective and cognitive domains of PL in the pre-adolescent population in further studies within the framework of this dissertation.

When trying to determine the reasons for the lower reliability of the CAPL-2 questionnaire from this perspective, the following can be highlighted as the most important. First, the questionnaire is generally designed to assess theoretical knowledge about PL, so children, despite the short interval between testing, could learn new information, which reduced the correlation between the initial and retest and affected the reliability parameters. Second, the questions were probably too difficult for children aged 9 to 11, so they often "guessed" the answers, further reducing the consistency of the results (Vuletic et al., 2023).

However, we must note that although PLAYself demonstrated satisfactory reliability and validity at this stage, its subsequent application in intervention research (please see later) revealed its limited capacity for detecting change. This shortcoming was subsequently observed when the PL intervention was implemented and it was shown that PLAYself, despite its good psychometric properties in cross-sectional measurement, is not sufficiently sensitive to changes that occur after intervention programs. This will be discussed in more detail in the following sections. This issue is discussed in later chapters.

6.2 Impact of the intervention on physical activity

Among the objectives of the doctoral thesis was to determine the impact of the intervention on PA levels, including direct and indirect measurements of PA. In general, tools for measuring and assessing PA levels can be divided into two groups: (i) direct/objective methods and (ii) indirect/subjective methods. Direct methods (e.g., accelerometers, heart rate monitoring) provide precise data on movement, intensity, and duration, eliminating subjective bias. These methods are ideal for research,

but are expensive, technically demanding, and require user compliance. Nevertheless, direct methods are the gold standard for accurate and objective assessment of PA levels (Barreira et al., 2015). On the other hand, indirect methods, such as questionnaires, represent cost-effective and practical ways to assess PA levels in large populations. (Sunda, Gilic, & Bascevan, 2022). However, questionnaires rely on respondents' self-reports, which makes them prone to "recall bias". Specifically, respondents often incorrectly remember or estimate past activities, especially if a long time has passed since the event, and this problem is particularly prevalent among younger children (Doma, Speyer, Leicht, & Cordier, 2017; Doma, Speyer, Parsons, & Cordier, 2019). This bias has been documented in validation studies of the PAQ-C-a², which highlight the limitations of self-report measures for children under 10 years of age (Chen et al., 2003; Voss, Dean, Gardner, Duncombe, & Harris, 2017). It is also important to note that when using questionnaires "socially desirability bias" can also occurs, and this is particularly possible in children (Cuberek, Janíková, & Dygrýn, 2021). This actually means that tested persons can give overly positive answers about their PA in order to portray themselves in a "socially desirable" way (e.g. they exaggerate the amount of sports or activities because they believe that this is what adults (teachers, parents) expect or praise (Janz, Lutuchy, Wenthe, & Levy, 2008; Voss et al., 2017; Vuletic, Matijasevic, & Pavlinovic, 2025). Despite their shortcomings, indirect measurement methods often complement objective measurements. In this dissertation, both types of methods for assessing PA levels directly – by accelerometry, and indirectly (by questionnaires).

The first study examined the effects of an intervention, and PA was measured directly (via accelerometers). The research evaluated effects of a 12-week PL-based intervention conducted on 119 children (51 girls) aged 9 to 11 years, divided into experimental and control groups (Rajkovic Vuletic, Gilic, et al., 2026). GENEActiv accelerometers were used, and children wore them 24 hours a day for 4 days (2 weekdays and 2 weekends). Based on these data, an average for the week was calculated. The number of steps, sedentary behavior, and time spent in light, moderate-vigorous PA (MVPA) and vigorous PA (VPA) were analysed. The results showed that sedentary behavior levels in the experimental group (E) remained unchanged throughout the study, whereas they significantly increased in the control group (C). This increase in sedentary behavior in the C group is explained by the standard changes that occur during the school year, including academic obligations, as well as the time of year and weather conditions. Similarly, the step count remained stable in the E group during the school year, while it decreased in the C group. Furthermore, VPA was maintained in the E group, whereas it decreased significantly in the C group.

Meanwhile, in the second study, the effects of the PL-based intervention on indirectly measured PA were examined (the PAQ-C questionnaire was applied). Study included slightly more participants, specifically 125 children (57 girls) of whom 55 were in the E group and 70 in the C group (Rajkovic Vuletic, Pranjic, et al., 2026). Unlike the first study, which reported positive effects of the intervention, the second study where PL was indirectly evaluated by PAQ-C questionnaire did not report a statistically significant effects (Rajkovic Vuletic, Pranjic, et al., 2026). Therefore, it is clear that the results of these two studies are partially inconsistent. However, this difference can be explained in several ways.

First, accelerometers, such as the GENEActiv device are considered the gold standard for objective assessment of PA (Barakat et al., 2024; Dillon et al., 2016; Larrivee, Avery, Leiter, & Old, 2021). What is particularly important to note is that research has shown that the mere awareness of wearing an accelerometer does not change behavior or significantly affect activity levels in young people aged 10 to 18, which supports the claim that an accelerometer provides an objective measure without a strong subjective influence (Vanhelst, Béghin, Drumez, Coopman, & Gottrand, 2017). On the other hand, researches done so far indicate limited reliability of questionnaires in assessing PA (Rostami Haji Abadi et al., 2025). A study conducted in Croatia found that the PAQ-C is not reliable for children younger

² Version of the questionnaire used in this dissertation

than 8 years, whereas its reliability for ages 8–10 is moderate but not strong (Podnar, Sušilović, & Radman, 2017). Supportively, a recent review of questionnaires for assessing PA levels reported that reliability is generally higher in adolescents than in younger children, while results are more variable in younger children (Rostami Haji Abadi et al., 2025). This can probably be explained by poorer recall, cognitive immaturity, and a weaker understanding of the intensity and duration of the activity itself in younger children. This was certainly possible in the study conducted here> In other words it is possible that the lower reliability of the questionnaire reduced the accuracy of the measurement, which ultimately affected the outcome of the intervention.

Second, the validity of the questionnaire in assessing PA could also be questioned. Researches indicates that the associations between questionnaire-based and accelerometer-based measurements is (generally) statistically significant, but relatively weak (Marasso, Lupo, Collura, Rainoldi, & Brustio, 2021; Vuletic et al., 2025). Specifically, the results of a recent study conducted on Croatian children showed a statistically significant but weak association between PAQ-C and accelerometry (Vuletic et al., 2025), which is in agreement with the meta-analysis which showed that the correlations between PAQ-C and accelerometry are generally weak to moderate (Marasso et al., 2021).

Third, we should not ignore the fact that the testing in this dissertation was conducted with a large gap (September – December – May). This certainly affected the "seasonality" of activities that are characteristic of certain periods of the year (Atkin, Sharp, Harrison, Brage, & Van Sluijs, 2016; X. Janssen et al., 2015; Weaver, Hensing, Armstrong, Adams, & Beets, 2022). This undoubtedly made it difficult to obtain precise and comparable results by testing PA using questionnaires.

In conclusion, it is clear that the disagreement between the results of the two studies that analyzed the effect of the intervention on PA stems from: (i) the greater precision of objective accelerometric measurements over subjective questionnaires in children, (ii) the limited reliability of the PAQ-C at this age, and (iii) the questionable validity of PA assessment using questionnaires. All this confirms the importance of a combined approach with an emphasis on direct methods for accurately assessing the effect of the intervention on PA levels.

6.3 Impact of the physical literacy based intervention on physical fitness

6.3.1 Effects on body composition

One of the aims doctoral research was to assess the impact of the PL-based intervention on PF in pre-adolescents. In general, PF is defined as a state of good physical and mental health and good physical condition that results from regular physical activity, proper nutrition, and taking care of one's own health (Caspersen, Powell, & Christenson, 1985). One of the five fundamental components of PF is body composition (Caspersen et al., 1985). It is most often defined as the quantitative ratio of fat mass to fat-free mass in the body, where fat-free mass includes muscle, bone, water, and internal organs (Newman & Newman, 2022). Body composition is an important health parameter in childhood and adolescence. Specifically, high fat mass and reduced muscle mass are associated with impaired cardiovascular endurance, reduced mobility, and a higher risk of developing metabolic disorders, while favorable body composition (adequate muscle mass and moderate fat mass) is associated with better overall PF and long-term health. (Dewi, Rimawati, & Purbodjati, 2021; Oh et al., 2021).

Body composition is generally assessed using laboratory and field methods that measure the proportions of fat, lean tissue, water, bone, and muscle. One of the most commonly used in clinical practice and research is bioelectrical impedance (BIA) (Lemos & Gallagher, 2017; Mehra, Starkoff, & Nickerson, 2025). BIA is a simple, portable, non-invasive and fast method ideal for field conditions (e.g. schools, sports clubs), without the need for expensive and unavailable laboratory equipment (Lemos

& Gallagher, 2017; Mehra et al., 2025). In this dissertation, a bioelectrical impedance analyzer Tanita TBF-300 (Tokyo, Japan) was used (Rajkovic Vuletic, Gilic, et al., 2026).

In the first intervention study, where the effects of the intervention were examined along with measuring PA levels with accelerometers, body composition was assessed as a secondary outcome - with PA measured with accelerometers as the primary outcome (Rajkovic Vuletic, Gilic, et al., 2026). AS said previously this research included a 12-week PL-based educational intervention conducted on 119 children (51 girls) aged 9 to 11, divided into experimental and control groups (Rajkovic Vuletic, Gilic, et al., 2026). Body composition was assessed using the Tanita device using height, gender, and age data. Measurements were taken in the morning, at least three hours after waking up and after usual food and fluid intake. The variables assessed included body weight, body mass index, fat mass, and skeletal muscle mass.

The results showed no statistically significant changes in body composition parameters at either the final measurement after the intervention or the retention measurement conducted six months later. More precisely, there were some changes, but with no differential effect between control and experimental program,. Several factors may explain this finding, which are interpreted in more detail in the paper itself (Rajkovic Vuletic, Gilic, et al., 2026).

First, it is well known that diet plays a dominant role in regulating body composition, and research shows that PA alone, but without changes in dietary habits, is generally not sufficient to expect the significant changes in body composition (Williams et al., 2013). Also, it is important to point out that children at this age do not have autonomy over their diet, and are dependent on their parents' eating habits, the availability of food in the household, and (eventually) the school's meal offerings (Kocaadam-Bozkurt, Sözlü, & Macit-Çelebi, 2023; Shloim, Edelson, Martin, & Hetherington, 2015; Tomayko et al., 2021). The significant influence of parents on children's nutrition is also confirmed by previous research. Specifically, a study by Kocaadam-Bozkurt et al. (2021) on 596 children aged 3-12 and their parents indicates that parental factors (e.g. parental BMI, eating styles and family environment) are significantly associated with children's BMI and nutritional status (Kocaadam-Bozkurt et al., 2023). Similarly, a systematic review showed that healthier parenting styles and structured, controlled dietary practices can significantly contribute to improved body composition outcomes in children aged 4-12 years (Tomayko et al., 2021). Also, in their systematic review of nutrition and PA interventions, Tomayko et al. (2021) emphasized that parental involvement is a key factor for improving body mass and preventing obesity in children in this age group (Tomayko et al., 2021). Although the intervention implemented as part of this dissertation included two educational videos about nutrition, it did not include an intervention with parents, so it was difficult to expect changes in children's diet patterns.

Another possible reason for the lack of significant effects on children's body composition may be the insufficient duration of the intervention. Namely, a recent systematic review and meta-analysis on a sample of 20,462 children aged 5–10 years showed that interventions longer than 12 weeks (3 months) generally achieve better and more sustainable results in reducing BMI and improving body composition than shorter interventions (Tanous et al., 2025). On the other hand, the intervention studied in the dissertation lasted a total of 3 months.

Third, it is important to consider the natural variability of anthropometric parameters in children aged 9-11 years, who undergo intensive growth and prepubertal development. During this period, significant changes in adipose and lean tissue are typical, influenced by genetic factors, individual phases of pubertal development and hormonal fluctuations, which may mask the effects of short-term interventions (Rowland, 2005).

6.3.2 Effects on physical fitness measures

The PF is generally considered to be one of the most important indicators of health in children and adolescents (Demchenko et al., 2025; Maicas-Pérez et al., 2024; Ortega, Ruiz, Castillo, & Sjöström, 2008; Wei, Li, & Sun, 2025). Accordingly, research shows a strong association between high levels of PF in youth and better health status in adulthood (Aly, El-Gyar, Shalaby, & Abdelkarim, 2025; Ortega et al., 2008). According to Capersen et al. (1985) the components that determine PF are (I) cardiovascular endurance, (II) muscular endurance, (III) muscular strength, (IV) body composition and (V) flexibility (Caspersen et al., 1985). Given the key role of TF in the health of children and adolescents, its assessment is of utmost importance.

The first intervention study (Rajkovic Vuletic, Gilic, et al., 2026) examined the effects of the intervention on the body composition component and results are discussed in the previous subsection. The second intervention study analyzed the effects of the intervention on the remaining four components of PF, specifically cardiovascular endurance, muscular endurance, strength and flexibility (Rajkovic Vuletic, Pranjic, et al., 2026). This research was conducted on a sample of 125 participants (57 girls), of whom 55 were in the experimental group and 70 in the control group. As said previously the components of PF were assessed using the FitnessGram battery of tests. In general, the FitnessGram represents one of the most widely used field batteries for assessing TF in children and adolescents (Kolimechikov, 2017; Marques et al., 2021). The battery is valid and reliable, with high Cronbach's alpha values (0.91-0.95) for inter-rater reliability, and is considered a reliable tool for assessing body shape in the pediatric population according to systematic reviews (Kolimechikov, 2017; Marques et al., 2021). As a part of the dissertations, the battery was validated in children from Croatia (Rajkovic Vuletic et al., 2024). In general, the results showed significant effects of the PL-based intervention in some components of PF. Specifically, positive changes were evidenced in power capacity (long jump from a standing position) and abdominal muscle strength (sit-ups). There are several possible explanations for the obtained results.

First, the PL-based intervention, which included short, structured educational videos on PL, likely improved participants' knowledge of PF and knowledge of the physical training principles. Consequently, this could have led to more positive attitudes and clearer intentions to involve children in various forms of PA. Educational videos, such as "What is strength and how to train?", "Where can strength training be done?", "Examples of strength training", etc., probably encouraged greater involvement of students in strength exercises (e.g., squats, sit-ups, and core exercises) during PE classes, but also during their free time. From the perspective of specific tests where positive effects were noted, it is important to note that previous researches have shown that improvements in tests such as standing long jump and sit-ups can be achieved relatively quickly, through greater engagement, better technique and greater effort, without the need for long-term or highly specific training programs (Baxter, Moore, Pendergrass, Crowder, & Lynch, 2003; H. Zhou, Yu, Thirupathi, & Liang, 2020). In general, these findings are consistent with previous studies that examined the impact of different PL interventions and PL programs on various PF variables in preadolescents (Carl et al., 2022; D. Zhang et al., 2023). For example, a study comparing a sports-oriented elementary school with a traditional school reported that students from the sports-oriented school achieved better results in the standing long jump (Demetriou, Bachner, Reimers, & Göhner, 2018). Furthermore, in a pilot study of active breaks in children aged 8-12 years, the authors reported that 4 weeks of short, structured PL content resulted in significant improvements in abdominal muscle strength (Mendoza-Muñoz et al., 2022). A similar effect was achieved by an intervention aimed at developing PL in children aged 7 to 9 years, which also showed improvements in individual components of PF, further confirming our findings (D. Zhang et al., 2023).

Another possible explanation relates to the improvement of self-efficacy. Namely, high cognitive load during exercise performance may reduce self-efficacy, which consequently leads to poorer results and less participation in PA. On the other hand, education focused on the development of PL encourages beliefs such as “I can do it” and “I know how”, which may increase effort, persistence and performance in motor tasks (Graham, Li, Bray, & Cairney, 2018; Morano, Bortoli, Ruiz, Vitali, & Robazza, 2019; Ning, Gao, & Lodewyk, 2012; Signorini et al., 2025). Children with higher levels of self-efficacy are more likely to engage in PA, as it contributes to better understanding, a sense of competence, greater enjoyment, and greater motivation to participate (de Bruijn & Brocken, 2025; Morano et al., 2019; Russo, De Matteis, Oparina, Ceciliani, & Bigliassi, 2025). In this regard, it is likely that the applied intervention had a positive effect in this sense, which could also have produced positive effects on PF itself.

Meanwhile, it is interesting that significant effects of the intervention were not observed in flexibility and aerobic (cardiovascular) endurance, although the educational content of PL included topics related to these components of PF. This also can be explained from several perspectives.

First explanation is related to the possible influence of season-period. Specifically, during the initial measurement period (September), children still did not have intensive school obligations and had more free time for spontaneous PA such as outdoor play. The final measurement was held in December, during the winter period when days are shorter and weather conditions are colder, which is known to reduce children's overall PA due to fewer opportunities for outdoor activities. (Atkin et al., 2016; I. Janssen & LeBlanc, 2010; Weaver et al., 2022). Finally, the retention measurement was conducted near the end of the school year (May), when academic obligations are greatest, which reduces children's free time and negatively affects PA (Atkin et al., 2016; I. Janssen & LeBlanc, 2010; Weaver et al., 2022). Therefore it is clear that during the study period, children had limited opportunities to engage in activities that would lead to improved aerobic capacity, given that these activities themselves require both: (i) time (which children do not have due to school obligations), and (ii) "open space" (which is largely inaccessible to children during this period due to unfavorable weather conditions). Supportively, research regularly shows that the development of aerobic endurance requires longer, more intense and structured training programs, while educational interventions without increasing the volume of training often do not result in significant changes (Bremer, Graham, & Cairney, 2020; Coyne et al., 2019; Crozier et al., 2022; X. Zhou, Li, & Jiang, 2024).

The lack of significant changes in flexibility can be explained as follows. The participants were 9-to-11 year old children. During this developmental period, the pronounced longitudinal bone growth may mask real improvements in flexibility, as the tests do not take into account changes in skeletal proportions (Alter, 2004). Consistent with our findings, previous studies of PL also failed to show significant effects on flexibility (Carl et al., 2022). Even a comparison of a sports-oriented elementary school with a traditional school did not show improvements in flexibility, despite the greater volume of organized PA in the sports school. This finding suggests that even more intensive, sports-enriched programs do not by themselves guarantee improvements in flexibility if content specifically aimed at developing flexibility is not systematically and intentionally included in the program (Demetriou et al., 2018).

6.4 Impact of intervention on physical literacy

One of the aims of the doctoral thesis was to investigate the impact of the PLO-based intervention on the affective and cognitive domains of PL. The affective domain includes motivation and self-confidence, and refers to emotions and feelings towards movement and PA, with an emphasis on self-esteem, self-confidence, motivation, and understanding of emotional responses related to movement

and PA (Keegan et al., 2019). The cognitive domain implies knowledge and understanding, i.e. acquiring knowledge about the way, time and reasons for movement, as well as awareness of the benefits and importance of movement and PA in terms of improving health (Keegan et al., 2019).

The affective and cognitive domains of PL were assessed with standardized questionnaires, with those integrated into the CAPL-2 and PLAY tools being most often used in research (Jean de Dieu & Zhou, 2021; Shearer et al., 2021). The validation of the Croatian versions of the aforementioned questionnaires for children aged 9 to 11 was conducted in one of the studies that is an integral part of this dissertation, and is described in the first part of the discussion (Vuletic et al., 2023). Based on these findings, the PLAYself questionnaire was selected for further research as part of the dissertation as the primary tool for assessing the affective and cognitive domain of TP in pre-adolescent age, given that it showed the best metric characteristics³.

In the second intervention study, the effects of an PL-based educational intervention on the affective and cognitive domains of PL were examined (Rajkovic Vuletic, Pranjic, et al., 2026). The research was conducted on a sample of 125 participants (57 girls), of whom 55 were in the experimental group and 70 in the control group. As other previously discussed variables, the affective and cognitive domains of PL were assessed at three time points: at the beginning of the school year (initial measurement), immediately before the intervention, after the 12-week intervention (final measurement), and 5 months later (retention measurement), in order to determine the retention of any effects. The results of the study showed that although PL in children generally increased, the intervention did not result in significant differential effects, based on the assessment using the PLAYself questionnaire. Although these results were objectively not expected, and were somewhat surprising, the author believes that there is a possible explanation for them.

First, the PLAYself questionnaire is in general based on self-assessment of competences based on the comparison that children make in relation to their peers, e.g. "How good do you think you are in sports or indoor activities (football, basketball, volleyball, gymnastics, martial arts, table tennis...)?", "How good do you think you are in sports/activities 'on the street' (i.e. jumping rope, hula hoop, catch, hooves), 'I am most often the best in my class in sports.'" ... In this study, it was probably the case that children compared themselves primarily with other children, but within their own group (children from the experimental group compared themselves "within the group", and children from the control group did the same). In this regard, it is logical that their self-assessment of physical competence did not change relatively. This is partly confirmed by a previous study that dealt with the validation of the PLAYself questionnaire and the assessment of PL in children aged 9 to 11, where it was found that the PLAYself questionnaire showed good reliability and validity, but that self-perception of PL occurs mainly through comparisons with peers within the same social context, which can "stabilize" assessments in the absence of external references (Vuletic et al., 2023). In such circumstances, children rarely perceive their own progress if they do not have the opportunity to compare themselves with other groups or objective standards. This is supported by the findings of other authors, such as those reported in a study that analyzed the effects of an 8-9-week intervention with an enriched PE program in children aged 9 to 11, where no statistically significant changes were found in the affective and cognitive domains of PL assessed by the PLAYself questionnaire (Stoddart et al., 2023).

On the other hand, it is interesting to note that several interventions have shown significant improvements in the cognitive domain of PL in children aged 8 to 12 years (Coyne et al., 2019; Li et al., 2022; Mendoza-Muñoz et al., 2022). However, in these studies, PL was assessed with the CAPL-2 questionnaire (and not PLAYself, which was used here). For example, a 10-week PL program that included athletic games and fundamental motor skills exercises resulted in significant improvement in this domain (Coyne et al., 2019). Similarly, a 13-week intervention in children aged 9 to 12 that

² This is discussed in more detail in the first subsection of Discussion

combined instruction with digital content during the regular school day also showed statistically significant improvements (Li et al., 2022). Positive results were also recorded in a pilot study of active breaks in children aged 8–12 years, which included four weeks of short, structured and content-oriented activities, with improvements in the affective and cognitive domains (Mendoza-Muñoz et al., 2022).

Collectively, it is evident that intervention studies that used the PLAYself questionnaire generally did not report significant changes in the affective and cognitive domains of PL after the intervention, while improvements in these domains were recorded in studies that used the CAPL-2 questionnaire (Coyne et al., 2019; Li et al., 2022; Mendoza-Muñoz et al., 2022; Rajkovic Vuletic, Pranjic, et al., 2026; Stoddart et al., 2023). It suggests that it is possible that the CAPL-2 is more sensitive or appropriate for registering changes in motivation, self-confidence, knowledge and understanding in children, especially in the context of short-term interventions.

In addition, it should be noted that the PLAYself questionnaire, despite its good reliability and validity, may be subject to the bias inherent in the element of “social desirability” in children. In other words, children may sometimes give answers that they consider desirable or expected by the teacher or researcher, instead of fully expressing their own views or assessments of their abilities. Such a bias may reduce the sensitivity of the questionnaire to detect minor changes that occur as a result of the intervention.

Collectively, it can be concluded that the PL-based educational intervention did not result in statistically significant changes in the affective and cognitive domains of PL as assessed by the PLAYself questionnaire. However, given the improvements recorded in the PF and PA components, the specificity of the tool used, and the general problems of self-assessment in children, it is possible that certain changes occurred, but the measurement tool used (PLAYself) was not sensitive enough to register them. Therefore, future research should consider combining different measurement instruments or assessment approaches in order to more sensitively and comprehensively assess changes in the affective and cognitive domains of PL.

6.5 Qualitative changes

Qualitative changes have been relatively rarely investigated in the field of kinesiology recently, although this area was the subject of intense interest of researchers and scientists in this scientific field 30-40 years ago. (Katić, Maleš, & Miletić, 2002; Katić, Maleš, Ropac, & Padovan, 2002; Mandić, Pelemiš, Džinović, & Kojić, 2019; Konstantin Momirović, 1987; K Momirović et al., 1987). In short, research of the “qualitative changes” is about research into “changes in the relationship between variables”, as opposed to “quantitative changes in variables”, which actually investigate how the results on the variables themselves change quantitatively over time (most often as a result of a kinesiological intervention). There is no doubt that the main focus of kinesiological research is usually related to quantitative changes, because they vividly present the magnitude of numerical changes in a particular dimension or variable, which occurred as a result of a kinesiological treatment. However, qualitative changes could provide an additional information of the effects of the treatment, and this dissertation also devotes some attention to this research problem. It must be said that only a small part of the qualitative changes have been investigated, specifically, the changes in the relationships between (i) PF variables and (ii) body composition variables. (Sekulic et al., 2026). Briefly about the research itself and the findings.

This study investigated qualitative changes in the relationships between body composition and PF variables (aerobic endurance, flexibility, explosive strength, repetitive strength) in children (9-11 years old) during the school year, which occurred as a result of an PL-based intervention. The research

analyzes the structural relationships between the variables in the initial, final and retention measurements, and investigate how the interrelationships between muscle mass, fat tissue (as one set of variables) and PF measures second set) change from measurement to measurement. These changes in relationships are analyzed separately for the control group (children who did not participate in the PL-based intervention) and the experimental group (children who participated in the PL-based intervention). Results showed that the control group showed a gradual structural reorganization and partial disorganization of the relationships between the variables. On the other hand, the experimental group maintained a stable and coherent relationship structure, even 5 months after the intervention. In order to present the research and the results more clearly, it is necessary to clarify the term "organization of physiological relationships" that is mentioned in the research itself. Namely, the term "organization of physiological relationships" describes the natural/physiological way in which various physical and functional/fitness variables are intercorrelated. Specifically, when talking about the physical development of children and young people, it is not good to talk only about "individual condition and results" in individual abilities and characteristics (strength, endurance, amount of fat tissue, body length) but it is important to talk about how much and how these dimensions are naturally and physically logically aligned with each other. This alignment should be natural and physiologically justified, i.e. variables. Statistically/mathematically speaking, human characteristics and abilities should be logically correlated (positively or negatively), or these correlations should not exist if this is logical (the so-called "zero correlation").

For example, it is clear that a larger amount of adipose tissue should be negatively correlated with the state of aerobic endurance. The background to this connection should be sought in the simple fact that adipose tissue is ballast mass, which represents an aggravating factor in the manifestation of aerobic endurance, and there is no natural/physiological logic that under normal circumstances and in healthy children, "a larger amount of adipose tissue" contributes to "better aerobic endurance". Related to this, if an intervention (of any kind, including kinesiological) is physiologically justified and meaningful, the correlation between these two variables (adipose tissue and aerobic endurance) should exist and be "negative". On the other hand, the correlation should not decrease as a result of this intervention. Of course, the problem is not that simple, because especially in children and young people, there are a number of other factors that influence this relationship/correlation. However, if we are comparing two groups, as was the case in this dissertation, a "positive effect of treatment" would imply a better correlation between the variables. This was confirmed in the work itself. Namely, the correlation between body composition variables and physical fitness variables, which existed at the very beginning of the experiment, was maintained during the experiment only in the experimental group. In the control group, the correlations between the variables began to decline, which actually indicates a "functional disintegration" of the anthropological status of children who were not included in the intervention based on improving PL.

Overall, when the relationships (correlations) between dimensions are stable and logically connected, we are talking about a coherent and integrated system in which a change in one ability/trait has a predictable and functional effect on other abilities/traits. In the previous example, this would mean that (for example) a decrease in body fat leads to an improvement in aerobic endurance. On the other hand, if the relationships between these variables begin to change, weaken, or become inconsistent, we are talking about a disorganization of the system. In other words, this means that the physical components no longer develop in a coordinated manner, but in a fragmented manner.

In the context of the research conducted here, and from the obtained results, the PL-based intervention showed the ability to preserve stable and structurally logical relationships between traits (body composition) and abilities (PF). In fact, the PL-based intervention supported sustainable and long-term physical development of children, and not only achieved short-term improvement in individual results. Finally, these qualitative changes suggest that this PL-based intervention does not only bring

quantitative improvements (which have been shown and analyzed in other studies (Rajkovic Vuletic, Gilic, et al., 2026; Rajkovic Vuletic, Pranjic, et al., 2026) but there is evidence that it supports long-term organized and sustainable physical development of children.

7 Conclusion

7.1 Reliability and validity of the measurement instruments used in the dissertation

The reliability analysis of the measurement instruments for assessing PL indicated better reliability of the PLAYself questionnaire compared to the CAPL-2 questionnaire in preadolescents. This is primarily a consequence of the greater stability of the responses and the fact that the CAPL-2 questionnaire is more demanding and therefore less appropriate for this age group. However, it was later determined that PLAYself has certain limitations, especially in recognizing changes in PL itself. The results on the PLAYself questionnaire are based on self-assessment and comparison with peers, which limits the precision and reality of the responses. Future research should therefore consider the use of the CAPL-2 questionnaire or its adaptation to make it more suitable for children of this age.

The dissertation analyzed the reliability of tests for assessing PL using the Fitnessgram battery. In general, the reliability of the tests is satisfactory to high. To a certain extent, reliability is reduced in the torso lift test (extension/lifting of the trunk). Therefore, care should be taken to thoroughly review the test instructions when applying the torso lift test and to execute the test accordingly. Also, in order to reduce unsystematic measurement error it is of utmost importance to ensure that all children are measured by the same examiner..

7.2 The impact of the applied intervention on physical activity

The results obtained by objective PA measurement via accelerometers showed a certain positive effect of the 12-week PL-based educational intervention. Specifically, the stability of sedentary behavior, the number of steps and time spent in VPA was maintained in the experimental/intervention group. At the same time negative changes were evidences in the control group. Therefore, it can be concluded that PL-based intervention prevented the decrease in PA levels that normally occurs due to seasonal weather conditions and academic duties among schoolchildren.

It is important to highlight that the positive intervention effects indicates the practical benefit of PL education in school settings, especially during the transitional periods of the year.

On the other hand, positive interevention effects were not evidenced by indirect PA measurement through the PAQ-C questionnaire. This discrepancy in findings is explained by the limited reliability and validity of the PAQ-C in children, including poor correlation with direct measurement, recall bias, and social desirability bias. Also, given the three- and eight-month intervals between baseline and follow-up measurements, the seasonality of testing further complicates the comparison. Therefore, these results highlight the need for a combined approach with an emphasis on objective methods for the precise evaluation of intervention-effects on PA.

7.3 Impact of intervention on physical fitness

No significant effect of the intervention was determined in body composition. This finding can be explained by several factors, including the dominant role of nutrition in achieving body composition changes, insufficient duration of the intervention, and developmental characteristics of children in the observed period. It is especially important to emphasize the crucial role of the family environment and parents, who have a key influence on children's eating habits. Therefore, it can be concluded that interventions of short duration have limited potential for changes in body composition. In addition, the lack of integration of nutritional components and parental involvement probably further influenced the lack of an effect of the intervention on body composition.

On the other hand, results related to other PF components showed positive effects of the PL-based intervention in certain segments of PF. Specifically, significant improvements were evidenced in muscle strength and power capacities, with no significant effects in aerobic endurance and flexibility. Collectively, these results suggest that educational interventions based on PL can stimulate certain aspects of PF, especially those that do not require long-term and highly structured training. At the same time, the absence of changes in aerobic endurance and flexibility indicates the need for more specific and long-term programs aimed at developing these abilities.

7.4 Overview of the study hypotheses

H1: The PL-questionnaires will have appropriate validity and reliability

Overview: The hypothesis is partially confirmed. The PLAYself questionnaire has appropriate reliability and validity, but reliability of CAPL-2 is insufficient

H2: Fitnessgram battery will have appropriate validity and reliability

Overview: The hypothesis is confirmed. All tests included in the Fitnessgram battery were found to be reliable and valid

H3: The positive associations between PF, PA, and PL in preadolescents will be established

Overview: The hypothesis is confirmed. The PF, PA and PL were positively associated

H4: The PL-based intervention will have significant positive effect on PA, PF and PL in preadolescents

Overview: The hypothesis is partially accepted. The PL-based intervention induced positive changes in several facets of PF, and directly measured PA. No significant effects of the intervention were evidenced for indirectly measured PA, PL and some aspects of PF.

7.5 Study limitations and strengths

7.5.1 Limitations

This dissertation has several important limitations that should be considered. First of all, it should be noted that part of the research relies on subjective measures, especially questionnaires for PA and PL. Therefore, there was an evident possibility of social desirability- and- recall-bias. Second, the PL was evaluated by PLAYself questionnaire. Although the reliability and validity of this questionnaire was confirmed in initial studies, certain limitations were evidenced in the intervention studies. Therefore, further intervention studies should consider the usage of other measurement tools in evaluation of PL in children.

Although the dissertation includes longitudinal and intervention approaches, the duration is limited to one school year, which does not capture longer-term changes or seasonal variations in PA. Also, the intervention studies were conducted using a quasi-experimental design, without total randomization (e.g., classes, not children, were divided into experimental and control groups). Such an approach may reduce internal validity and increase the risk of bias. In this regard, it should be noted that the interventions were also implemented by different teachers, with limited monitoring of the consistency of implementation, which may result in variability in the quality of the intervention and the engagement of participants.

An important limitation also relates to the specificity of the sample, which included exclusively children from a relatively specific geographical area, with mild Mediterranean climate, which naturally favors higher levels of PA throughout most of the year. Therefore, there is a certain possibility that the PA levels, and related outcomes in this sample are more favorable than they would be in populations living in less favorable climatic conditions. Furthermore, some measurement instruments, e.g. BIA (Tanita) body composition assessment, have not been fully validated for the age and population analyzed here, which could have affected the precision and interpretation of the results to some extent. However, in this dissertation and published studies, no comparisons were made between groups of different ages, so this probably did not affect the interpretation of the results of intervention studies.

Finally, the studies did not include important sociocultural and environmental factors (e.g. family environment, parental supervision, neighborhood safety), which can have a significant impact on PA and the development of PL, which limits the interpretation of the results to some extent.

7.5.2 Strengths

This is one of the first studies in Europe to investigate PL-related problems among younger school-age children. Additionally, the dissertation investigated the reliability and validity of several tools for assessing PL, which enabled an objective comparison between them. The research used a sample of participants with a relatively narrow age range, which enabled a more precise observation of the relationship between variables. The application of different tests for assessing PF, which has rarely been done in previous research, provides additional value of the dissertation. Furthermore, the use of a pre-post-retention research design enabled insight not only into the immediate effects of interventions, but also into their sustainability over time. It is particularly important to emphasize that PA levels were measured (i) by objective methods (accelerometers), which reduced the influence of subjective bias and increased the reliability of the data obtained. Also, all measurements were carried out by trained and experienced examiners according to standardized protocols, which ensured a high level of consistency and reduced the possibility of measurement errors. Finally, probably the most important strength of the research is the implementation of the PL-based intervention itself in real school

conditions. This certainly ensured high ecological validity and enabled the direct application of the obtained results within regular PE classes.

8 References

- Alter, M. J. (2004). *Science of flexibility*: Human Kinetics.
- Aly, M., El-Gyar, N., Shalaby, A. M., & Abdelkarim, O. (2025). Health-related physical fitness in children among five Mediterranean countries: a cross-cultural study from the DELICIOUS project. *Frontiers in Public Health*, 12, 1520096.
- Atkin, A. J., Sharp, S. J., Harrison, F., Brage, S., & Van Sluijs, E. M. (2016). Seasonal variation in children's physical activity and sedentary time. *Medicine and science in sports and exercise*, 48(3), 449.
- Aubert, S., Barnes, J. D., Demchenko, I., Hawthorne, M., Abdeta, C., Abi Nader, P., . . . Bakalár, P. (2022). Global matrix 4.0 physical activity report card grades for children and adolescents: results and analyses from 57 countries. *Journal of physical activity and health*, 19(11), 700-728.
- Aubert, S., Brazo-Sayavera, J., González, S. A., Janssen, I., Manyanga, T., Oyeyemi, A. L., . . . Tremblay, M. S. (2021). Global prevalence of physical activity for children and adolescents; inconsistencies, research gaps, and recommendations: a narrative review. *International journal of behavioral nutrition and physical activity*, 18(1), 81.
- Barakat, A., Manga, A., Sheikh, A., McWilliams, R., Rowlands, A. V., & Singh, H. (2024). Feasibility of Using a GENEActiv Accelerometer with Triaxial Acceleration and Temperature Sensors to Monitor Adherence to Shoulder Sling Wear Following Surgery. *Sensors*, 24(3), 880.
- Barreira, T. V., Schuna, J., Tudor-Locke, C., Chaput, J.-P., Church, T. S., Fogelholm, M., . . . Lambert, E. V. (2015). Reliability of accelerometer-determined physical activity and sedentary behavior in school-aged children: a 12-country study. *International journal of obesity supplements*, 5(2), S29-S35.
- Baxter, R. E., Moore, J. H., Pendergrass, T. L., Crowder, T. A., & Lynch, S. (2003). Improvement in sit-up performance associated with 2 different training regimens. *Journal of Orthopaedic & Sports Physical Therapy*, 33(1), 40-47.
- Blažević, J., Blazevic, M., & Sekulic, D. (2024). Is There a Meaningful Association Between Physical Literacy and Health Literacy? A Cross-Sectional Study in Older Adolescents. *Sport Mont*, 22(2), 85-91.
- Bremer, E., Graham, J. D., & Cairney, J. (2020). Outcomes and feasibility of a 12-week physical literacy intervention for children in an afterschool program. *International Journal of Environmental Research and Public Health*, 17(9), 3129.
- Caldwell, H. A., Di Cristofaro, N. A., Cairney, J., Bray, S. R., & Timmons, B. W. (2021). Measurement properties of the Physical Literacy Assessment for Youth (PLAY) tools. *Applied Physiology, Nutrition, and Metabolism*, 46(6), 571-578.
- Carl, J., Barratt, J., Wanner, P., Toepfer, C., Cairney, J., & Pfeifer, K. (2022). The effectiveness of physical literacy interventions: a systematic review with meta-analysis. *Sports medicine*, 52(12), 2965-2999.
- Carl, J., Bryant, A. S., Edwards, L. C., Bartle, G., Birch, J. E., Christodoulides, E., . . . Gilic, B. (2023). Physical literacy in Europe: The current state of implementation in research, practice, and policy. *Journal of Exercise Science & Fitness*, 21(1), 165-176.
- Carl, J., Goss, H., Lundvall, S., Pavlova, I., Algurén, B., Antala, B., . . . Bryant, A. (2025). Compatibility of physical education curricula with physical literacy across 40 European countries. *Journal of Curriculum Studies*, 1-21.

- Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public health reports*, 100(2), 126.
- Chacón-Cuberos, R., Zurita-Ortega, F., Ramírez-Granizo, I., & Castro-Sánchez, M. (2020). Physical activity and academic performance in children and preadolescents: a systematic review. *Apunts. Educación Física y Deportes*, 139, 1-9.
- Chen, X., Sekine, M., Hamanishi, S., Wang, H., Gaina, A., Yamagami, T., & Kagamimori, S. (2003). Validation of a self-reported physical activity questionnaire for schoolchildren. *Journal of epidemiology*, 13(5), 278-287.
- Coyne, P., Vandeborn, E., Santarossa, S., Milne, M. M., Milne, K. J., & Woodruff, S. J. (2019). Physical literacy improves with the Run Jump Throw Wheel program among students in grades 4–6 in southwestern Ontario. *Applied physiology, nutrition, and metabolism*, 44(6), 645-649.
- Crocker, P. R., Bailey, D. A., Faulkner, R. A., Kowalski, K. C., & McGrath, R. (1997). Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. *Medicine & Science in Sports & Exercise*, 29(10), 1344-1349.
- Crozier, M., Wasenius, N. S., Denize, K. M., da Silva, D. F., Nagpal, T. S., & Adamo, K. B. (2022). Evaluation of Afterschool Activity Programs' (ASAP) effect on children's physical activity, physical health, and fundamental movement skills. *Health Education & Behavior*, 49(1), 87-96.
- Cuberek, R., Janíková, M., & Dygrýn, J. (2021). Adaptation and validation of the Physical Activity Questionnaire for Older Children (PAQ-C) among Czech children. *PloS one*, 16(1), e0245256.
- Dania, A., Kaioglou, V., & Venetsanou, F. (2020). Validation of the Canadian Assessment of Physical Literacy for Greek children: Understanding assessment in response to culture and pedagogy. *European Physical Education Review*, 26(4), 903-919. doi:Artn 1356336x20904079
- 10.1177/1356336x20904079
- de Bruijn, A. G., & Brocken, J. E. (2025). Motor and prosocial skills relate to enjoyment and physical activity levels during primary school recess. *Journal of Sports Sciences*, 43(15), 1532-1546.
- Demchenko, I., Prince, S. A., Merucci, K., Cadenas-Sanchez, C., Chaput, J.-P., Fraser, B. J., . . . Singh, B. (2025). Cardiorespiratory fitness and health in children and adolescents: an overview of systematic reviews with meta-analyses representing over 125 000 observations covering 33 health-related outcomes. *British Journal of Sports Medicine*, 59(12), 856-865.
- Demetriou, Y., Bachner, J., Reimers, A. K., & Göhner, W. (2018). Effects of a sports-oriented primary school on students' physical literacy and cognitive performance. *Journal of Functional Morphology and Kinesiology*, 3(3), 37.
- Dewi, R. C., Rimawati, N., & Purbodjati. (2021). Body mass index, physical activity, and physical fitness of adolescence. *Journal of public health research*, 10(2), jphr. 2021.2230.
- Dillon, C. B., Fitzgerald, A. P., Kearney, P. M., Perry, I. J., Rennie, K. L., Kozarski, R., & Phillips, C. M. (2016). Number of days required to estimate habitual activity using wrist-worn GENEActiv accelerometer: a cross-sectional study. *PloS one*, 11(5), e0109913.
- Doma, K., Speyer, R., Leicht, A. S., & Cordier, R. (2017). Comparison of psychometric properties between usual-week and past-week self-reported physical activity questionnaires: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, 14(1), 10.
- Doma, K., Speyer, R., Parsons, L. A., & Cordier, R. (2019). Comparison of psychometric properties between recall methods of interview-based physical activity questionnaires: a systematic review. *BMC Medical Research Methodology*, 19(1), 43.
- Dudley, D., & Cairney, J. (2021). Physical literacy: answering the call for quality education and sustainable development. *Prospects*, 50(1), 5-11.
- Elsborg, P., Melby, P. S., Kurtzhals, M., Tremblay, M. S., Nielsen, G., & Bentsen, P. (2021). Translation and validation of the Canadian assessment of physical literacy-2 in a Danish sample. *BMC Public Health*, 21(1), 2236.

- Esliger, D. W., Rowlands, A. V., Hurst, T. L., Catt, M., Murray, P., & Eston, R. G. (2011). Validation of the GENE Accelerometer. *Medicine & Science in Sports & Exercise*, 43(6), 1085-1093.
- Farooq, A., Martin, A., Janssen, X., Wilson, M. G., Gibson, A. M., Hughes, A., & Reilly, J. J. (2020). Longitudinal changes in moderate-to-vigorous-intensity physical activity in children and adolescents: A systematic review and meta-analysis. *Obesity reviews*, 21(1), e12953.
- Francis, C. E., Longmuir, P. E., Boyer, C., Andersen, L. B., Barnes, J. D., Boiarskaia, E., . . . Hands, B. P. (2016). The Canadian assessment of physical literacy: development of a model of children's capacity for a healthy, active lifestyle through a Delphi process. *Journal of physical activity and health*, 13(2), 214-222.
- Fu, Q., Li, L., Li, Q., & Wang, J. (2025). The effects of physical activity on the mental health of typically developing children and adolescents: a systematic review and meta-analysis. *BMC Public Health*, 25(1), 1514.
- Gallahue, D., Ozmun, J., & Goodway, J. (2012). Development of fundamental movement: Locomotor skills. *Understanding Motor Development: Infants, Children, Adolescents, Adults*, 185-221.
- George, A. M., Rohr, L. E., & Byrne, J. (2016). Impact of Nintendo Wii games on physical literacy in children: Motor skills, physical fitness, activity behaviors, and knowledge. *Sports*, 4(1), 3.
- Gilic, B., Malovic, P., Sunda, M., Maras, N., & Zenic, N. (2022). Adolescents with higher cognitive and affective domains of physical literacy possess better physical fitness: the importance of developing the concept of physical literacy in high schools. *Children*, 9(6), 796.
- Gilic, B., Sekulic, D., Munoz, M. M., Jaunig, J., & Carl, J. (2025). Translation, cultural adaptation, and psychometric properties of the Perceived Physical Literacy Questionnaire (PPLQ) for adults in Southeastern Europe. *Journal of Public Health*, 1-11.
- Gilic, B., Sunda, M., Versic, S., Modric, T., Olujic, D., & Sekulic, D. (2023). Effectiveness of Physical-Literacy-Based Online Education on Indices of Physical Fitness in High-School Adolescents: Intervention Study during the COVID-19 Pandemic Period. *Children*, 10(10), 1666.
- Gilmore, K., & Meersand, P. (2014). *The little book of child and adolescent development*: Oxford University Press.
- Graham, J. D., Li, Y.-C., Bray, S. R., & Cairney, J. (2018). Effects of cognitive control exertion and motor coordination on task self-efficacy and muscular endurance performance in children. *Frontiers in Human Neuroscience*, 12, 379.
- Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1· 6 million participants. *The lancet child & adolescent health*, 4(1), 23-35.
- Habyarimana, J. d. D., Tugirumukiza, E., He, S., Pathirana, A., & Ke, Z. (2025). From active play to sedentary lifestyles: understanding the decline in physical activity from childhood through adolescence-a systematic review. *Frontiers in Public Health*, 13, 1636891.
- Hui, L., Wei, S., Luping, Q., & Nannan, G. (2024). Developing the optimal gross movement interventions to improve the physical fitness of 3–10 year-old children: a systematic review and meta-analysis. *Frontiers in psychology*, 15, 1355821.
- Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International journal of behavioral nutrition and physical activity*, 7(1), 40.
- Janssen, X., Basterfield, L., Parkinson, K., Pearce, M., Reilly, J., Adamson, A., & Reilly, J. (2015). Determinants of changes in sedentary time and breaks in sedentary time among 9 and 12 year old children. *Preventive medicine reports*, 2, 880-885.
- Janz, K. F., Lutuchy, E. M., Wenthe, P., & Levy, S. M. (2008). Measuring activity in children and adolescents using self-report: PAQ-C and PAQ-A. *Medicine & Science in Sports & Exercise*, 40(4), 767-772.
- Jean de Dieu, H., & Zhou, K. (2021). Physical literacy assessment tools: a systematic literature review for why, what, who, and how. *International Journal of Environmental Research and Public Health*, 18(15), 7954.

- Jefferies, P., Bremer, E., Kozera, T., Cairney, J., & Kriellaars, D. (2021). Psychometric properties and construct validity of PLAYself: a self-reported measure of physical literacy for children and youth. *Applied physiology, nutrition, and metabolism*, 46(6), 579-588.
- Johnstone, A., Hughes, A. R., Janssen, X., & Reilly, J. J. (2017). Pragmatic evaluation of the Go2Play active play intervention on physical activity and fundamental movement skills in children. *Preventive medicine reports*, 7, 58-63.
- Jones, M., Defever, E., Letsinger, A., Steele, J., & Mackintosh, K. A. (2020). A mixed-studies systematic review and meta-analysis of school-based interventions to promote physical activity and/or reduce sedentary time in children. *Journal of sport and health science*, 9(1), 3-17.
- Katić, R., Maleš, B., & Miletić, Đ. (2002). Effect of 6-month athletic training on motor abilities in seven-year-old schoolgirls. *Collegium antropologicum*, 26(2), 533-538.
- Katić, R., Maleš, B., Ropac, D., & Padovan, M. (2002). Effect of programmed kinesiological treatment on structural transformation of some strength and endurance manifestations in Croatian army draftees. *Collegium antropologicum*, 26(1), 229-237.
- Keegan, R., Barnett, L., & Dudley, D. (2019). The Australian Physical Literacy Framework (Version 2). ISBN-13, 978-971.
- Kelley, G. A., Kelley, K. S., & Pate, R. R. (2022). Exercise and cardiovascular disease risk factors in children and adolescents with obesity: A systematic review with meta-analysis of randomized controlled trials. *American Journal of Lifestyle Medicine*, 16(4), 485-510.
- Kesic, M. G., Peric, M., Gilic, B., Manojlovic, M., Drid, P., Modric, T., . . . Pajtler, A. (2022). Are health literacy and physical literacy independent concepts? A gender-stratified analysis in medical school students from croatia. *Children*, 9(8), 1231.
- Kesic, M. G., Savicevic, A. J., Peric, M., Gilic, B., & Zenic, N. (2022). Specificity of the associations between indices of cardiovascular health with health literacy and physical literacy; a cross-sectional study in older adolescents. *Medicina*, 58(10), 1316.
- Kocaadam-Bozkurt, B., Sözlü, S., & Macit-Çelebi, M. S. (2023). Exploring the understanding of how parenting influences the children's nutritional status, physical activity, and BMI. *Frontiers in nutrition*, 9, 1096182.
- Kokstajn, J., Grobar, M., Vampola, J., & Musalek, M. (2025). Why Motor Competence Matters: Fundamental Movement Skills and Their Role in Promoting Physical Activity and Health in Czech Children Aged 9–10 Years. *Journal of Functional Morphology and Kinesiology*, 10(3), 258.
- Kolimechkov, S. (2017). Physical fitness assessment in children and adolescents: A systematic review. *European Journal of Physical Education and Sport Science*.
- Larrivee, S., Avery, E., Leiter, J., & Old, J. (2021). Accelerometry as an objective measure of upper-extremity activity. *Medical & Biological Engineering & Computing*, 59(1), 187-194.
- Lemos, T., & Gallagher, D. (2017). Current body composition measurement techniques. *Current Opinion in Endocrinology, Diabetes and Obesity*, 24(5), 310-314.
- Li, M. H., Rudd, J., Chow, J. Y., Sit, C. H. P., Wong, S. H. S., & Sum, R. K. W. (2022). A randomized controlled trial of a blended physical literacy intervention to support physical activity and health of primary school children. *Sports Medicine-Open*, 8(1), 55.
- Liu, C., Cao, Y., Zhang, Z., Gao, R., & Qu, G. (2023). Correlation of fundamental movement skills with health-related fitness elements in children and adolescents: A systematic review. *Frontiers in Public Health*, 11, 1129258.
- Liu, Y., & Chen, S. (2021). Physical literacy in children and adolescents: Definitions, assessments, and interventions. *European Physical Education Review*, 27(1), 96-112.
- Liu, Y., & Chen, S. (2022). Characterizing middle school Students' physical literacy development: a self-determination theory-based pilot intervention in physical education. *Frontiers in Sports and Active Living*, 3, 809447.
- Lončar Kubura, P. (2025). *Utjecaj edukativnih video sadržaja na povećanje razine tjelesne pismenosti te ostvarivanje ishoda kurikuluma međupredmetne teme zdravlje*. Sveučilište u Zagrebu, Sveučilište u Zagrebu Kineziološki fakultet,

- Longmuir, P. E., Boyer, C., Lloyd, M., Yang, Y., Boiarskaia, E., Zhu, W., & Tremblay, M. S. (2015). The Canadian assessment of physical literacy: methods for children in grades 4 to 6 (8 to 12 years). *BMC Public Health*, 15(1), 767.
- Longmuir, P. E., Gunnell, K. E., Barnes, J. D., Belanger, K., Leduc, G., Woodruff, S. J., & Tremblay, M. S. (2018). Canadian Assessment of Physical Literacy Second Edition: a streamlined assessment of the capacity for physical activity among children 8 to 12 years of age. *BMC Public Health*, 18(Suppl 2), 1047.
- Longmuir, P. E., Woodruff, S. J., Boyer, C., Lloyd, M., & Tremblay, M. S. (2018). Physical Literacy Knowledge Questionnaire: feasibility, validity, and reliability for Canadian children aged 8 to 12 years. *BMC Public Health*, 18(Suppl 2), 1035.
- Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., & Okely, A. D. (2010). Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports medicine*, 40(12), 1019-1035.
- Maicas-Pérez, L., Hernández-Lougedo, J., Maté-Muñoz, J. L., Villagra-Astudillo, A., García-Fernández, P., Suárez-Villadat, B., & Jiménez-Rojo, B. (2024). *Effect of physical activity interventions on health parameters in children and adolescents with intellectual disabilities: a systematic review*. Paper presented at the Healthcare.
- Mandić, D., Pelemiš, V., Džinović, D., & Kojić, D. M. a. F. (2019). Quantitative and Qualitative Characteristics of Preschool Children's Motor Skills. *Croatian Journal of Education/Hrvatski Časopis za Odgoj i Obrazovanje*, 21(1).
- Manojlovic, M., Roklicer, R., Trivic, T., Milic, R., Maksimović, N., Tabakov, R., . . . Drid, P. (2023). Effects of school-based physical activity interventions on physical fitness and cardiometabolic health in children and adolescents with disabilities: a systematic review. *Frontiers in Physiology*, 14, 1180639.
- Marasso, D., Lupo, C., Collura, S., Rainoldi, A., & Brustio, P. R. (2021). Subjective versus objective measure of physical activity: a systematic review and meta-analysis of the convergent validity of the physical activity questionnaire for children (PAQ-C). *International Journal of Environmental Research and Public Health*, 18(7), 3413.
- Mardešić, D. (2016). Pedijatrija, osmo, prerađeno i dopunjeno izdanje. *Zagreb: Školska knjiga, dd*, 17, 706-729.
- Marques, A., Henriques-Neto, D., Peralta, M., Martins, J., Gomes, F., Popovic, S., . . . Ihle, A. (2021). Field-based health-related physical fitness tests in children and adolescents: a systematic review. *Frontiers in Pediatrics*, 9, 640028.
- McCaskie, C., Siafarikas, A., Cochrane Wilkie, J., Sutton, V., Chivers, P., Hart, N. H., & Murphy, M. C. (2022). The benefits to bone health in children and pre-school children with additional exercise interventions: a systematic review and meta-analysis. *Nutrients*, 15(1), 127.
- McDonough, D. J., Liu, W., & Gao, Z. (2020). Effects of physical activity on children's motor skill development: a systematic review of randomized controlled trials. *BioMed research international*, 2020(1), 8160756.
- Mehra, A., Starkoff, B. E., & Nickerson, B. S. (2025). The evolution of bioimpedance analysis: From traditional methods to wearable technology. *Nutrition*, 129, 112601.
- Mendoza-Muñoz, M., Calle-Guisado, V., Pastor-Cisneros, R., Barrios-Fernandez, S., Rojo-Ramos, J., Vega-Muñoz, A., . . . Carlos-Vivas, J. (2022). Effects of active breaks on physical literacy: a cross-sectional pilot study in a region of Spain. *International Journal of Environmental Research and Public Health*, 19(13), 7597.
- Meredith, M. D., & Welk, G. J. (2005). *Fitnessgram/Activitygram test administration manual: Human Kinetics* 1.
- Momirović, K. (1987). Prikaz nekih novih metoda, algoritama i programa za analizu kvantitativnih i kvalitativnih promjena. *Defektologija*, 23(1), 45-56.
- Momirović, K., Prot, F., Dugić, D., Knezović, Z., Bosnar, K., & Erjavec, N. (1987). Metode, algoritmi i programi za analizu kvantitativnih i kvalitativnih promena (Methods, algorithms and programs

- for analysis of quantitative and qualitative changes). In: Zagreb: Institute of Kinesiology, Faculty of Physical Culture, University of ...
- Moon, J., Webster, C. A., Stodden, D. F., Brian, A., Mulvey, K. L., Beets, M., . . . Russ, L. (2024). Systematic review and meta-analysis of physical activity interventions to increase elementary children's motor competence: a comprehensive school physical activity program perspective. *BMC Public Health*, 24(1), 826.
- Morano, M., Bortoli, L., Ruiz, M. C., Vitali, F., & Robazza, C. (2019). Self-efficacy and enjoyment of physical activity in children: Factorial validity of two pictorial scales. *PeerJ*, 7, e7402.
- Mudrinic, L., Musa, M., Metikos, B., Vuletic, P. R., & Sekulic, D. (2025). Rethinking Sociodemographic Predictors of Physical Literacy and Health Literacy in Older Females. *Sport Mont*, 23(2), 79-86.
- Neljak, B. (2013). *Opća kineziološka metodika*: Zagreb: Gopal doo.
- Newman, B. M., & Newman, P. R. (2022). *Theories of human development*: Routledge.
- Nezondet, C., Gandrieau, J., Bourrelier, J., Nguyen, P., & Zunquin, G. (2023). The effectiveness of a physical literacy-based intervention for increasing physical activity levels and improving health indicators in overweight and obese adolescents (CAPACITES 64). *Children*, 10(6), 956.
- Ning, W., Gao, Z., & Lodewyk, K. (2012). Associations between Socio-Motivational Factors, Physical Education Activity Levels and Physical Activity Behavior among Youth. *ICHPER-SD Journal of Research*, 7(2), 3-10.
- Oh, Y. H., Choi, S., Lee, G., Son, J. S., Kim, K. H., & Park, S. M. (2021). Changes in body composition are associated with metabolic changes and the risk of metabolic syndrome. *Journal of clinical medicine*, 10(4), 745.
- World Health Organization (2019). *Global action plan on physical activity 2018-2030: more active people for a healthier world*: World Health Organization.
- World Health Organization (2022a). Global status report on physical activity 2022: country profiles.
- World Health Organization (2022b). *Physical activity and sedentary behaviour: a brief to support people living with type 2 diabetes*: World Health Organization.
- Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjöström, M. (2008). Physical fitness in childhood and adolescence: a powerful marker of health. *International journal of obesity*, 32(1), 1-11.
- Pastor-Cisneros, R., Carlos-Vivas, J., Adsuar, J. C., Barrios-Fernández, S., Rojo-Ramos, J., Vega-Muñoz, A., . . . Mendoza-Muñoz, M. (2022). Spanish Translation and Cultural Adaptation of the Canadian Assessment of Physical Literacy-2 (CAPL-2) Questionnaires. *International Journal of Environmental Research and Public Health*, 19(14), 8850.
- Podnar, H., Sušilović, M. K., & Radman, I. (2017). Internal Consistency and Retest Reliability of the Croatian Version of PAQ-C. *Croatian Journal of Education/Hrvatski Časopis za Odgoj i Obrazovanje*, 19(1).
- Rajkovic Vuletic, P., Gilic, B., Pavlinovic, V., Matijasevic, P., & Sekulic, D. (2026). Effects of a Physical-Literacy-Based Educational Intervention on Physical Activity and Body Composition in Preadolescent Children: A School-Based Controlled Trial. *Sports*, 14(2), 77. Retrieved from <https://www.mdpi.com/2075-4663/14/2/77>
- Rajkovic Vuletic, P., Gilic, B., Zenic, N., Pavlinovic, V., Kesic, M. G., Idrizovic, K., . . . Sekulic, D. (2024). Analyzing the associations between facets of physical literacy, physical fitness, and physical activity levels: Gender-and age-specific cross-sectional study in preadolescent children. *Education sciences*, 14(4), 391.
- Rajkovic Vuletic, P., Pranjić, T., Gilic Skugor, B., Lešnik, B., Sekulic, D., & Šajber, D. (2026). *Physical Literacy-Focused Education Improves Fitness Markers in Preadolescents: Implications for School-Based Health Promotion*. Paper presented at the Healthcare.
- Rathi, N., & Rastogi, R. (2007). Meaning in life and psychological well-being in pre-adolescents and adolescents. *Journal of the Indian Academy of Applied Psychology*, 33(1), 31-38.
- Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports medicine*, 45(9), 1273-1284.

- Rostami Haji Abadi, M., Kwaghbo, N., Onyeso, O. K., Sadia, F., Benavides Castro, J. K., Silva, D. A. S., . . . Sarmiento, O. L. (2025). Psychometric Properties of Physical Activity Questionnaires for Children and Adolescents: An Updated Systematic Review: MRH Abadi et al. *Sports medicine*, 55(9), 2225-2301.
- Rowland, T. W. (2005). Children's exercise physiology. (*No Title*).
- Russo, G., De Matteis, F., Oparina, E., Ceciliani, A., & Bigliassi, M. (2025). Exploring the relationship between physical activity behavior, sport modality, and higher-order psychosocial skills in children. *Heliyon*, 11(13).
- Samaržija, D. V., & Mišigoj-Duraković, M. (2013). Reliability of croatian version of the questionnaire for assessment of overall level of physical activity of younger school children.
- Sekulic, D., Pranjic, T., Cerkez Zovko, I., Corluka, M., & Rajkovic Vuletic, P. (2026). Examining Qualitative Changes in Physical Fitness and Body Composition in a School-Based Physical Literacy Intervention: Methodological and Practical Considerations. *Sport Mont*, 24(1), 149-158.
- Sestan, A., Zovko, I. C., & Sekulic, D. (2025). Analysis of the Associations between Physical Literacy and Health Literacy in Older Females; Cross Sectional Study. *Sport Mont*, 23(2), 17-23.
- Shearer, C., Goss, H. R., Boddy, L. M., Knowles, Z. R., Durden-Myers, E. J., & Foweather, L. (2021). Assessments related to the physical, affective and cognitive domains of physical literacy amongst children aged 7–11.9 years: a systematic review. *Sports Medicine-Open*, 7(1), 37.
- Shloim, N., Edelson, L. R., Martin, N., & Hetherington, M. M. (2015). Parenting styles, feeding styles, feeding practices, and weight status in 4–12 year-old children: A systematic review of the literature. *Frontiers in psychology*, 6, 1849.
- Signorini, G., Scurati, R., Bosio, A., Pizzoli, M., Pagano, A., Raiola, G., & Invernizzi, P. L. (2025). The Perception of Effort as a Basis for Improving Physical Efficacy and Efficiency in Italian Military School Students. *Sports*, 13(4), 128.
- Song, Y., Jia, S., Wang, X., Wang, A., Ma, T., Li, S., . . . Ren, Y. (2025). Effects of physical exercise on anxiety depression and emotion regulation in children with attention deficit hyperactivity disorder: a systematic review and meta-analysis. *Frontiers in Pediatrics*, 12, 1479615.
- Stoddart, A. L., Humbert, M. L., Kerpan, S., Cameron, N., & Kriellaars, D. (2023). PLitPE: an intervention for physical literacy enriched pedagogy in Canadian elementary school physical education classes. *Physical Education and Sport Pedagogy*, 28(6), 675-691.
- Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Robertson, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest*, 60(2), 290-306.
- Strobl, H., Ptack, K., Töpfer, C., Sygusch, R., & Tittlbach, S. (2020). Effects of a participatory school-based intervention on students' health-related knowledge and understanding. *Frontiers in Public Health*, 8, 122.
- Šunda, M. (2022). *Utjecaj učenja na daljinu i unaprjeđenja tjelesne pismenosti na promjene stanja fitnesa i tjelesne aktivnosti adolescenata*. University of Zagreb. Faculty of Kinesiology,
- Sunda, M., Gilic, B., & Bascevan, A. (2022). Association between enjoyment in physical education online classes and physical activity levels in adolescents during the COVID-19 pandemic. *Sport Mont*, 20(1), 97-101.
- Sunda, M., Gilic, B., Sekulic, D., Matic, R., Drid, P., Alexe, D. I., . . . Lupu, G. S. (2022). Out-of-School Sports Participation Is Positively Associated with Physical Literacy, but What about Physical Education? A Cross-Sectional Gender-Stratified Analysis during the COVID-19 Pandemic among High-School Adolescents. *Children*, 9(5), 753.
- Tanous, D. R., Ruedl, G., Motevalli, M., Drenowatz, C., Cocca, A., Schauer, M., . . . Wirnitzer, K. C. (2025). Randomized controlled trials on physical activity, diet, or both for public health through body weight management in 5-to 10-year-old pupils: a systematic review and meta-analysis. *European Journal of Public Health*, 35(3), 555-562.
- Telford, R. M., Olive, L. S., Keegan, R. J., Keegan, S., Barnett, L. M., & Telford, R. D. (2021). Student outcomes of the physical education and physical literacy (PEPL) approach: a pragmatic cluster

- randomised controlled trial of a multicomponent intervention to improve physical literacy in primary schools. *Physical Education and Sport Pedagogy*, 26(1), 97-110.
- Tomayko, E. J., Tovar, A., Fitzgerald, N., Howe, C. L., Hingle, M. D., Murphy, M. P., . . . Hubbs-Tait, L. (2021). Parent involvement in diet or physical activity interventions to treat or prevent childhood obesity: an umbrella review. *Nutrients*, 13(9), 3227.
- Tomljenović, B. (2018). *Struktura i razlike antropoloških obilježja učenika i učenica razredne nastave gradskih i seoskih sredina Like*. University of Zagreb. Faculty of Kinesiology,
- UNESCO. Quality physical education (QPE): guidelines for policy-makers. Preuzeto s <https://en.unesco.org/inclusivepolicylab/sites/default/files/learning/document/2017/1/231101E.pdf>
- Urbano-Mairena, J., Munoz-Bermejo, L., Carlos-Vivas, J., Pastor-Cisneros, R., Montenegro-Espinosa, J. A., & Mendoza-Muñoz, M. (2025). Effects of a 7-week active breaks intervention program on physical literacy and body mass index. *Frontiers in psychology*, 16, 1535729.
- Vanhelst, J., Béghin, L., Drumez, E., Coopman, S., & Gottrand, F. (2017). Awareness of wearing an accelerometer does not affect physical activity in youth. *BMC medical research methodology*, 17(1), 99.
- Voss, C., Dean, P. H., Gardner, R. F., Duncombe, S. L., & Harris, K. C. (2017). Validity and reliability of the Physical Activity Questionnaire for Children (PAQ-C) and Adolescents (PAQ-A) in individuals with congenital heart disease. *PloS one*, 12(4), e0175806.
- Vuletic, P. R., Kesic, M. G., Gilic, B., Pehar, M., Uzicanin, E., Idrizovic, K., & Sekulic, D. (2023). Evaluation of physical literacy in 9-to 11-Year-Old children: reliability and validity of two measurement tools in three southeastern European countries. *Children*, 10(11), 1722.
- Vuletic, P. R., Matijasevic, P., & Pavlinovic, V. (2025). Is the PAQ-C a Valid Measurement Tool for Evaluating Physical Activity Levels in Rural Children? Cross-Sectional Study in Southern Croatia. *Sport Mont*, 23(1), 85-91.
- Wang, P., Gao, X., Cui, X., & Shi, C. (2025). Associations between physical exercise and social-emotional competence in primary school children. *Scientific Reports*, 15(1), 19554.
- Warner, M., Robinson, J., Heal, B., Lloyd, J., Mandigo, J., Lennox, B., & Davenport Hoyer, L. (2021). Increasing physical literacy in youth: A two-week Sport for Development program for children aged 6-10. *Prospects*, 50(1), 165-182.
- Weaver, R. G., Hensing, C., Armstrong, B., Adams, E. L., & Beets, M. (2022). Seasonal shifts in Children's sedentary behaviors, physical activity, and sleep: a systematic review and meta-analysis. *Pediatric Clinics of North America*, 69(4), 671-693.
- Wei, L., Li, Z., & Sun, Y. (2025). *Types and Frequencies of Physical Activity Associated with Physical Fitness in Chinese Children and Adolescents: A National Cross-Sectional Study*. Paper presented at the Healthcare.
- Whitehead, M. (2013). Definition of Physical Literacy and Clarification of Related Issues. ICSSPE Bulletin, 65. In.
- Williams, A. J., Henley, W. E., Williams, C. A., Hurst, A. J., Logan, S., & Wyatt, K. M. (2013). Systematic review and meta-analysis of the association between childhood overweight and obesity and primary school diet and physical activity policies. *International journal of behavioral nutrition and physical activity*, 10(1), 101.
- Zhang, D., Shi, L., Zhu, X., Chen, S., & Liu, Y. (2023). Effects of intervention integrating physical literacy into active school recesses on physical fitness and academic achievement in Chinese children. *Journal of Exercise Science & Fitness*, 21(4), 376-384.
- Zhang, W., Wang, X., Liu, Y., He, Q., Ding, Q., Mei, J., & Li, X. (2024). Effects of exercise on bone mass and bone metabolism in adolescents: a systematic review and meta-analysis. *Frontiers in Physiology*, 15, 1512822.
- Zhou, H., Yu, P., Thirupathi, A., & Liang, M. (2020). How to improve the standing long jump performance? A mininarrative review. *Applied Bionics and Biomechanics*, 2020(1), 8829036.

Zhou, X., Li, J., & Jiang, X. (2024). Effects of different types of exercise intensity on improving health-related physical fitness in children and adolescents: a systematic review. *Scientific Reports*, 14(1), 14301.