Health Literacy, Physical Activity and Health Status Of High School Adolescents

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HEALTH LITERACY, PHYSICAL ACTIVITY AND HEALTH STATUS OF HIGH SCHOOL ADOLESCENTS

DOCTORAL THESIS

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Mia Perić; Associate professor at the University of Split, Split, Croatia; Born 1983 in Split, Croatia.

She earned her PhD title in Kinesiology at the University of Split, Split, Croatia in 2012. She started her sport career in artistic swimming in 1996. At first, she was involved as a swimmer and then continued to move up being a coach, international judge and instructor, and achieved a highlight in 2012. with the Ph.D. title.

Although aesthetic sports were her initial scientific field, she published over 40 papers in various journals (25 in Web od Science, with more than 300 citations). Except sport science she covered fields like community-specific adolescent behaviour, eating disorders in artistic sports, nutrition and doping, sport-specific tests and injuries, public health related issues.

At Faculty of Kinesiology in Split, she teaches Physical Activity Fitness and health, Artistic swimming, Sports and recreational water activities, Aquatic fitness and Animation in Tourism.

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LIST OF ABBREVIATIONS

HL – Health Literacy

PL – Physical Literacy

PA – Physical Activity

PAL – Physical Activity Level

PAQ-A – Physical Activity Questionnaire for Adolescents

HLS-EU-Q47 – European Health Literacy Questionnaire 47

POCT – Pont of Care Testing

U.S. – United States

WHO – World Health Organisation

MVPA – Moderate to Vigorous Physical Activity

DM – diabetes mellitus

CVD – cardiovascular disease

CHD – coronary heart disease

CVHS – cardiovascular health status

TCHOL – Total Cholesterol

HDL – High Density Lipoproteins

LDL – Low Density Lipoproteins

TG – Triglycerides

NHLBI – National Heart, Lung, and Blood Institute

CONTENTS

ABSTRACT

The aim of this doctoral thesis was to investigate factors that determine the connections between health literacy, physical literacy, physical activity and indicators of health status. It also aimed to determine some factors related to health literacy in adolescents. In this sense, partial goals were set to: i) investigate factors that influence the physical activity level (PAL) in adolescents; ii) investigate the level of health literacy (HL) and physical literacy (PL) and their relationship with different health parameters; iii) investigate the correlation between HL and indicators of school achievement. The thesis comprised of four pieces of research.

This study included high-school students from two different areas: Bosnia and Herzegovina; and the coastal region of Croatia. In the first study, the students were stratified into two groups - older and younger adolescents. It was a prospective study in which the participants were tested in two waves (before lockdown and after). In studies two, three and four, only older adolescents were tested, and the samples were gender stratified. Variables included in this study were PAL (assessed by the Physical Activity Questionnaire for Adolescents - PAQ-A), PL (assessed by the PLAYself questionnaire), HL (assessed by the European Health Literacy Survey Questionnaire – HLS-EU-Q47), body composition (measured by the bioimpedance scale), lipid profile (measured by Point of Care Testing – POCT) and scholastic achievement (which included grade point average and school absence - all data were collected from the class register book in electronic format from the e-Dnevnik application) .

The result from the first study showed that the PAL significantly declined as a result of lockdown measures in the total sample (from 2.76±0.79 to 2.50±0.82). The study evidenced a larger absolute decline was evidenced in younger adolescents relative to older adolescents. Participation in sports positively influenced PAL before lockdown, with no significant influence during the lockdown. Older adolescents whose mothers were better educated were less likely to be in a high risk group with regard to a large decline of PAL as a result of COVID lockdown (OR = 0.50, 95% CI: 0.21–0.84). The result of the second study showed a similar level of HL (t-test = 0.2; p = 0.83), and PL (t-test = 0.01; p = 0.99) in boys and girls. Significant but small correlations were identified between HL and PL only in the girls (<10% of common variance). The body composition indices were significantly correlated with PL only in the boys (15–20% of common variance). The result from the third study showed that the lipid profile was better in girls with higher HL scores. Additionally, clusters consisting of participants with

a better PL were characterised by higher PAL. No evidence was found that HL is associated with PAL, while PL was not associated with the lipid profile. The results of the fourth research study showed generally poor gender-stratified correlations between HL and scholastic variables, while statistically significant correlations between grade point average and HL were noted only among girls ($R=0.16$, $p<0.05$).

This study gives a new perspective on adolescent specific literacy: health literacy; and physical literacy; and their relationship with adolescent health and health behaviour. This research generated the following conclusions: (i) parental education (especially mother education/ level of HL) influences adolescents health-related behaviour and it is a protective factor against a decrease in PAL during COVID-19; (ii) the association between HL and PL is weak in the adolescent population; (iii) HL and PL are associated with specific health indicators in the way that HL is more associated with direct health indicators, while PL is more related to PAL; and (iv) the association between HL and PL with scholastic achievement is generally poor. These findings suggested that these two concepts related to health and health behaviour are of important interest as a preventive measure and should be an integral part of both educational and public health strategies to promote adolescent's health behaviour, health, and wellbeing.

Keywords: pandemic, youth, sport participation, familial factors, physical activity, health literacy, health behaviours, knowledge translation, public health, community-engaged research, body build, lipid profile, adolescents, lifestyle, pedagogy, teachers.

SAŽETAK

Cilj ovog doktorskog rada bio je istražiti faktore koji određuju povezanosti koje postoje između zdravstvene pismenosti, tjelesne pismenosti, tjelesne aktivnosti i pokazatelja zdravstvenog statusa, te utvrditi neke faktore povezane sa zdravstvenom pismenošću kod adolescenata. U tom smislu postavljeni su parcijalni ciljevi i to i) istražiti čimbenike koji utječu na razinu tjelesne aktivnosti (RTA) kod adolescenata; ii) istražiti razinu zdravstvene pismenosti (ZP) i tjelesne pismenosti (TP) i njihov odnos s različitim zdravstvenim parametrima ; iii) istražiti povezanost ZP i pokazatelja školskog uspjeha. Ovaj doktorski rad sastoji se od četiri objavljena istraživanja.

Uzorak ispitanika istraživanja sačinjavali su učenici srednjih škola iz Bosne i Hercegovine i primorskog dijela Hrvatske. U prvom dijelu istraživanja učenici su bili podijeljeni na starije i mlađe adolescente. Testiranje se provelo prije i poslije karantene. U drugom, trećem i četvrtom dijelu istraživanju testirani su samo stariji adolescenti, a koje smo prethodno podijelili po spolu. Nadalje, u istraživanju su korištene sljedeće varijable: RTA (procijenjena upitnikom o tjelesnoj aktivnosti za adolescente (PAQ-A)), TP (procijenjena PLAYself upitnikom), ZP (procijenjena Europskom anketom o zdravstvenoj pismenosti (HLS-EU-Q47)), sastav tijela (izmjeren pomoću bioimpedanske vage), lipidni status (izmjeren pomoću Point of Care Testing (POCT)) i školski uspjeh koji je uključivao prosjek ocjenâ i izostanak iz škole (podaci prikupljeni iz matične knjige učenika, u elektroničkom obliku, pomoću online aplikacije eDnevnik).

Rezultati iz prvog dijela istraživanja, a na ukupnom uzorku, pokazali su da se razina RTA, uslijed COVID-19 restriktivnih mjera, značajno smanjila (s 2,76±0,79 na 2,50±0,82). Štoviše, značajan pad razine RTA zabilježen je kod mlađih adolescenata a u odnosu na starije adolescente. Istraživanje je također utvrdilo da je sudjelovanje u sportu pozitivno utjecalo na RTA i to prije stupanja na snagu restriktivnih mjera, kao i tijekom trajanja istih. Također, manje je bilo vjerojatno da će stariji adolescenti, a čije majke imaju viši stupanj obrazovanja, biti u visokorizičnoj skupini uslijed zabilježenog pada RTA uzrokovanog COVID-19 karantenom (OR = 0,50, 95% CI: 0,21–0,84). Rezultat drugog dijela istraživanja pokazao je sličnu razinu ZP (t-test = 0,2; p = 0,83) i PL (t-test = 0,01; p = 0,99) kod dječaka i djevojčica. Značajne, ali male korelacije, utvrđene su između ZP i TP ali samo kod djevojčica (<10% zajedničke varijance). Nadalje, indeks sastava tijela značajno je povezan s TP ali samo kod dječaka (15–20% zajedničke varijance). Rezultat trećeg dijela istraživanja utvrdio je značajniji lipidni status

kod djevojčica s boljim rezultatima iz TP. Štoviše, pokazalo se da klasteri sudionika s višom razinom TP imaju i višu razinu TA. Međutim, istraživanjem se nije dokazala povezanost između TP s RTA kao ni TP s lipidnim statusom. Rezultati četvrtog dijela istraživanja pokazali su općenito loše spolno stratificirane korelacije između ZP i varijable školski uspjeh, dok su statistički značajne korelacije između prosjeka ocjena i TP zabilježene samo kod djevojčica ($R=0,16$, $p<0,05$).

Ovim se istraživanjem željelo ukazalo na drugačiji oblik promišljanja o specifičnom obliku pismenosti kod adolescenata: zdravstvenoj pismenost i tjelesnoj pismenost, kao i na njihov odnos sa zdravljem i ponašanjem adolescenata.

Zaključno, ovim se istraživanjem došlo do sljedećih zaključaka: (i) obrazovanje roditelja (osobito obrazovanje majke/razina TP) utječe na ponašanje adolescenata vezano uz zdravlje te predstavlja obrambeni čimbenik pri smanjenju RTA tijekom COVID-19; (ii) povezanost između ZP i TP je slaba kod adolescenata; (iii) ZP i TP povezani su sa specifičnim zdravstvenim pokazateljima na način da je ZP više povezana s izravnim zdravstvenim pokazateljima, dok je TP više povezan s RTA; (iv) povezanost između ZP i TP sa školskim uspjehom općenito je niska. Ovi rezultati ukazuju na to da su ZP i TP, a koji su povezani sa zdravljem i zdravstvenim ponašanjem, od velike važnosti u prevenciji te bi kao takve trebale biti sastavnim dijelom obrazovnih i javnozdravstvenih strategija za promicanje zdravstvenog ponašanja, zdravlja i opće dobrobiti adolescenata.

Ključne riječi: pandemija, mladi, bavljenje sportom, obiteljski čimbenici, tjelesna aktivnost, zdravstvena pismenost, zdrava ponašanja, prijenos znanja, javno zdravstvo, istraživanje usmjereno na aktivnost zajednice, građa tijela, lipidni status, adolescenti, način života, pedagogija, učitelji.

THESIS OUTLINE

This doctoral thesis consists of four published articles:

1. Geets Kesic, M., Gilic, B., Cerkez Zovko, I., Drid, P., Korovljev, D., & Sekulic, D. (2021). Differential impact of COVID-19 lockdown on physical activity in younger and older adolescents–prospective study. *Medycyna Pracy*, *72*(6), 633-643.

2. Kesic, M. G., Peric, M., Gilic, B., Manojlovic, M., Drid, P., Modric, T., Znidaric, Z., Zenic, N. 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.

3. 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.

4. Geets-Kesić, M., Maras, N., & Gilić, B. (2023). 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 Journal of Sports Science and Medicine*, *12*(1), 3-9.

1 INTRODUCTION

1.1 Context

1.1.1 Health literacy

Health Literacy (HL), was a term which was first proposed in the 1970s (Simonds, 1974). Although it has been explained in numerous ways, according to a set of "all inclusive" terms and notions (it integrates medical and public health points of view), the comprehensive definition is: "*Health literacy relates to the literacy of a person's health knowledge, their capability to enhance and increase it; and how to contextualize it, apply it and put it into practice. It entails a persons: acquired knowledge; motivation and competence to access new knowledge (ability to seek, find and obtain health information); understanding (ability to comprehend the health information); appraise (ability to interpret, filter, judge and evaluate the health information); and apply (ability to communicate and use the information) health information in order to make judgments and take decisions in everyday life concerning healthcare; disease prevention and health promotion to maintain or improve quality of life during it's course"* (Sørensen et al., 2012).

The current common understanding is that HL is a multidimensional concept comprising a range of cognitive, affective, social, and personal skills and attributes. HL contains three levels, progressing from (i) basic skills in reading and writing (functional HL); to (ii) the ability to derive meaning from different forms of communication and apply new information to changing situations (interactive HL); and finally (iii) the ability to achieve policy and organizational changes (critical HL) (D. Nutbeam, 2008).

Although the concept of 'health literacy' originated from the United States (U.S.) and Canada, today it is used internationally, not only in clinical medicine and health care, but also within the public health and health education context (Pleasant & Kuruvilla, 2008) (Mei et al., 2023). This is exemplified by the inclusion of health literacy in European policy documents such as in the European Commission White Paper entitled 'Together for Health' (European Commission. Together for Health. A Strategic Approach for the EU 2008– 2013. COM(2007) 630 final. Brussels: European Commision, 2007). Furthermore, in the Shanghai „Declaration on Promoting Health in the 2030 Agenda for Sustainable Development", the World Health Organization (WHO) recognizes HL as a critical determinant of health and a vital component of efforts to reduce inequalities in health ("Shanghai declaration on promoting health in the

2030 Agenda for Sustainable Development," 2017). Finally, health literacy is recognized as an essential factor affecting health and a stronger predictor of the population's health status than age, income, education level, race or employment status (Shahid et al., 2022).

During the last two decades, the concept of health literacy has gained traction in research spheres. This is due to the significant contribution it can provide to individual and public health, and the continued sustainability of healthcare systems (Institute of Medicine Committee on Health, 2004; Don Nutbeam, 2000; Sørensen et al., 2012) (Berkman et al., 2011) (Ishikawa & Yano, 2008) (Peerson & Saunders, 2009). The research around HL is mainly based on two perspectives: the clinical perspective and the public health perspective (Mei et al., 2023).

Although, the majority of early studies on HL in North America were based on the clinical perspective, a development of different HL evaluation systems (surveys and questionnaires) shifted the research interest towards public health perspective (Visscher et al., 2018). Data has shown the relationship between helath literacy and health outcomes within all settings of healthcare (Sierra & Cianelli, 2019). A systematic review of HL and health outcomes reported that patients with low levels of HL were generally one and half to three times more likely to experience a given poor health outcome ("Health literacy: report of the Council on Scientific Affairs. Ad Hoc Committee on Health Literacy for the Council on Scientific Affairs, American Medical Association," 1999). Poor levels of HL have been associated with more hospitalizations; greater use of emergency care; a poorer ability to interpret drug labels and health messages; and higher mortality rates among elderly persons (Hibbard, Peters, Dixon, & Tusler, 2007). Shahid et al. reported that about 50% of hospitalized patients in various hospital settings have difficulty reading, understanding, and interpreting healthcare information (Shahid et al., 2022). The connection between HL and outcomes of infectious and non infectious disease is well documented. Several studies show a link between HL and health outcomes to non comunicable diseases such as asthma, diabetes, hypertension and congestive heart failure (Sierra & Cianelli, 2019). Regarding infectious disease, limited or insufficient health literacy was associated with reduced adoption of protective behaviours and protective measures such as immunization, as well as inadequate understanding of antibiotics (Castro-Sánchez, Chang, Vila-Candel, Escobedo, & Holmes, 2016) (Berkman et al., 2011). Furthermore, people with a poor level of health literacy make riskier health decisions and generally, they take poorer care of their health (Shieh & Halstead, 2009). However, people with good HL can manage their health more effectively than those without or with poor health literacy (Sørensen et al., 2012).

Finaly, insuficient health literacy increases health care cost in U.S. between $106 and $236 bilion annually (Caldwell & Melton, 2020)

HL is a global challenge. It seems that HL is generally low in both developed, and developing countries (WHO. Policy brief 4: health literacy. The 9th global conference on health promotion. Shanghai, China. 2017.). According to the reports, more than 43 milion people in the United States have inadequate health literacy and nearly half of adult Canadians (Shahid et al., 2022). A report by Baccolini for European Union member states, showed the proportion of low HL adults within the general population, ranged from 27% to 48% (Baccolini et al., 2021). A health literacy survey with 10,024 general public participants showed insufficient health literacy in the general public in different countries such as Indonesia, Kazakhstan, Vietnam, Malaysia and Myanmar (Chu-Ko et al., 2021)

1.1.2 Health literacy in adolescence

Although HL is a concept primarily devoted to the adult population, recent negative public-health trends among adolescents and youth (i.e. obesity, metabolic syndrome, unhealthy lifestyle, risky health behavior, inactivity) raised the need for awareness of HL even in younger populations (Hayes, Dowd, MacDonncha, & Donnelly, 2019). Moreover, health behaviour in adolescents is influenced by HL (Fleary, Joseph, & Pappagianopoulos, 2018). Adolescence is a vital stage in human development between 10 and 19 years of age. It is a period characterised with intensive changes in psychological, physiological and social growth (Kuruvilla et al., 2016). In this period children are developing essential social, emotional, and cognitive skills, including responsibility for their own healthcare (Sansom-Daly et al., 2016). Also, adolescence is a key time to adopt healthy lifestyle habits and behaviours that will have a crucial impact on the health and healthy lifestyle in adulthood. The majority of adolescents successfully pass this transition and become healty and productive adults. Some adolescents however have a higher prevalence of many health-risk behaviors like smoking, drinking, and risky sexual behavior. This puts them at risk in adulthood from needless early morbidity, mortality and social problems (Kann et al., 2018).

Several studies reported that obesity and obesity-related health problems in adult years, such as cardiovascular disease (heart disease and stroke), metabolic sindrom, musculosceletal disorders, and some cancers (breast, ovarial, prostat, liver et...) are greater if during the adolescens person/individuals take part in obesogenic behaviors (Fleary et al., 2018). Further,

adolescents who smoke are more likley to be nicotin-dependent and they have higher risk to develop cancer and/or cardiovascular disease in adult age. Also, the use of alcohol in adolescents is conected with alcohol related disorders and mental health problems in adulthood. It is approximated that adolescent behavior contributes to 70% of premature adult deaths (Fleary et al., 2018).

Today, modern technology and an infatuation with electronic equipment poses a threat to adolescent health and growth. Reports from different countries on adolescent populations aged 16-18 years showed that 15% of adolescent smoked; 21% were overweight or obese; 80% did not have sufficient daly intake of vegetable and fruit; 55% do not have enough sleep or experience insomnia; 14% to 21% are engaging in risk sexual behavior; and 3% experience anxiety or depression (Bhatti, Watkin, Butterfill, & Li, 2020) (Hayes et al., 2019) (Kann et al., 2018). Moreover, an unhealthy lifestyle characterized by the lack of physical activity (PA) is widespread amongst adolescents. Globally, 81% of adolescents do not have adequate physical activity level (PAL) (R. Guthold, G. A. Stevens, L. M. Riley, & F. C. Bull, 2020).

1.1.3 Physical activity and health literacy

Physical activity (PA) is described as any bodily movement produced by skeletal muscle that engages energy expenditure, and it refers to all movement including during leisure time, for transport to get to and from places, or as a part of persons work (Caspersen, Powell, & Christenson, 1985). The lifelong health benefits of PA and the health risk of inactive and sedentary lifestyle are well documented. In the context of exercise physiology, PA can contribute to positive physiological adaptation as a response to stress with consequently positive health benefits/outcomes (D. E. Warburton, Nicol, & Bredin, 2006). Reports identified regular PA during adolescence as a behaviour that increases probability for a physically active lifestyle in adulthood (Kjønniksen, Anderssen, & Wold, 2009). Thus, can reduce risk of 25 chronic diseases; such as cancer, cardiovascular condition, obesity, and metabolic syndrome (D. E. R. Warburton & Bredin, 2017). A recent systematic literature review carried out by Buja showed positive association between PA and HL in different ages groups (Buja et al., 2020). In adolescence, PA is influenced by knowledge about healthy living and the health benefits of engaging in PA in everyday life. Considering that HL is one's capacity/ ability to receive, understand and process information about health, PA is a form of healthy lifestyle that can be

influenced by the level of HL: individuals with more active lifestyle/ higher PAL showed higher levels of HL (Geboers, de Winter, Luten, Jansen, & Reijneveld, 2014).

It has been well documented that PA and participation in different sports are negatively correlated with cigarette and marijuana intake, sexual intercourse, and positively associated with self-esteem and academic performance (Nelson & Gordon-Larsen, 2006). Furthermore, recent scientific literature showed the positive impact of physical activity on cognitive development and prosocial behaviour in adolescent age (R. Guthold et al., 2020). Also, PA in adolescence affects a person's agility. Subsequently this can have a positive effect on the body through the promotion of bone and muscle growth, improving the quality of sleep, and better stress management (Berlianti & Arifah). To achieve these specific health benefits, the WHO recommends 60 min per day of moderate to vigorous physical activity (MVPA) for adolescents (Sallis, Prochaska, & Taylor, 2000). The level of PA declines during the lifespan, but especially in the adolescent group (Regina Guthold, Gretchen A. Stevens, Leanne M. Riley, & Fiona C. Bull, 2020). Recent global estimates show that 27.5% of adults and 81% of adolescents do not meets the WHO recommendation (Bull et al., 2020). The peak in PAL occurs at age 13, and later it decreases by 7% annually (Bauman et al., 2012). Prevalence of adolescents aged 11-17 who do not meet the WHO recommendations were 78.4% for boys and 84.4% for girls (R. Guthold et al., 2020). Additionally, during the COVID-19 pandemic PAL decreased even more, causing the deterioration of adolescent's health (Sekulic, Blazevic, Gilic, Kvesic, & Zenic, 2020). Worryingly, lack of PA (or physical inactivity) and sedentary lifestyle, has been identified as one of the biggest public health concerns of the 21th century (Dumith, Gigante, Domingues, & Kohl, 2011).

Hancox et.al. reported that child and adolescent sedentary behaviour is associated with higher body mass index, lower cardiorespiratory fitness, increased cigarette smoking and elevated serum cholesterol in adulthood (Hancox, Milne, & Poulton, 2004). WHO reports that globally, there are more people who are obese than underweight (Boutari & Mantzoros, 2022). This tallies with a constant rise in obesity rates, resulting in the prevalence of overweight and obesity among children and adolescents age 5-19. The latter having risen dramatically form 4% in 1975 to just over 18% in 2016 and occurring similarly among both groups of boys and girls. Interestingly, 50-75% obese children and adolescents will become obese adults with higher prevalence of metabolic disease (type 2 diabetes mellitus (DM)), vascular and musculoskeletal disorders. Obesity triples the risk of cardiovascular disease (CVD), and colon cancer, and increase risk of liver disease and osteoarthritis (Kumar, Robinson, & Till, 2015). Among obese

adolescents, more than 60% have additional risk factor such as hypertension or dyslipidaemia (Turer, Brady, & de Ferranti, 2018). Also, a strong positive association has been identified between abnormal lipid profile in childhood and adolescents and development of coronary heart disease (CHD) later in life (Friedland, Nemet, Gorodnitsky, Wolach, & Eliakim, 2002). The desirable outcome of recommended PA is the remodelling (metabolically and molecular) of skeletal muscle to adjust its glycaemic and lipid profile (Morelli et al., 2020). Therefore, sufficient PA is in the special interest of public health due its positive association with health. Considering that there is a clear theoretical interrelationship between HL and PA, and that PA is linked to favourable lipid profiles, it could be concluded that HL, PA and lipid profiles are the 3 key indicators of good health status.

1.1.4 Lipid profile

Lipid profiles present serum concentrations of lipoproteins, such as total cholesterol (TCHOL), high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides (TG), and is a key determinant for assessing cardiovascular health status (CVHS) (Mann, Beedie, & Jimenez, 2014). Serum lipid abnormalities during chilhood and adolesence are associated with early initiation of the atherosclerosis process which affects CVHS in adulthood, and can lead to poor health outcomes. The prevalence of lipid disorders increases globaly, and 20% of patients aged 12-19 years show dyslipidemia. Approximately, 50% of children with elevated lipid level (above the 75th percentile) will also have elevated lipid levels in adult age (Mainieri, La Bella, & Chiarelli, 2023).

High blood LDL cholesterol levels and triglycerides indicate an increased risk of cardiovascular disease, while increased HDL cholesterol levels indicate a healthy cardiovascular system (Carroll, Kit, & Lacher, 2012). Knowing that inadequate lipid levels in youth may serve as a good predictor for health outcomes in adulthood, the National Heart, Lung, and Blood Institute (NHLBI), and the American Academy of Pediatrics recommended universal screening using non-HDL-C levels to detect lipid disorders in all children 9–11 years old and adolescents 17–21 years old (Shin, Cheong, Cheuh, & Yoo, 2020). Firstly NHLBI recommended universal screening for lipid disorders, suggesting that all children have their lipids tested once between the ages of 9 and 11. Such a test can be carried out with either a fasting lipid profile or a non-fasting test to evaluate non-HDL-C. This universal screening, deviates from previous approaches based on a selective family history, which would potentially

exclude 30-60% of children and adolescents with substantial elevations of cholesterol (Kwiterovich & Gidding, 2012).

Generally, the first line of intervention in case of unsatisfactory lipid levels is lifestyle modificaton, with specific diet and increase of PA. Reduced plasma lipid levels enhanc the ability of muscles to use lipids as a source of energy as opposed to glycogen. Several studies support this, reporting that children and adolescents with higher PAL had improved lipid levels with respect to those with low PAL. For example, one study regarding a sample of youth between the ages of 9 and 18, noted that PAL and physical fitness have a strong association with the lipid profile and a lower risk of coronary heart disease (Katzmarzyk, Malina, & Bouchard, 1999). Furthermore, children and adolescents aged between 6 and 17 years who attained recommended daily PAL had more beneficial HDL cholesterol levels (Baran et al., 2018).

1.2 Research aims and hypotheses

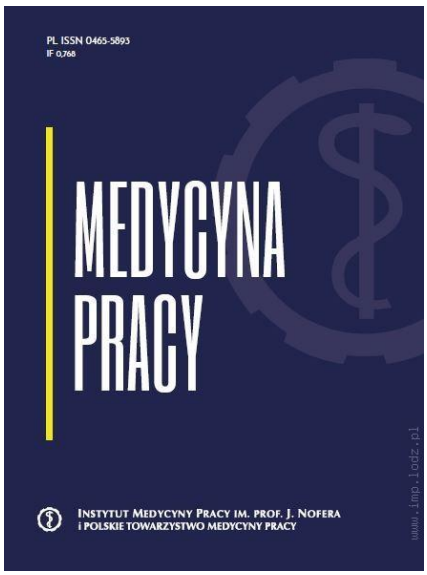
The main aims of this research were: (i) to examine the changes in PAL which occurred as a result of the COVID-19 pandemic, and to examine the age-specific, socio-demographic, familial, and sport-factors as correlates of PAL among younger and older adolescents during the COVID-19 lockdown, (ii) to evaluate the gender-specific associations between HL and PL in a sample of Croatian high school students, (iii) to investigate the associations between HL and PL (on one side) and the lipid profile and PAL (on the other side), and (iv) to determine whether HL and PL are related to scholastic variables (grade point average and school absences) in high school students.

The hypotheses of this research are as follows: (i) observed predictors will positively influence PAL of studied adolescents before and during the COVID-19 lockdown, irrespective of participants age, (ii) HL and PL would not be significantly correlated in gender-stratified analyses, (iii) adolescents with better HL and PL would generally have better CVHS, with some gender differences in established associations, and (iv) students with higher grade point averages and fewer school absences will have higher HL and PL levels.

2 ORIGINAL STUDIES

2.1 Study 1: Differential impact of COVID-19 lockdown on physical activity in younger and older adolescents – prospective study

Geets Kesic, M., Gilic, B., Cerkez Zovko, I., Drid, P., Korovljev, D., & Sekulic, D. (2021). Differential impact of COVID-19 lockdown on physical activity in younger and older adolescents - prospective study. *Medycyna pracy*, *72*(6), 633–643. https://doi.org/10.13075/mp.5893.01180



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ORIGINAL PAPER

DIFFERENTIAL IMPACT OF COVID-19 LOCKDOWN ON PHYSICAL ACTIVITY IN YOUNGER AND OLDER ADOLESCENTS – PROSPECTIVE STUDY

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Abstract

Background: Insufficient physical activity levels (PAL) during adolescence is a major public health concern, which is even more pronounced during the COVID-19 pandemic due to restricting movement opportunities. This study aimed to identify PAL changes and examine the age-specific determinants of PAL in younger and older adolescents during the COVID-19 lockdown. **Material and Methods:** This study included 859 high-school students from Bosnia and Herzegovina stratified into 2 age groups: younger (N = 420, 14–16 years of age), and older adolescents (N = 439, 16–18 years of age). Participants were tested over 2 testing waves: before the COVID-19 lockdown (January 2020) and during the COVID-19 lockdown (April 2020). Variables included PAL assessed by the Physical Activity Questionnaire for Adolescents, sports factors, and parental factors. **Results:** The PAL significantly declined as a result of lockdown measures in the total sample (from 2.76±0.79 to 2.50±0.82). Larger absolute and relative decline of PAL was evidenced in younger adolescents. Sport participation positively influenced PAL before lockdown, with no significant influence during the lockdown. Older adolescents whose mothers were better educated were less likely to be in high risk group with regard to a large decline of PAL as a result of COVID lockdown (OR = 0.50, 95% CI: 0.21–0.84). **Conclusions:** Results of the study suggest that parental education influences health-related behaviors and that parental education is a protective factor against a decrease in PAL during the COVID-19 pandemic. Main educational agents (i.e., school and parents) should pay more attention to provide children and adolescents adequate information and develop their health literacy, which will hopefully positively impact children's PAL even in challenging situations similar to COVID-19 lockdown. Med Pr. 2021;72(6):633–43

Key words: pandemic, youth, sport participation, familial factors, physical activity, health literacy

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2.1.1 Introduction

Engaging in physical activity (PA) in adolescence is one of the main determinants of health status because it has been reported that PA can prevent many non-communicable diseases. Specifically, sufficient PA in adolescence is associated with a reduced risk of metabolic syndrome, obesity, coronary heart disease, and mental disorders [1]. However, it is a worrying fact that 81% of adolescents do not have adequate PA levels (PAL) globally, which

is a major public health concern [2]. Specifically for Bosnia and Herzegovina, recent study recorded that children aged 14 years had 18% lower PAL compared with 10-year-old children, indicating alarming decline of PAL from childhood to adolescents, and the fact that that adolescents should be considered as vulnerable group for decreasing PAL [3]. Therefore, in order to be able to create adequate programs to increase PAL, numerous studies have examined which factors influence PAL among adolescents. In brief, previous studies identified various correlates of PA in adolescents including demographic factors (gender and age), behavioral factors (previous PA, sports participation, smoking and drinking alcohol), social factors (parental and friends support), and environmental factors (population density and living environment) [4]. Precisely, positive associations with PA were continuously confirmed for the male gender, urban living environment, sports participation, parental education, and parental and friends support [5].

Adolescence is the period in which the most pronounced decrease in PAL in life span occurs. In a review study involving children and adolescents aged 10–19 years, it was recorded that the peak in PAL occurs at age 13, and PAL later begins to decrease by 7% annually [6]. Given that a decrease in PAL was recorded in pre-adolescents aged 10–14 years [3], due to dramatic changes in life habits (i.e., drop-out from sports, social influences, increased scholastic duties), an even greater decrease in PAL was expected in older adolescents. Supportively, a study by Miljanovic Damjanovic et al. [7] confirmed this hypothesis. Prospective studies in southeastern Europe additionally confirmed the decline in PAL in adolescents from the first to the second grade of high school (14–15 years of age) [8]; first to the second grade of high school (14–16 years of age) [9]; and third to the fourth grade of high school (16–18 years of age) [10]. Also, age-specific correlates of PAL in younger and older adolescents were observed. Specifically, positive changes in the PAL of younger adolescents were determined mainly by higher parental education [9], while parental conflict and the rural living environment determined a larger decline in PAL among older adolescents [11].

The proclamation of the COVID-19 pandemic in March 2020 has led to the introduction of social distancing measures and reduced movement opportunities. Precisely, stay-at-home restrictions, school closures, and cancellation of sports club practices led to a world-wide decrease in PAL among children and adolescents. Not surprisingly, studies in southeastern Europe recorded a decrease in PAL in adolescents during COVID-19 lockdown [12,13]. Apart from evidencing the changes in PAL, authors examined factors that have influenced changes in PAL among adolescents. Briefly, a greater decrease in PAL was observed in boys than in girls;

the reduction in PAL was greater in urban than in rural adolescents, conflict with parents determined a larger decline in PAL, adolescents with better fitness status before pandemic had higher PAL during the pandemic [13], adolescents that participated in sports activities before the pandemic were more likely to have higher PAL during the pandemic [12], while adolescents who smoked cigarettes had lower PAL levels during the pandemic [12,13].

From the previous literature review, it is evident that studies extensively examined changes in PAL as a result of the COVID-19 pandemic and factors which could influence such negative changes. However, practically all studies done so far examined adolescents of a relatively large age span (i.e., 14–18 years old, high-school students). More precisely, previous studies done in regular circumstances confirmed that younger adolescents had higher PAL than older adolescents and that different factors influence changes in PAL among older and younger adolescents [11]. Supportively, a study on Chinese adolescents noted that younger adolescents (12–15 years) had higher PAL than older adolescents (15–18 years) during the COVID-19 pandemic [14]. Finally, it seems that trends of higher PAL in younger age groups is characteristic even for lockdown period, since recent study evidenced that Canadian children (5–11 years) were more physically active than youth (12–17 years) during lockdown [15].

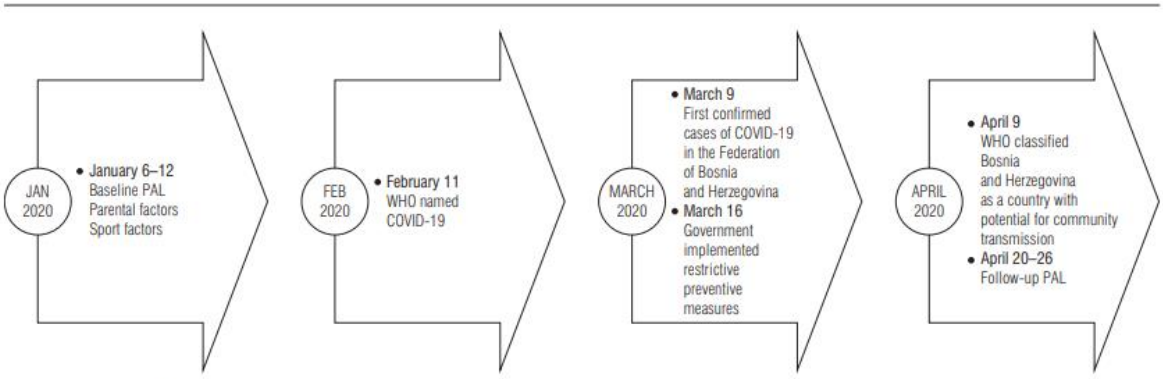
Collectively, there is a lack of prospective data about changes in PAL during the COVID-19 pandemic in different age groups of adolescents (i.e., younger adolescents aged 14–16 years vs. older adolescents aged 16–18 years). Also, to the best of the authors' knowledge, no study examined factors that may influence changes in PAL, which occurred during the COVID-19 pandemic, specifically in younger vs. older adolescents. Therefore, the aim of this study was to examine the changes in PAL which occurred as a result of the COVID-19 pandemic, and to examine the age-specific socio-demographic, familial, and sport-factors as correlates of PAL among younger and older adolescents during the COVID-19 lockdown. The authors hypothesized that observed predictors will positively influence PAL of studied adolescents before and during the COVID-19 lockdown, irrespective of participants' age. This data is vital in developing targeted interventions in terms of improving PAL during COVID-19 lockdown and similar crises in different age groups.

2.1.2 Material and methods

Participants and design of the study

This research included 859 students attending high schools from several regions in Bosnia and Herzegovina (Tuzla, Herzegovina-Neretva, and West Herzegovina Canton). For the purpose of this study, the total sample was stratified into two subsamples: younger adolescents (N = 420, 14–16 years of age at study baseline) and older adolescents (N = 439, 16–18 years of age at study base-line). Before the study initiation, students regularly attended physical education classes at least twice a week. The response rate (based on responses at follow-up – please see later for details on design), was 86%. All participants gave their informed consent, and a parent or a legal guardian gave their approval for those participants younger than 18 years. The investigation was approved by the Ethical Board of the University of Split, Faculty of Kinesiology, Croatia (EBO: 2181-205-05-02-05-14-005).

This prospective study was commenced over 2 testing waves: 1) baseline, representing the measurement before implementation of the social distancing measures due to the COVID-19 pandemic (January 2020), and 2) follow-up, representing the measurement during the period when social distancing measures were implemented (i.e., COVID-19 lockdown; late April 2020). Baseline measurement included socio-demographic factors, parental/familial factors, sport factors, and baseline PAL. Follow-up measurement was conducted during the lockdown and included only follow-up PAL. In order to preserve participants' anonymity and collect more honest and precise answers in the questionnaire, students were asked to create their personal code and use it at baseline and follow-up measurement. The design of the study and detailed information about the study period are presented in Figure 1.



PAL – physical activity levels.

Figure 1. Timeline of the study done in Bosnia and Herzegovina and most important dates in first half of 2020

Variables

This study included socio-demographic factors (age, gender), parental/familial factors, sport factors (independent variables), and PAL (dependent variable).

The Physical Activity Questionnaire for Adolescents (PAQ-A) was used for assessing baseline and follow-up PAL [16]. PAQ-A has been frequently used for assessing PAL at similar samples of adolescents and has displayed appropriate validity and reliability [7,10]. It is a self-administered questionnaire that assesses the frequency of PA during the last 7 days. It consists of 9 items, first 8 assess PA during spare time, during physical education classes, after school, during evenings, and during the weekend, and are scaled 1–5, representing low and high PA, respectively. The ninth item questions whether participants were injured or ill and is not included in the final score, which is calculated as the arithmetic mean of the first 8 items. In this study, the authors observed crude results of PAL at baseline (PALBL), and PAL at follow-up (PALFU). Next, crude PAL was also observedas the binomial variable with 2 categories: results; insufficient/inadequate vs. sufficient/adequate PAL (scores≤2.73 and >2.73, respectively), as suggested previously [17]. Further, to quantify the changes in PALBL and PALFU, the authors calculated crude numerical difference between these 2 values (PALΔ = PALBL – PALFU). Next, the authors calculated relative changes in PAL between baseline and follow-up (in %) using the calculation: PALΔ% = (PALBL – PALFU) / PALBL × 100. For the purpose of later statistical calculations, participants were ordered according to their PALΔ%, and then grouped into 2 groups (0–50 percentiles, and above). The participants with a greater relative decline of PAL (ordered >50 per- centiles) were evidenced as “high risk group”, while those placed in the first 50 percentiles were evidenced as “low risk group”. Such dichotomization allowed the authors to calculate logistic regression for PALΔ% as a binomial criterion (please see later for details).

Parental/familial factors included the following variables: self-reported socioeconomic status (below average–average–above average); maternal and paternal education level (university degree-college degree-high school-elementary school); conflict with parents (never–rarely–from time to time-regularly/frequently); parental absence from home (never–rarely–from time to time-regularly/frequently); and parental/familial care (very poor care–low care–my parents/family care about me–my parents/family care about me a lot).

Sports factors were assessed by questions on participation in individual or team sports (with answers: never been involved–quit–currently involved), best results in competitions (with answers on a 4-point scale ranging from “never competed” to “international competitions”),

and years of involvement in sports (with answers: never involved–less than one year–two to five years–more than five years).

Statistics

Normality of the distribution was checked by Kolmogorov Smirnov's test, and descriptive statistics included means and standard deviations (for numerical variables) and frequencies and percentages (for ordinal and nominal variables).

Differences between groups were evidenced by t-test for independent samples (for quantitative variables), and Chi square ($\chi 2$). T-test for dependent samples was used to identify the changes in PAL between baseline (pre-pandemic period) and follow-up (lock-down period).

Logistic regression (with Odds Ratio – OR, and Confidence Interval – CI reported) was applied to evidence the association between predictors and categorized PAL (insufficient PAL – coded as "1" vs. sufficient PAL – coded as "2") at baseline and follow-up.

Also, in order to identify the association which may exist between predictors and changes that occurred in PAL, the authors additionally calculated logistic regression with dichotomized PALΔ% as a criterion (low-risk group – coded as "1" vs. high-risk group – coded as "2").

All analyses were stratified for age groups (e.g., younger vs. older adolescents).

A p-value of 95% was applied, and the Statistica ver. 13.5 statistical package (Tibco Inc., CA) was used for all calculations.

2.1.3 Results

Age groups significantly differed in self-perception of socioeconomic status, with somewhat better familial socioeconomic status among older adolescents ($\chi 2 = 9.05$, $p < 0.01$). Younger adolescents were more involved in individual sports ($\chi 2 = 25.76$, $p < 0.01$), and team sports ($\chi 2 = 35.71$, $p < 0.01$) than older adolescents, while sport achievement was higher in older adolescents ($\chi 2 = 23.76$, $p < 0.01$) at baseline testing (Table 1).

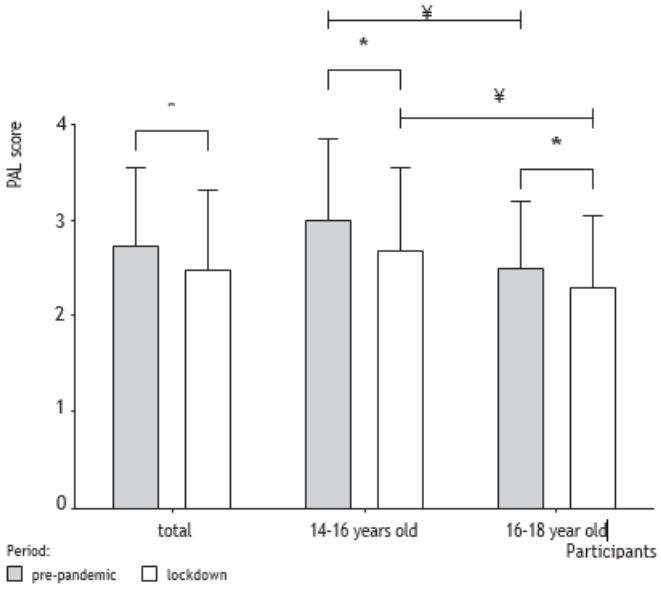
Table 1. Descriptive statistics and differences between age groups of adolescents from Bosnia and Herzegovina in early 2020

Variable	Participants (N = 859)				χ^2	p
	14–16 years old (N = 420)		16–18 years old (N = 439)			
	n	%	n	%		
Socio-demographic and familial/parental status						
gender					0.79	0.37
males	244	58.10	239	54.44		
females	176	41.90	195	44.42		
socio-economic status					9.05	0.01
below average	46	10.95	28	6.38		
average	368	87.62	405	92.26		
above average	1	0.24	6	1.37		
paternal education					0.07	0.96
elementary school	28	6.67	31	7.06		
high school	303	72.14	317	72.21		
college/university degree	89	21	91	21		
maternal education					0.19	0.90
elementary school	98	23.33	108	24.60		
high school	269	64.05	276	62.87		
college/university degree	53	12.62	55	12.53		
parental conflict					0.12	0.98
never	162	38.57	174	39.64		
rarely	162	38.57	165	37.59		
from time to time	82	19.52	85	19.36		
often	14	3.33	15	3.42		
parental absence					0.23	0.97
never	78	18.57	87	19.82		
rarely	92	21.90	95	21.64		
from time to time	157	37.38	163	37.13		
often	92	21.90	93	21.18		
parental care					0.05	0.99
very poor care	6	1.43	11	2.51		
low care	11	2.62	6	1.37		
they care about me	144	34.29	148	33.71		
they care a lot	259	61.67	274	62.41		
Sport factors at baseline testing						
individual sport participation					25.76	0.01
currently involved	112	26.67	94	21.41		
quit	83	19.76	156	35.54		
never been involved	221	52.62	189	43.05		

Table 1. Descriptive statistics and differences between age groups of adolescents from Bosnia and Herzegovina in early 2020 – cont.

Variable	Participants (N = 859)				χ^2	p
	14–16 years old (N = 420)		16–18 years old (N = 439)			
	n	%	n	%		
Sport factors at baseline testing – cont.						
team sport participation					35.71	0.01
currently involved	168	40.00	102	23.23		
quit	106	25.24	181	41.23		
never been involved	144	34.29	156	35.54		
sport experience					7.70	0.07
never been involved	109	25.95	106	24.15		
<1 year	67	15.95	101	23.01		
2–5 years	150	35.71	129	29.38		
>5 years	89	21.19	103	23.46		
sport achievement					23.76	0.01
never competed	193	45.95	215	48.97		
lower rank competition	149	35.48	190	43.28		
regional competition	50	11.90	25	5.69		
national/international level	21	5.00	5	1.14		

At baseline, 55% of younger and 43% of older ado- lescents had sufficient PAL, while only 35% of younger and 28% of older adolescents had sufficient PAL at follow-up (during lockdown). Observing in crude PAQ-A results, the PAL significantly declined as a result of lock-down measures in the total sample (from 2.76±0.79 to 2.50±0.82, $p < 0.001$), and separately in older adolescents (from 2.52±0.68 to 2.31±0.74, $p < 0.01$), and in younger adolescents (from 3.02±0.82 to 2.71±0.85), $p < 0.001$. Younger adolescents had higher PAL than their older peers at baseline (before lockdown) and follow-up (during lockdown) (Figure 2). Significant differences between age groups were evidenced in PALΔ (t-test = 1.98, $p < 0.01$), with larger decrease in younger adolescents, than in older adolescents (0.31±0.80 and 0.21±0.68 for younger and older adolescents, respectively), with significant difference in PALΔ% between age groups (t-test = 1.76, $p = 0.04$).



Significant ($p < 0.001$) differences between (¥) and within groups (*).

Figure 2. Descriptive statistics, changes and t-test differences in physical activity levels (PAL) before and during the COVID-19 lockdown in Bosnia and Herzegovina in 2020

Table 2 presents results of logistic regression analysis for dichotomized PAL at baseline and follow-up as criterion variable (insufficient vs. sufficient PAL). In brief, for the pre-pandemic period, sufficient PAL was more likely to be achieved in males (for both age groups), in adolescents whose fathers were better educated (only among younger adolescents), in adolescents whose mothers were better educated (for both age groups), in adolescents who participated in individual sports (for both age groups), and those who participated in team sports (for both age groups). Sufficient PAL during the lockdown period was more likely to be achieved in males (for younger adolescents), adolescents whose mothers were better educated (for the older group), adolescents who declared better parental care (for the older group), those who participated in individual sports (for younger age group), and those who achieved better sport success (for younger age group).

Table 2. Associations between independent variables and physical activity levels (sufficient physical activity – reference group) before and during COVID-19 lockdown in younger and older adolescents from Bosnia and Herzegovina in early 2020

Variable	Pre-pandemic period				Lockdown period			
	14–16 year old participants (N = 420)		16–18 year old participants (N = 439)		14–16 year old participants (N = 420)		16–18 year old participants (N = 439)	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Male gender	1.25	1.09–1.4	1.2	1.01–1.44	1.11	1–1.21	1.09	0.88–1.38
Socio-economic status	0.99	0.5–1.5	0.98	0.6–1.42	0.99	0.44–1.6	1.02	0.55–1.59
Paternal education	1.61	1.25–1.88	1.44	0.98–1.88	1.32	0.8–1.76	1.3	0.45–2.32
Maternal education	1.55	1.21–1.86	1.74	1.44–2.05	1.32	0.88–1.71	1.66	1.11–2.2
Parental conflict	0.78	0.44–1.11	0.8	0.5–1.1	0.88	0.45–1.11	0.81	0.32–1.44
Parental absence	0.75	0.44–1.09	0.8	0.61–1.02	0.91	0.77–1.33	0.95	0.46–1.41
Parental care	0.89	0.65–1.21	0.9	0.7–1.11	1.21	0.98–1.56	1.31	1.02–1.61
Individual sports	2.09	1.5–2.61	1.66	1.33–1.99	1.45	1.03–1.88	1.21	0.81–1.65
Team sports	2.21	1.95–2.55	2	1.75–2.28	1.28	0.71–1.76	1.11	0.45–1.88
Sport experience	1.92	1.71–2.21	1.44	0.97–1.98	1.09	0.51–1.65	1	0.87–1.36
Sport achievement	1.84	1.11–2.5	1.22	0.74–1.75	1.54	1.11–1.91	1.21	0.66–1.89

Figure 3 presents associations between studied predictors and PALΔ%, separately for younger and older adolescents. The only significant predictor was the level of maternal education. More precisely, older adolescents whose mothers were better educated were less likely to be in "high-risk group" with regard to a large decline of PAL as a result of COVID lockdown (OR = 0.50, 95% CI: 0.21–0.84).

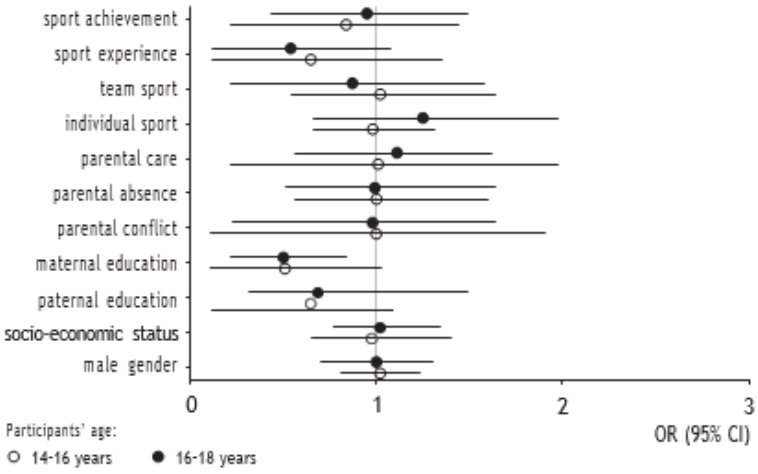


Figure 3. Associations between independent variables and relative changes in physical activity levels ($PAL_{\Delta\%}$) in younger and older adolescents (with group of higher risk for large decrease of PAL as reference category) from Bosnia and Herzegovina in 2020

2.1.4 Discussion

The main aim of this study was to investigate the impact of mainly scholastic factors on PAL, and changes in PAL during the COVID-19 pandemic in younger and older adolescents. Apart from the expected decrease of PAL as a result of COVID-19 lockdown, there are several most important findings of this study. First, a larger absolute and relative decrease of PAL was evidenced in younger adolescents. Second, maternal education was a stronger factor of influence on PAL in older (16–18 years) adolescents. Third, a lower decrease of PAL was evidenced in older adolescents whose parents were better educated. Therefore, the authors' initial hypothesis might be partially accepted.

PAL changes in younger and older adolescents

The total sample of participants declined their PAL. This is in accordance with previous studies conducted on adolescents globally, including the adolescents from Bosnia and Herzegovina and neighboring countries [12–14,18]. However, the novel finding of this study is that younger adolescents had higher PAL than older adolescents in the pre-COVID period, with no significant difference between age groups in PAL for the pandemic period. Almost certainly, the lack of differences in PAL between age groups during COVID-19 lockdown can be attributed to a larger decline in PAL due to COVID-19 lockdown in younger adolescents. On the other hand, both findings (higher pre-pandemic PAL, and greater decrease of PAL in younger adolescents) may be associated with participation in sports.

In brief, the results of the study confirmed higher involvement in sports among younger adolescents (please see Results for details). The participation in sports contributes to a large part of the total PAL in children and adolescents [19]. It was repeatedly reported that adolescents involved in organized sports activities have significantly higher PAL than their peers who do not participate in sports [20]. Further, it is known that there is the largest sport drop-out rate at the age of 14–15 years [21]. Evidenced differences in sports participation between younger and older adolescents are likely to occur due to increased commitments, lack of free time, focus on academic achievement [6], socialization with friends in sedentary activities, and employment in older adolescents [20].

It is also important to note that the high-school period is known for dropping out of sport as adolescents are mainly oriented towards competitive success in sports. At the same time,

adolescents are not sufficiently educated about the importance of PA and its' positive impact on health [22]. Supportively, a study on adolescents from Portugal suggested that the degree of participation in sports is related to competitive sport achievement, which limits participation only to students who have better physical predispositions and who are talented [23]. Meanwhile, another Portuguese study highlighted insufficient education about the importance of the impact of PA on health as an even more likely cause of giving up sports [24].

Collectively, older adolescents in this study have lower PAL most likely as a consequence of dropping out from organized sports, compared to younger adolescents who are not yet at the point of the decision to continue or stop sports participation. Putting it altogether, it is absolutely logical that younger adolescents reduced their PAL to a greater extent during the COVID-19 lockdown simply because they did not have the opportunity to participate in sports activities during follow-up (i.e., sports clubs, facilities, and organized recreational activities were closed and banned during the lockdown period). Finally, as younger adolescents generally had higher PALs than older adolescents in the pre-lockdown period, it is understandable that their PAL decreased to a larger extent than the PAL of their older peers.

Parental factors and PAL before and during lockdown

Parental education is known to be an important factor of influence on children's PAL [25], and the authors' results of the study support such considerations. The association can be explained through the background of general parents' influence on the behavioral patterns of their children. Precisely, parents with their attitudes, values, and knowledge guide their children to form their own behavioral patterns, including participating in any form of PA [25]. Parents are acting as role models to their children, meaning that parents who are physically active and who promote PA with their behavior positively influence PA habits of their children.

This phenomenon occurs according to the theory that children imitate parents and their habits, which means that children are likely to adopt PA habits as well. Besides the importance of role modeling and parental encouragement, attitudes and tangible support are considered as important determinants of parental influence on children's PAL. Thus, parents with higher educational levels may better perceive the health-related benefits of PA, which will provoke greater parental support and encouragement for PA and influence the overall formation of healthy habits of their children.

Previous studies noted somewhat different influences of maternal and paternal education on their children's PAL. Specifically, fathers are more likely to act as role models for PAL and sports activities compared with mothers. Furthermore, fathers more frequently engage in PA and are actively involved in PA with their children in terms of co-physical activities [26]. On the other hand, mothers have a great role in their children's educational achievement, which includes health-related education. Supportively, a study on Nigerian children noted that mothers with higher education levels had better knowledge of PA [27]. It is assumed that better educated and informed mothers possess higher health literacy skills that they transmit to their children and create a positive influence on making healthier decisions and encouraging children to participate in PA and other health behaviors [28].

Therefore, the authors' finding that maternal education positively influences PAL during the COVID-19 lockdown in older adolescents could be explained in the context of the situation and period when the study was conducted. Namely, during the pre-pandemic period, adolescents regularly participated in sports, and consequently, fathers probably had a stronger influence on their PAL. Meanwhile, during the COVID-19 lock-down, adolescents were required to stay at home due to movement restrictions (school and sports facilities closure). Therefore, they were probably more exposed to the control and influence of mothers.

The study recorded that the influence of maternal education on PAL in children was more pronounced in older adolescents. A recent study evidenced that younger adolescents (14–16 years of age) with better-educated mothers and fathers had a higher likelihood of having sufficient PAL in regular circumstances [9]. However, a study on older adolescents (16–18 years of age) evidenced that paternal education was correlated with adolescents' PAL aged 16 years old, but at the age of 17 years, the correlation started to weaken [11]. Moreover, prospective studies on older adolescents (16–18 years old) reported that adolescents with more educated mothers are more likely to incline PAL during late adolescence [7,10]. This altogether indicates that the influence of paternal education on their children's PAL weakens during late adolescence, while the level of maternal education remains the significant influential factor on PAL even in late adolescence.

This is one of the first studies to prove that parental education acts as a preventive factor against a decrease of PAL during a COVID-19 lockdown. The results of this study can be supported by recent research on Spanish children, which recorded a more evident PAL decline during the COVID-19 lockdown in children (10–14 years) whose mothers were less-educated [29]. However, the authors' results of this study extend the previous knowledge regarding

factors of influence on changes in PAL during the COVID-19 lockdown, since the authors investigated older children/adolescents (16– 18 years of age) than authors' Spanish colleagues, and showed a significant influence of both maternal and paternal educational levels on changes in PAL.

The fact that maternal education prevents the decline of PAL leads the authors to conclude that children of better-educated mothers are physically active more because of health-related issues and not because of involvement in competitive sports. Also, it is reasonable to hypothesize that older adolescents had better "health literacy" and that they knew how important it was to maintain appropriate PAL even during the lockdown. If the authors define health literacy as "the ability to selectively access and analyze information and to take action to promote personal and someone else's health behaviors" [30], the preventive effect of better maternal education on the decrease of PAL during lockdown is understandable.

Supportively, previous studies noted that adolescents who had better fitness status and were involved in sports before the pandemic efficiently maintained PAL during the pandemic [12,13]. The authors explained this finding with the term "physical literacy" precisely, with the assumption that adolescents of advanced fitness status have sufficient knowledge and motivation to create exercise programs themselves even with limited equipment and space during the lockdown. Health literacy and physical literacy, although not the same, are considered to be lifelong health-promoting behaviors [30]. Therefore, it is likely that adolescents whose mothers were better educated had better health literacy, recognized the importance of PA for their health, and strived to maintain PAL even during COVID-19 lockdown.

Considering all the above mentioned, it is not surprising that the authors have found a stronger influence of maternal education on PAL in older than in younger adolescents. It can be assumed that mothers influence adolescent habit formation and that older adolescents will more likely recognize and use it. On the other hand, younger adolescents are still in the process of forming their habits and may not yet be able to identify and choose what is good for them in terms of healthy behavior. In other words, younger children are more likely to participate in PA because of fun and parental supervision, while older children are more likely to participate in PA because they know what the health benefits of the PA are [10].

Limitations and strengths

Most of the variables were self-reported, which could be considered as the main limitation of the study. Precisely, students might answer some questions not completely honestly and provide more socially desirable answers. However, participants filled in questionnaires anonymously (for the purpose of repeated testing they use confidential codes); therefore, leaning towards socially desirable answers was less likely. In this research results on PAQ-A were clustered into 2 groups, which undoubtedly allocated participants with similar results into opposed groups. In the future studies division into three groups is therefore suggested.

This is one of the first studies investigating the changes and correlates of PAL during the COVID-19 lockdown in relation to age groups of adolescents (younger and older adolescents). Therefore, this study expands the knowledge on physical activity in adolescents during the COVID-19 pandemic and other similar situations and creates the background for future research. Additionally, this study used a measurement instrument (PAQ-A) which is widely used in studies on similar participants; therefore, the results of this study could be compared with other similar studies.

2.1.5 Conclusions

The greater decline in PAL during the COVID-19 lock-down was evidenced in younger adolescents compared to older adolescents, which was attributed to higher pre-pandemic PAL of younger adolescents and younger adolescents' higher engagement in sports in the pre-pandemic period.

This study's results can be considered great value for creating public-health policies for improving PAL in adolescents in regular circumstances and in situations similar to COVID-19 lockdown. Specifically, in order to achieve proper PAL, younger adolescents should be encouraged to continue participating in sports with an emphasis on the health benefits of PA and not on competitive achievements.

Schools or sports clubs should promote sports as health-enhancing behavior and teach children to participate in sports for their health regardless of competitive achievement. It will have direct positive repercussions on PAL in situations similar to COVID-19 lockdown when circumstances will limit regular sports participation. In such situations, adolescents with better

health literacy will be able to recognize the importance of PA and will try to maintain sufficient PAL. Further studies are needed in order to:

- evaluate a specific insight into various components of PAL during lockdown (i.e., physical education, sports, and free time),
- overview the changes which occur in each component, and
- investigate the factors of influence on changes in each component.

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2.2 Study 2: Are Health Literacy and Physical Literacy Independent Concepts? A Gender-Stratified Analysis in Medical School Students from Croatia

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Are Health Literacy and Physical Literacy Independent Concepts? A Gender-Stratified Analysis in Medical School Students from Croatia

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Abstract: Health literacy (HL) and physical literacy (PL) are concepts responsible for achieving and maintaining positive health behaviors. This study aimed to investigate gender-specific associations: (i) between PL and HL; and (ii) among HL, PL, and body composition. We observed 253 students attending health-area high schools from southern Croatia (181 girls; 16.9 ± 1.4 years). HL was assessed by the European Health Literacy Survey Questionnaire, PL by the PLAYself questionnaire, and body composition by bioimpedance analysis. The *t*-test was used to assess the differences between genders, and Pearson's correlation coefficients were calculated to establish the associations between variables. The results showed a similar level of HL (*t*-test = 0.2; $p = 0.83$) and PL (*t*-test = 0.01; $p = 0.99$) in boys and girls. Significant but small correlations were identified between HL and PL only in the girls (<10% of common variance). The body composition indices were significantly correlated with PL only in the boys (15–20% of common variance). Our research highlights the necessity of the independent evaluation of HL and PL in adolescence. Further studies evaluating other indices of health status in relation to PL and HL are warranted.

Keywords: health behaviors; knowledge translation; public health; community-engaged research; youth; body build

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2.2.1 Introduction

From the perspective of public health, adolescence is one of the most important stages of life, because in this period individuals shape their own health behavior, as parental control decreases and the adolescent's autonomy increases [1]. In other words, adolescents make health decisions that will determine their health outcomes in later stages of life. Among the most important factors of health behavior in this period of life are nutritional habits, the level of physical activity, and substance misuse (i.e., alcohol and tobacco consumption). Indeed, education regarding physical activity and healthy nutrition begins from a very young age (i.e., as a child) in the perspective of active games [2]. This emphasizes the importance of early education and the acquisition of healthy habits, related to improved physical fitness and cardio-metabolic health [3].

Worryingly, more than 80% of children and adolescents do not have sufficient physical activity levels [4]. Globally, the prevalence of tobacco and alcohol consumption has increased [5], and youth have poor nutritional habits [6]. All of the factors mentioned above are considered leading causes of chronic noncommunicable diseases and could be prevented with adequate health-promoting strategies [7]. Thus, it is crucial to identify the determinants and concepts that influence the formation of adolescents' health behaviors to prevent adverse health outcomes. Several concepts and skills are deemed important in order for adolescents to adopt, nurture, and maintain healthy behaviors, including health literacy and physical literacy [8,9].

Health literacy (HL) is defined as "the characteristics and social resources needed for people to access, understand and use information to make decisions about health. HL includes the capacity to communicate, assert and enact these decisions" [10]. Therefore, HL has been accepted as an effective concept for health promotion [11]. Indeed, in a comprehensive review, it was shown that the individuals with lower HL had poorer global health status, were more likely to express symptoms of depression, and had higher all-cause mortality rates [8]. In addition, a study on Indonesian adolescents identified that HL was related to health behaviors, including physical activity [12], while another study recorded that HL was associated with health-related quality of life (i.e., self-perception of mental and physical health conditions) among Chinese schoolchildren [13]. Moreover, low levels of HL were linked to increased body weight and obesity [14,15] and poor nutritional habits, including increased sugar, fat, and salt intake in children and adolescents [16].

Another important concept for achieving positive health behaviors and outcomes is physical literacy (PL). The most commonly used definition of PL is: "the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engagement in physical activities for life" [17]. Thus, it has been suggested that PL should be considered a determinant of health, as it leads to increased physical activity resulting in improved physical, social, and mental health [18]. Indeed, numerous studies reported a positive relationship between PL and health indicators [9,18,19]. A review study by Cornish et al. (2020) reported that PL was associated with numerous health indicators, including body mass index, waist circumference, body weight, cardiorespiratory fitness, systolic blood pressure, health-related quality of life, and physical activity [9]. Moreover, in Spanish children, body composition was correlated to PL, with BMI, fat mass, and percentage of fat mass being inversely related to lower PL scores [19]. Similarly, a study on Canadian children and adolescents found a negative relationship between PL and the percentage of fat mass [20].

Based on Bandura's social cognitive theory, the determinants of one's behaviors include self-efficacy (defined as an individual's belief in their capability to organize and carry out actions to reach results), attitude, knowledge, and social support [21,22]. From the previous brief descriptions of HL and PL, it can be theorized that HL and PL are associated with the social cognitive determinants of health behavior, with an emphasis on self-efficacy and knowledge, and could be responsible for influencing health outcomes. However, the interrelationships between HL and PL are rarely reported, while there is an evident lack of knowledge on the associations that may exist among HL, PL, and body composition as important determinants of health status in adolescence. The main aim of the study was to evaluate the gender-specific associations between HL and PL in a sample of Croatian high school students. Additionally, we examined gender-specific associations between PL, HL, and body composition. Initially, we hypothesized that HL and PL would not be significantly correlated in gender-stratified analyses. As a methodological remark, we must note that the previous studies on adolescents regularly confirmed differences between genders in PL, HL, and body composition [23–26]. Therefore, we considered a gender-stratified analyses as being more appropriate in studying the relationships among PL, HL, and body composition. Otherwise, the difference between the genders could influence the results of the correlation analyses (i.e., gender could be a covariate), resulting in inappropriate and ecologically non-valid findings/conclusions.

2.2.2 Materials and methods

Participants and Design of the Study

In this cross-sectional study, the participants were 253 adolescents (16.9 1.4 years of age, 181 females) attending health-area high schools in Split-Dalmatia County, in southern Croatia. On the basis of a correlation between HL and PL of 0.30, established in a pilot study on Croatian college students [27], with a type-I-error rate of 0.05, and a type-II-error rate of 0.20, the necessary sample size was 85 participants [28]. The inclusion criterion for the study was that the mean age of the participants fell within the World Health Organization's (WHO) definition of adolescents (10–19 years of age). The exclusion criterion was students with acute inflammatory disease (e.g., COVID-19).

The study was approved by the Ethical Board of the University of Split, Faculty of Kinesiology (EBO: 2181-205-02-01-21-0011; date of approval, 23 September 2021). After

ethical approval, one of the first authors of the study presented the aim and procedure of the study to all of the school classes. The written informed consent was signed by the interested student, or by a parent/legal guardian (for those younger than 18 years), prior to the study's initiation. Therefore, 400 consent waivers were distributed. A total of 295 waivers were recovered, with a response rate of 74%. The participants were aware that they could withdraw from the study at any time. In total, 42 participants withdrew, which resulted in a final sample of 253 participants. The measurements were conducted in April and May 2022, during the school day from 08:00 am to 10:00 am.

The study variables and idea of the investigation are presented in Figure 1.

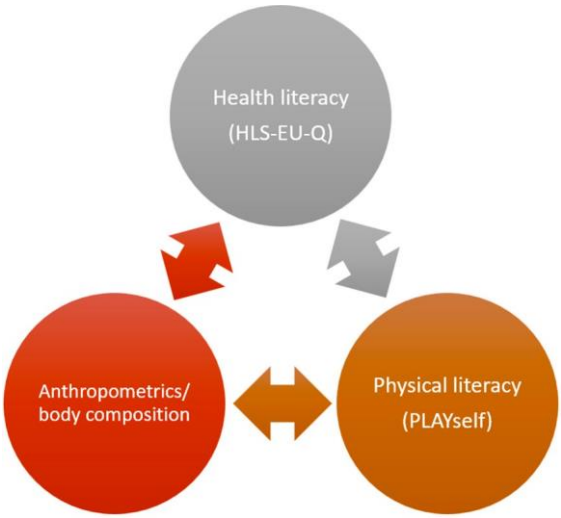

Figure 1. Study variables and studied associations.

Variables and Measurement

The variables included evaluation of HL, PL, and anthropometric/body-build indices.

The HL was evaluated using the European Health Literacy Survey Questionnaire (HLS-EU-Q), developed by Sorensen et al. [29]. The HLS-EU-Q comprises 47 questions, which measure an individual's ability to access, understand, appraise, and apply health-related information [30]. The general index of HL was constructed using a 4-point Likert scale, with responses from very difficult 1 to very easy 4. The score was calculated using the following formula: index = (mean - 1) x (50/3). The HL scale (from 0 to 50) was formed, where 0 represented the lowest and 50 the highest score. Four levels of HL were defined: inadequate (from 0 to 25); problematic (26–33); sufficient (34–42); and excellent (43–50). The HLS-EU-

Q was first translated from English into Croatian and then back-translated by two different professional translators. Geets-Kesic et al. (2022) conducted the survey among 134 Croatian students and demonstrated that the HLS-EU-Q had good reliability (Kappa:0.79, with 91% of the answers equally responded to) [27]. The HLS-EU-Q was evaluated using the online platform SurveyMonkey (SurveyMonkey Inc.,San Mateo, CA, USA).

The PL was evaluated by the PLAYself questionnaire. It is a self-assessment questionnaire designed to evaluate the current degree of PL. Four groups of questions measure (i) the affective and cognitive aspect of PL; (ii) the environmental ability; (iii) the estimation of literacy, numeracy, and physical literacy in different settings; and iv) fitness [31]. The final score was the sum of the first three groups of questions divided by the number of questions. A total score of 100 points indicated the highest self-perceived PL. In this study, we used the Croatian version of the PLAYself questionnaire, which was previously shown to be reliable and valid among Croatian adolescents [32,33]. PLAYself was conducted using the online platform SurveyMonkey (SurveyMonkey Inc., San Mateo, CA, USA).

The anthropometric/body-build indices included measurement of body mass (in 0.1 kg), body height (in cm), fat free mass (in 0.1 kg), visceral fat (level), and muscle mass (in 0.1 kg), while the body mass index (BMI = mass (kg)/height2(m)) was also calculated. The body composition was measured by the bioimpedance scale (Tanita BC 418 scale; serial number: 15010067, 2015, Tanita, Tokyo, Japan). The measurement was completed in the school laboratory by a medical doctor—the first author of the study (privacy was secured) at room temperature in the morning from 08:00 to 10:00. Prior to the measurement, the procedure and protocol were explained to each student. During the measurement, students were dressed in their underwear, and they were barefoot.

Statistical Analysis

The normality of the distributions was checked by the Kolmogorov–Smirnov test of normality. All of the variables were evidenced as being normally distributed, and the means and standard deviations were reported.

The t-test for independent samples was used to determine the possible differences between the boys and girls.

Pearson's product moment correlation coefficient, as a measure of correlation between normally distributed variables, was calculated to evaluate the association between the pairs of variables, and this was performed for the total sample, and was gender-stratified.

Statistica 13.5 (Tibco Inc, Palo Alto, CA, USA) was used for all of the calculations, and p-value of 0.05 was applied.

2.2.3 Results

The descriptive statistics for the measured variables and differences between the genders are presented in Table 1. In brief, the boys and girls differed significantly in the anthropometric-body composition measures; the boys were taller, heavier, had a lower level of body fat, and more muscle mass than the girls. Generally, there were no significant differences between the genders in HL and PL, except for the PLAY literacy sub-score where the girls achieved higher results than the boys.

Table 1. Descriptive statistics and differences between genders in study variables.

	Boys (n = 68)		Girls (n = 198)		t-Test	
	Mean	Std. Dev.	Mean	Std. Dev.	t-Value	p-Value
Age (years)	17.08	1.31	16.96	1.41	0.62	0.53
Body height (cm)	180.97	14.30	169.27	6.53	9.10	0.001
Body mass (kg)	74.40	12.49	64.48	11.15	6.13	0.001
BMI (kg/m^2)	24.06	15.30	22.44	3.29	1.40	0.16
Fat mass (kg)	12.73	5.59	18.30	7.36	−5.70	0.001
Fat mass (%)	16.61	4.98	27.42	6.39	−12.69	0.001
Free fat mass (kg)	61.68	8.55	46.36	5.32	17.31	0.001
Muscle mass (kg)	58.90	8.11	43.89	4.45	19.04	0.001
Visceral fat (kg)	2.14	1.51	1.81	1.21	1.18	0.24
PLAYself $_{\text{environment}}$ (sub-score)	50.86	15.23	51.16	15.43	−0.13	0.89
PLAYself $_{\text{self-description}}$ (sub-score)	73.68	14.51	70.24	15.06	1.63	0.10
PLAYself $_{\text{literacy}}$ (sub-score)	72.51	16.25	83.11	17.31	−4.39	0.001
PLAYself $_{\text{numeracy}}$ (sub-score)	60.06	21.28	61.07	22.70	−0.32	0.75
PLAYself $_{\text{physical literacy}}$ (sub-score)	82.59	18.04	86.60	19.45	−1.48	0.14
PLAYself total (score)	68.05	11.04	68.03	11.36	0.01	0.99
HLS- EU-Q (score)	37.87	6.53	38.06	6.54	−0.21	0.83

Legend: PLAY = Physical literacy Assessment of Youth; HLS-EU-Q = European Health Literacy Survey Questionnaire.

The correlations between the study variables for the total sample of participants are presented in Table S1 (Supplementary Materials).

For the boys, the correlations between variables are presented in Table 2. Apart from significant correlations between the anthropometric/body composition variables (moderate to strong

correlations between the body composition indices and body mass; >35% of the common variance), and the significant correlations among the PLAYself sub-scores and the PLAYself total score (25–82% of the common variance), the associations between anthropometric/body composition with PL were small. Specifically, the indices of adipose body mass were significantly correlated to PL, with 16–20% of the common variance. Finally, the anthropometric/body composition indices were not significantly correlated to HL for the boys.

Table 2. Correlations between study variables for boys (* indicates coefficients significant at $p < 0.05$).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Age (1)	-													
Body height (2)	0.10													
Body mass (3)	0.25 *	0.28												
BMI (4)	0.03	− 0.13	0.91 *											
Fat mass kg (5)	0.03	0.03	0.85 *	0.87 *										
Fat mass % (6)	0.09	−0.08	0.65 *	0.71 *	0.95 *									
Free fat mass (7)	0.35 *	0.40 *	0.95 *	0.81 *	0.64 *	0.37								
Muscle mass (8)	0.35	0.40 *	0.95 *	0.81 *	0.63 *	0.37	0.99 *							
Visceral fat (9)	0.30	−0.19	0.73 *	0.83 *	0.84 *	0.76 *	0.55 *	0.56 *						
PLAYself environment (10)	0.02	−0.03	0.30	0.30	0.39 *	0.40 *	0.20	0.20	0.24					
PLAYself self-description (11)	0.04	−0.04	0.52 *	0.54 *	0.59 *	0.55 *	0.40 *	0.41 *	0.57 *	0.62 *				
PLAYself literacy (12)	0.21	−0.07	0.03	0.06	0.09	0.10	−0.01	−0.01	0.13	0.09	0.30			
PLAYself numeracy (13)	0.03	0.21	0.14	0.05	−0.03	−0.12	0.23	0.23	0.00	0.06	0.27	0.64 *		
PLAYself physical literacy (14)	0.14	−0.34	−0.08	0.05	0.03	0.08	−0.14	−0.14	0.15	0.09	0.38	0.34	0.31	
PLAYself total (15)	0.05	−0.06	−0.40 *	−0.43 *	−0.47 *	−0.44 *	0.31	0.31	0.45 *	0.67 *	0.92 *	0.55 *	0.52 *	0.53 *
HLS-EU-Q (16)	0.04	0.19	0.08	−0.02	0.12	0.15	0.05	0.04	0.01	0.29	0.34	−0.15	0.09	0.28

Legend: PLAY = Physical literacy Assessment of Youth; HLS-EU-Q = European Health Literacy Survey Questionnaire.

The correlation between HLS-EU-Q and PLAYself among the boys is presented in Figure 2. The correlation did not reach statistical significance (Pearson's r = 0.08; p > 0.80).

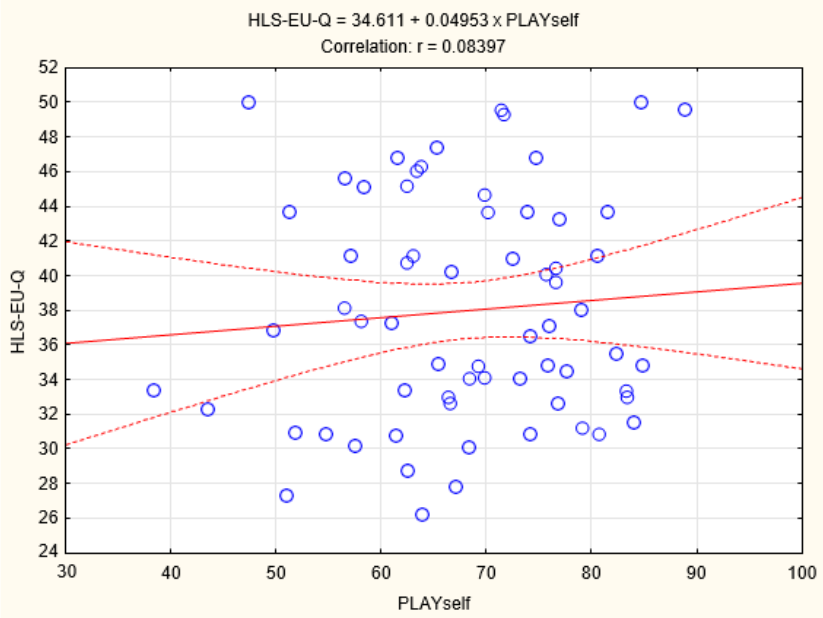

Figure 2. Correlation between physical literacy (PLAYself) and health literacy (HLS-EU-Q) in boys (scattered lines present 95% confidence intervals).

In the girls, the anthropometric/body composition indices were intercorrelated (>40% of the common variance). Meanwhile, no significant correlation between anthropometrics/body composition, PL and HL was evidenced (<2% of the common variance). Three of the PL sub-scores were significantly correlated to HL (7–13% of the common variance), indicating significant associations between the PLAYself numeracy, PLAYself literacy, and PLAYself physical literacy, with HL (Table 3).

Table 3. Correlations between study variables for girls (* indicates coefficients significant at $p < 0.05$).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Age (1)	-													
Body height (2)	0.04													
Body mass (3)	0.03	0.66 *												
BMI (4)	0.01	0.28 *	0.90 *											
Fat mass kg (5)	0.01	0.56 *	0.97 *	0.92 *										
Fat mass % (6)	0.03	0.48 *	0.89 *	0.87 *	0.97 *									
Free fat mass (7)	0.09	0.59 *	0.73 *	0.59 *	0.61 *	0.49 *								
Muscle mass (8)	0.09	0.73 *	0.89 *	0.71 *	0.74 *	0.59 *	0.81 *							
Visceral fat (9)	−0.17	0.31 *	0.86 *	0.92 *	0.91 *	0.85 *	0.52*	0.62 *						
PLAYself $_{environment}$ (10)	−0.21 *	−0.04	−0.07	−0.06	−0.09	−0.08	0.11	−0.02	−0.14					
PLAYself $_{self\text{-}description}$ (11)	0.07	0.00	−0.11	−0.14	−0.16	−0.19	−0.01	−0.03	−0.16	0.41 *				
PLAYself $_{literacy}$ (12)	0.13	0.05	0.15	0.17	0.19	0.21	0.07	0.07	0.16	0.12	0.05			
PLAYself $_{numeracy}$ (13)	0.11	−0.01	−0.01	−0.02	−0.04	−0.07	0.13	0.04	−0.02	−0.05	0.11	0.20		
PLAYself $_{physical\ literacy}$ (14)	0.03	0.16	0.07	−0.02	0.05	0.02	0.11	0.10	−0.01	0.25 *	0.39 *	0.19	0.43 *	
PLAYself total (15)	−0.04	0.03	−0.05	−0.09	−0.09	−0.12	0.10	0.02	−0.12	0.61 *	0.85 *	0.32 *	0.42 *	0.66 *
HLS- EU-Q (16)	0.19 *	−0.08	−0.01	0.04	0.00	0.05	0.03	−0.06	−0.03	0.05	0.26 *	0.27 *	0.38 *	0.04

Legend: PLAY = Physical literacy Assessment of Youth; HLS-EU-Q = European Health Literacy Survey Question-naire.

When the PLAYself and HLS-EU-Q results were correlated for the girls, the variables shared 10% of the common variance (Pearson's r = 0.31; p < 0.001), indicating a small but significant association between HL and PL among the studied adolescent girls (Figure 3).

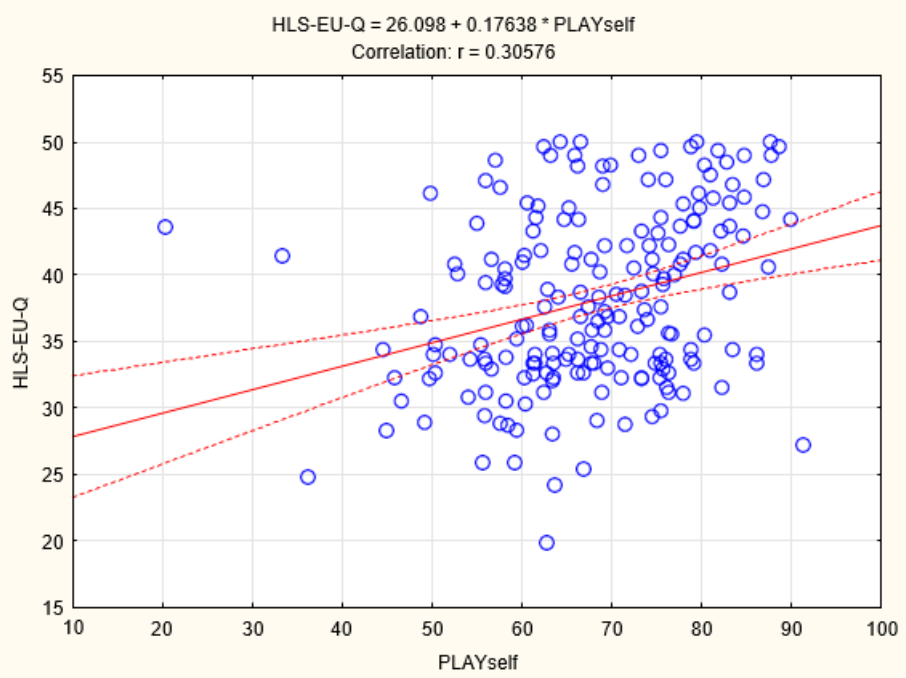

Figure 3. Correlation between physical literacy (PLAYself) and health literacy (HLS-EU-Q) in girls (scattered lines present 95% confidence intervals).

2.2.4 Discussion

This study aimed to investigate gender-specific associations between PL, HL, and body composition in Croatian adolescents. There are several main findings of this study: (i) the boys and girls did not differ, either in PL or in HL; (ii) HL and PL had low intercorrelations; and (iii) the body composition indices were not correlated to HL.

Gender Differences in Health Literacy and Physical Literacy

The finding that the boys and girls did not differ in PL is in accordance with previous studies. A study on Canadian children and adolescents aged 8–14 years recorded no differences between males and females in confidence, motivation, and knowledge domains of PL [34], which was also confirmed in a study on Canadian children aged 8–12 years [35]. A very recent study conducted on high school students aged 14–18 years from continental Croatia also did not find differences between the boys and girls in PL scores [32]. The authors explained such findings with the fact that the students have standardized fitness norms in their physical education classes, which enables them to compare their physical level within their gender. More specifically, the adolescents were most likely judging themselves within and not between genders; this is directly supported by a previous study that showed that youth judge themselves within a similar group (age, sex, and ethnicity), which leads to a precise evaluation of their abilities [36]. Collectively, it probably resulted in the nonsignificant difference in PL between genders in our study as well.

However, the lack of differences in the HL between genders is not in accordance with previous global studies. Specifically, a study on Korean adults reported that the females indicate higher HL than males in understanding medical forms and information [24]. Moreover, a study on non-medical college students from Egypt reported that the females had higher levels of HL than males, which was determined to be due to females' more frequent online health-information seeking [23]. Further, a review study on the gender differences in the mental HL of university students between 16 and 25 years old revealed that females were more able to identify common mental health disorders and had higher HL than males [37]. However, it must be noted that the previous studies that recorded differences in HL between genders investigated very diverse samples and adults, while our study included a significant proportion of students attending medical school, i.e., future health professionals. Therefore, it was logical to expect that all of the medical school students, regardless of gender, would possess high levels of HL,

consequently leading to no differences in the HL scores between the genders in our study. In addition, our study was completed in the period of the COVID-19 pandemic, which probably influenced the level of awareness on health issues in all of the participants, even the boys, as recently suggested [38].

Associations between Health Literacy and Physical Literacy

HL and PL were poorly intercorrelated, which could be explained by the fact that HL and PL, although both were related to health behaviors, are actually not the same concepts. In brief, HL relates to making sound and positive health decisions, leading to lifelong, health-promoting behaviors [39]. On the other side, PL promotes engagement in physical activity, which is one of the essential positive life habits that improves health [20,40]. It has been stressed that the terms HL and PL should be used with caution, as those terms are sometimes used synonymously [41]. The most probable reason is that the school subject is often called "Physical and Health Education" (or similar) which creates confusion and leads to considering health literacy and physical literacy as one concept [41]. However, those concepts relate to, and describe, different types of literacy, which is clearly supported by our results.

The lack of association between HL and PL in our study can also be attributed to the measurement tools we used to assess HL and PL. Namely, the HLS-EU-Q consists of items regarding the process of accessing/obtaining, understanding, processing/appraising, and applying/using health information in three domains, including healthcare (i.e., information on clinical or medical issues), disease prevention (information on health risk factors), and health promotion (updating oneself on health determinants in the physical and social environment) [30]. On the other side, PLAYself evaluates PL as a multidimensional construct comprising the competence, confidence, and knowledge to be active, and motivation to use movement skills. Additionally, PLAYself is a self-report measure of PL with items assessing affect (confidence, motivation), knowledge, and understanding of physical activities and movement [31]. Therefore, although both of the questionnaires assess the constructs that relate to health-related behaviors, they are actually distinct concepts and should be assessed separately.

Associations among Body Composition, Health Literacy, and Physical Literacy

The body composition indices did not strongly correlate to PL and HL, which is somewhat surprising, as we know that body composition is an important indicator of overall

health status (which is definitively related to HL) and physical fitness (which is known to be strongly associated with PL) [9,42]. Indeed, opposite to the results of our study, several studies recorded significant associations between body composition and anthropometric variables with HL in children and adolescents. A study on U.S. children and adolescents aged 6–19 years reported an inverse relation between HL and body mass index [43]. Moreover, a study on adolescents aged 12–19 years recorded that HL was strongly related to obesity; adolescents with low HL were more likely to be obese [44]. The reason for this was found in the fact that adolescents with low HL have poor nutritional habits, with an increased intake of sugar, fat, and salt [16,45], which leads to increased weight, body mass index, and body fat percentage.

However, not all of the studies have indicated a significant association between HL and anthropometrics/body composition. For example, a study on children aged 8–11 years did not find a significant correlation between HL and body mass index, which was explained by the limited variation in body mass index, as most of the children were within the normal range [46]. We can offer a similar explanation for the lack of association between HL and body-build indices in our research. First, when compared to studies where the authors evidenced significant associations between anthropometrics/body composition and HL, we observed a relatively narrow age span (14–18 years in our research, and 6–19 years and 12–19 years in the studies of our respective colleagues) [43,44]. Second, our adolescents had a mean body mass index score of 22.86 8.31, which falls within the normal range [47]. Simply put statistically, the narrow variance limited the possibility of reaching the higher correlation coefficient and statistical significance of the association [48].

The small correlation between PL and the anthropometric/body composition indices is more complex, especially when we consider that the studies regularly note clear correlations between body composition and PL. A study on Canadian youth evidenced a negative association between PL and body fat percentage [20], meaning that the children with low PL scores had an increased body fat percentage, which is an indicator of increased risk for metabolic dysfunctions and cardiovascular risk factors [49,50]. Moreover, it was shown that the children with healthy (i.e., lower) weight, body mass index, and waist circumference were more likely to have higher PL scores than the children with an unhealthy weight, body mass index, and waist circumference for their age and height [51,52]. However, the studies that recorded associations between PL and body composition mostly investigated a composite PL score, which consisted of physical, behavioral, cognitive, and affective domains [20]. Meanwhile, in this study, we investigated only the cognitive and affective domains of PL. Thus,

it could be hypothesized that the cognitive and affective domains of PL do not relate to body composition and anthropometric variables in the studied adolescents. In addition, we must note that the anthropometric/body composition indices were significantly correlated to PL in the boys studied here, but in the total sample, due to a larger number of girls (and the lack of association between anthropometric/body composition and PL among the girls), the overall correlation did not reach statistical significance.

Limitations and Strengths

The main limitation of this study was the cross-sectional nature of the investigation. Therefore, causality cannot be determined. Next, the tool used for assessing PL (i.e., PLAYself) is probably not the best option for assessing PL in high-school adolescents, nor for assessing all of the domains of PL as it includes only the cognitive and affective ones. Furthermore, this study included anthropometric/body-composition variables as the only indicator of health status, and in future studies, other indices of health status should be explored. Finally, HL and PL were evaluated through questionnaires, which raises the possibility of receiving socially desirable and not honest answers. However, this problem was eliminated to some extent, as the participants answered anonymously (they used only codes to enable the researchers to match their answers to other investigated variables).

As far as the authors are aware, this is one of the first studies investigating HL in Croatian adolescents, which is this study's major strength. Moreover, the studies investigating the associations among PL, HL, and body composition are generally lacking, while there is also an evident lack of investigations where this problem is analyzed through a gender-specific approach. Therefore, we believe that this study will contribute to the overall knowledge in the field and will hopefully initiate further research.

2.2.5 Conclusions

We found weak associations between HL and PL; our research highlights the necessity for the separate evaluation of each of these important abilities in adolescence.

The significant association between PL and body composition was established for the boys, but not for the girls. Therefore, improvement of PL could be effective for the improve-

ment of body composition for the boys, but not for the girls. However, before drawing final conclusions, additional correlational studies examining the more heterogenous sample of participants are needed.

In future studies, all of the aspects of PL should be observed to objectively evaluate PL itself and to establish the associations that may exist between PL, HL, and health-status. In addition, future studies should focus on the additional indices of health (other than body composition), in order to objectively evaluate the associations that may exist among HL, PL, and health status.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/children9081231/s1, Table S1: Correlations between study variables for total sample.

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

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study older than 18 years, while parents/legal guardian signed the consent form for underaged children.

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

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

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2.3 Study 3: Specificity of the Associations between Indices of Cardiovascular Health with Health Literacy and Physical Literacy; A Cross-Sectional Study in Older Adolescents

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Specificity of the Associations between Indices of Cardiovascular Health with Health Literacy and Physical Literacy; A Cross-Sectional Study in Older Adolescents

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Abstract: *Background and Objectives*: Cardiovascular health status (CVHS) is an important determinant of health, while it is theorized that health literacy (HL) and physical literacy (PL) could be directly related to CVHS. The aim of this study was to evaluate gender-specific associations between PL and HL and indices of CVHS in adolescence. *Materials and Methods*: The participants were 247 adolescents (177 females) from Split-Dalmatia county in Croatia who were tested on HL, PL, and CVHS (physical activity level (PAL) and lipid profile). The lipid profile included total cholesterol, triglycerides, high-density lipoproteins, non-high-density lipoprotein-cholesterol, and low-density lipoproteins. Gender-stratified multivariate cluster analysis (K-means clustering) was used to group participants into three homogenous groups on the basis of their HL and PL, while differences between clusters in CVHS were evidenced by analysis of the variance and consecutive post-hoc tests. *Results*: The lipid profile was better in girls with higher HL scores. Additionally, clusters consisting of participants with a better PL were characterized by higher PAL. We have found no evidence that HL is associated with PAL, while PL was not associated with the lipid profile. *Conclusions*: HL was specifically associated with direct indicators of health status (lipid profile) in girls, while PL was associated with PAL as a particular behavioral health indicator in both genders. The study highlights the necessity of including education of HL and PL in schools.

Keywords: health behaviors; lipid profile; public health; youth

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2.3.1 Introduction

Health literacy (HL) and physical literacy (PL) are concepts that are associated with health behaviors and outcomes [1,2], which is especially important during adolescence, as adolescents form their health habits during this life period [3]. HL entails "people's knowledge, motivation, and competencies to access, understand, appraise and apply health information to make judgments and take decisions in everyday life concerning healthcare, disease prevention and health promotion to maintain or improve quality of life during the life course" [4]. Numerous studies report that HL directly influences the health of adolescents. For example, high school students with higher HL had better health-promoting behaviors (i.e., good nutritional habits, not using psychoactive substances, higher physical activity), health outcomes, and better health-related quality of life [5–8]. On the other side, PL, defined as "the motivation, confidence, physical competence, knowledge, and understanding to value and take

responsibility for engagement in physical activities for life" [9], is also connected to positive health outcomes, mainly through fostering involve- ment in physical activities [1]. Briefly, PL has been associated with various health indicators, including cardiorespiratory fitness, physical activity, and health-related quality of life [1,10]. However, a recent study on Croatian adolescents reported that HL and PL, although both related to health behaviors and outcomes, are not interrelated and should be assessed separately in evaluating health behaviors [11].

Having adequate and maintaining physical activity level (PAL) is an essential factor that influences health status, including cardiovascular health status (CVHS) [12,13]. As engaging in physically demanding activities is one of the most important positive health behaviors, high levels of both HL and PL are essential for reaching adequate PAL [10,14]. However, the majority of adolescents worldwide (81%) do not have a sufficient PAL [15], which deteriorates their present and future health, including CVHS [16]. Moreover, adolescents were recently exposed to movement restrictions as a preventive measure for the COVID-19 pandemic, which decreased their PAL even more. Indeed, numerous studies around the globe reported a decrease in PAL in adolescents as a result of the COVID-19 lockdown [17–20]. Consequently, a decline in PAL due to the COVID-19 pandemic deteriorated adolescents' health [21]. Thus, concepts related to improving skills necessary for maintaining health habits (i.e., HL and PL) became even more important [22].

The lipid profile is one of the most important determinants of CVHS [23,24]. In most common words, lipid profile describes levels of lipids in the blood and most commonly consists of high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides [25]. High blood LDL cholesterol levels and triglycerides indicate an increased risk of cardiovascular disease, while increased HDL cholesterol levels indicate a healthy cardiovascular system [26]. Physical activity and exercise improve lipid profiles by enhancing the ability of muscles to use lipids as opposed to glycogen, leading to reduced plasma lipid levels [27]. Supportively, several studies reported that children and adolescents with higher PAL had better lipid profiles than those with low PAL. Precisely, a study on youth aged 9–18 years recorded that PAL and physical fitness are strongly associated with the lipid profile and a lower risk for coronary heart disease [28]. Moreover, children and adolescents aged 6–17 years who reached recommended daily PAL had more favorable HDL cholesterol [29]. Thus, as PAL is known to be linked to both HL and PL, it is expected that adolescents with better PL and HL will also have a better/healthier lipid profile. However, studies directly investigating the associations between HL and PL and lipid profiles in adolescents are missing.

From the previous literature overview, it is clear that better HL and PL should be linked to positive health behaviors even in adolescence, and it is expected that adolescents with better HL and PL will have better PAL and lipid profiles. However, studies done so far have rarely examined all indices simultaneously, and there is a lack of comprehensive knowledge regarding how HL and PL correspond to PAL and lipid profile in adolescents. Thus, the main aim of this study was to investigate the associations between HL and PL (on one side) and the lipid profile and PAL (on the other side). Since previous studies reported significant differences between males and females in study variables [15,30–33], we decided to make a more methodologically correct and precise investigation and to determine the gender-stratified associations between HL and PL and indices of CVHS (PAL and lipid profile). We hypothesized that adolescents with better HL and PL would generally have better CVHS, with some gender differences in established associations.

2.3.2 Materials and Methods

Participants and Study Design

The study had a cross-sectional character. The study included high school students (in total 247 participants), of which 70 were male, 177 were female, and average age was 16.8 ± 1.3 years. The location for the study was a training college for medical students in Split, Croatia. A minimum sample size of 85 participants was established based on a correlation between HL and PL of 0.30 suggested in a pilot study on Croatian college students, with a type-I error rate of 0.05 and a type-II error rate of 0.20 [34].

The study permitted the inclusion of participants with their mean age falling within the World Health Organization's (WHO) definition of adolescents (10–19 years of age). Potential participants with (or suspected of) acute inflammatory disease (e.g., COVID-19) at the time of testing were excluded from the study. The Ethical Board of the University of Split, Faculty of Kinesiology, approved the study on 23 September 2021 (EBO: 2181-205-02-01-21-0011).

Successive to ethical approval, the scope and procedure for the study were presented to all classes targeted to participate by one of the first authors. Students (or parents/legal guardians for those younger than 18 years of age) were requested to sign a written consent form to participate before starting the study. In total, more than 401 consent waivers were distributed, of which 289 were recovered, with a response rate of 72%. In this study, we included

participants who were successfully tested for all variables observed (please see later for details). Participants were informed that they had the right to withdraw from the study anytime. Measuring was conducted during May and April 2022 during school hours (08:00 a.m. to 10:00 a.m.).

Variables and Measurement

HL, PL, PAL, standard anthropometric measures, and lipid profiles were included as variables in this study.

The basis for evaluating HL was the European Health Literacy Survey Questionnaire (HLS-EU-Q), developed by Sørensen, et al. [35]. The questionnaire comprises 47 questions measuring an individual's capacity to obtain, process, and understand basic health information and services to make appropriate health decisions or to access, understand, appraise, and apply health-related information. A 4-point Likert scale, with responses from very difficult—1 to very easy—4, was used to construct a general index of HL. The formula: index = (mean 1) x (50/3) was employed to calculate the score. An HL scale of 0–50 was created, considering 0 as the lowest score and 50 as the highest. The index was split into four bands of HL as follows: inadequate (from 0 to 25); problematic (26–33); sufficient (34–42); excellent (43–50). In this study, we used the Croatian version of the HLS-EU-Q47 questionnaire, which was previously shown to be reliable and valid among Croatian adolescents) [34].

To evaluate the current level of PL, the PLAYself questionnaire was used. This is a self-assessment tool and considers four main groups of questions: (i) the affective and cognitive aspect of PL; (ii) the environmental ability; (iii) the estimation of literacy, numeracy, and physical literacy in different settings; (iv) fitness. Final scoring for the assessment is made by combining the sum of the first three groups to obtain a total and then dividing by the number of questions asked [36]. A total score of 100 indicated the maximum self-perceived PL. The study employed the Croatian version of the PLAYself questionnaire, which produced reliable results in previous works regarding Croatian adolescents [37,38].

PAL was evaluated using the Physical Activity Questionnaire for Youth (PAQ-A). The PAQ-A consists of 9 questions regarding physical activity habits, answered on a 5-point Likert scale (1-no/low activity, 5-high activity) [39].

The platform SurveyMonkey (SurveyMonkey Inc., San Mateo, CA, USA) was used to carry out all questionnaires, HLS-EU-Q47, PLAYself, and PAQ-A.

The anthropometric measures included body mass (to the nearest 0.1 kg) and body height (to the nearest cm). The anthropometric measurement took place in the school laboratory with strict privacy conditions every morning from 08:00 to 10:00. The procedure and protocols were explained to each student preceding the measurement. During the measurement, students were dressed in their underwear and barefoot.

The participant's/student's lipid profiles consisted of total cholesterol (TCHOL), triglycerides (TG), high-density lipoprotein (HDL-C), non-high-density lipoprotein-cholesterol (non-HDL-C), low-density lipoproteins (LDL-C), and the CHOL/HDL ratio. To evaluate this study's lipid profile, we used point-of-care testing (POCT). POCT is a minimally invasive diagnostic method that has the potential to provide rapid and accurate results [40]. The testing is based on reactive strips consisting of a membrane that removes the red blood cells, while plasma lipids are determined by a dry chemical reaction. In this study, we used Mission Cholesterol Test Devices (ACON Laboratories, Inc., San Diego, CA, USA). The device uses total capillary blood samples. The 3-in-1 Lipid Panel Strips from the same producer simultaneously measures the concentration of total cholesterol (TCHOL), high-density lipoprotein (HDL), and triglycerides (TRIG), while the LDL and CHOL/HDL ratio are automatically calculated. Several recent studies recommended calculating non- HDL-C because it has more atherogenic properties than all other lipoproteins [41,42]. Sigdel, et al. [43] found in a multinational study that a high concentration of non-HDL-C can predict cardiovascular risk [43]. Non-HDL-C is calculated as the total cholesterol minus HDL-C [44].

The guidelines of the manufacturer's protocol were observed. In brief, before starting sampling, each new box of the test device was calibrated by inserting a cod chip that automatically calibrates the meter. Further, all students were instructed to undergo an 8–12 h fasting period before the examination. The finger puncture to collect a capillary blood drop was performed in the School Hematology Laboratory by laboratory technicians supervised by a medical doctor. The optimal operating temperature was set at 20 ◦C. The finger punction each student was informed by a medical doctor about the procedures, risks, benefits, and rights, and all their doubts were clarified. To transfer the fresh capillary blood sample to the test strips in the right volume (35 µL), we used a capillary transfer tube (ACON, Mission, San Diego, CA, USA).

According to the National Cholesterol Education Program (NCEP) Expert Panel on Cholesterol Levels in Children and Adolescents [45], cut-off values for plasma lipid and lipoprotein levels were used, as presented in Table 1.

Table 1. Plasma lipid and lipoprotein level cut-off values.

Category	Acceptable mg/dL (mmol/L)	Borderline mg/dL (mmol/L)	High mg/dL (mmol/L)
TCHOL	<170 (4.4)	170 to 199 (4.4 to 5.2)	≥200 (5.2)
LDL-C	<110 (2.8)	110 to 129 (2.8 to 3.3)	≥130 (3.4)
Non-HDL-C	<120 (3.1)	120 to 144 (3.1 to 3.7)	≥145 (3.8)
TG	<90 (1 mmol/L)	90 to 129 (1 to 1.5)	≥130 (1.5)
HDL-C	<40 (1)	40 to 45 (1 to 1.2)	>45 (1.2)

Legend: TCHOL—total cholesterol, TG—triglycerides, HDL-C—high-density lipoprotein, non-HDL-C—non-high-density lipoprotein-cholesterol, LDL-C—low-density lipoproteins.

Statistical Analyses

All variables were checked for normality of the distributions by the Kolmogorov–Smirnov test, and means and standard deviations were reported. Plasma lipid and lipoprotein levels are reported in percentages according to cut-off values (please see Table 1 for details).

In the first phase, we calculated Spearman's correlation coefficients between all observed variables. Next, a multivariate cluster analysis (K-means clustering method), with a predefined number of clusters (three) was performed to identify the member of three homogenous groups of participants on the basis of their HL and PL (i.e., the multivariate design allows simultaneous observation of the results on both applied variables). Although this statistical procedure performs grouping into two clusters by default, the number of three clusters was predefined to avoid simplified grouping into two clusters (high PL and HL vs. low HL and PL) and to allow an eventual, more complex identification of participants' characteristics (see later result for more details). In the next phase, participants were allocated to clusters, and cluster characteristics with regard to grouping variables (HL and PL) were identified by a one-way analysis of variance (ANOVA).

ANOVA was used to identify the differences among clusters for each gender. Specifically, in ANOVA calculations, the allocation to each cluster was used as a "grouping variable" (categorical factor), while CVHS indices were observed as dependent variables. When ANOVA reached a statistical significance of $p < 0.05$, a Scheffe post-hoc analysis was calculated to identify the significance of the between-cluster differences.

All analyses were gender-stratified. Statistica ver. 13.5 (Tibco Inc., Palo Alto, Ca, USA) was used, and $p < 0.05$ was applied.

2.3.3 Results

Plasma lipid and lipoprotein status in adolescents are presented in Table 2.

Table 2. Plasma lipid and lipoprotein status in studied adolescents.

	High F (%)	Borderline F (%)	Acceptable F (%)
TCHOL	2 (1)	15 (6)	230 (93)
TG	16 (7)	48 (20)	183 (73)
HDL-C	47 (19)	20 (8)	181 (73)
non-HDL-C	4 (2)	13 (5)	231 (93)
LDL-C	2 (1)	9 (4)	236 (95)

Legend: TCHOL—total cholesterol, TG—triglycerides, HDL-C—high-density lipoprotein, non-HDL-C—non-high-density lipoprotein-cholesterol, LDL-C—low-density lipoproteins.

Descriptive statistics for the study variables are presented in Table 3.

Table 3. Descriptive statistics for studied variables (data are given as means ± standard deviations).

	Total Sample (n = 247)	Boys (n = 70)	Girls (n = 177)
Body height (cm)	1.71 ± 0.18	1.81 ± 0.14	1.68 ± 0.18
Body mass (kg)	67.01 ± 12.27	74.4 ± 12.49	64.48 ± 11.15
PAL (score)	2.51 ± 0.72	2.64 ± 0.72	2.47 ± 0.72
PL (score)	69.1 ± 11.11	69.05 ± 11.04	68.91 ± 11.40
HL (score)	37.91 ± 6.31	37.78 ± 6.53	38.07 ± 6.42
TCHOL (mg/dL)	132.58 ± 24.63	120.9 ± 23.82	136.25 ± 23.78
TG (mg/dL)	82.89 ± 29.86	82.25 ± 33.99	83.09 ± 28.53
HDL-C (mg/dL)	51.46 ± 13.68	40.12 ± 13.17	55.02 ± 11.79
non-HDL-C (mg/dL)	78.32 ± 28.02	76.94 ± 30.29	78.76 ± 27.32
LDL-C (mg/dL)	58.98 ± 30.32	52.33 ± 35.58	61.07 ± 28.25
CHOL/HDL ratio (ratio)	2.5 ± 1.6	2.48 ± 1.68	2.51 ± 1.58

Legend: PAL—physical activity level, PL—physical literacy, HL—health literacy, TCHOL—total cholesterol, TG—triglycerides, HDL-C—high-density lipoprotein, non-HDL-C—non-high-density lipoprotein-cholesterol, LDL-C—low-density lipoproteins.

Apart from some logical and expected correlations between variables that were derived on the basis of calculations (i.e., correlation between non-HDL-C and LDL-C, LDL-C and CHOL/HDL ratio) in boys, some interesting associations are as follows. The TG was correlated with body mass (less than 5% of the common variance), while PL and PAL were significantly correlated in boys (17% of the common variance). Lipid panel indicators were significantly intercorrelated. Positive correlations were evidenced between TCHOL and TG (25% of the common variance), non-HDL-C (75% of the common variance), LDL-C (70% of the common

variance), and CHOL/HDL ratio (51% of the common variance). TG was correlated with non-HDL-C (35% of the common variance), LDL-C (11% of the common variance), and CHOL/HDL ratio (13% of the common variance) (Table 4).

Table 4. Correlations between studied variables for boys (n = 70).

	1	2	3	4	5	6	7	8	9	10
Body height (1)	–									
Body mass (2)	0.00	–								
PAL (3)	−0.10	0.02	–							
PL (4)	0.09	0.01	0.43 *	–						
HL (5)	−0.11	0.03	0.04	0.07	–					
TCHOL (6)	−0.13	0.08	0.03	−0.07	−0.03	–				
TG (7)	0.06	0.29 *	0.01	0.03	−0.06	0.53 *	–			
HDL-C (8)	0.04	−0.23	0.11	0.23	0.23	0.14	−0.20	–		
non-HDL-C (9)	−0.15	0.19	−0.03	−0.18	−0.15	0.86 *	0.59 *	−0.39 *	–	
LDL-C (10)	−0.18	−0.01	0.04	−0.21	−0.02	0.84 *	0.32 *	0.05	0.76 *	–
CHOL/HDL ratio (11)	−0.14	0.03	0.00	−0.23	−0.01	0.71 *	0.36 *	−0.08	0.71 *	0.96 *

Legend: PAL—physical activity level, PL—physical literacy, HL—health literacy, TCHOL—total cholesterol, TG—triglycerides, HDL-C—high-density lipoprotein, non-HDL-C—non-high-density lipoprotein-cholesterol, LDL-C—low-density lipoproteins; * indicates the statistical significance of $p < 0.05$.

In girls, body mass was negatively correlated to HDL-C (4% of the common variance) and positively correlated to non-HDL-C (>4% of the common variance), and LDL-C (3% of the common variance). PL was significantly correlated to PAL (25% of the common variance) and HL (9% of the common variance). HL was found to be positively correlated with TCHOL (4% of the common variance), negatively correlated to LDL-C (6% of the common variance), and negatively correlated with non-HDL-C (6% of the common variance). TCHOL was positively correlated with TG (8% of the common variance), HDL-C (6% of the common variance), non-HDL-C (7% of the common variance), LDL-C (70% of the common variance), and CHOL/HDL ratio (10% of the common variance). TG was correlated with non-HDL-C (12% of the common variance) and LDL-C (3% of the common variance) (Table 5).

Table 5. Correlations between studied variables for girls (n = 177).

	1	2	3	4	5	6	7	8	9	10
Body height (1)	-									
Body mass (2)	0.54 *	-								
PAL (3)	−0.08	0.07	-							
PL (4)	−0.01	−0.05	0.51 *	-						
HL (5)	−0.01	0.08	0.07	0.31 *	-					
TCHOL (6)	0.01	0.11	0.04	0.06	0.20 *	-				
TG (7)	0.09	0.11	0.01	−0.09	0.11	0.28 *	-			
HDL-C (8)	−0.04	−0.19 *	0.04	0.05	0.06	0.21 *	−0.15	-		
non-HDL-C (9)	0.03	0.21 *	0.02	0.04	−0.25 *	0.88 *	0.35 *	−0.25 *	-	
LDL-C (10)	0.02	0.17 *	0.00	0.01	−0.24 *	0.84 *	0.18 *	−0.09	0.88 *	-
CHOL/HDL ratio (11)	−0.07	0.07	−0.03	−0.04	0.07	0.32 *	0.12	−0.13	0.39 *	0.47 *

Legend: PAL—physical activity level, PL—physical literacy, HL—health literacy, TCHOL—total cholesterol, TG—triglycerides, HDL-C—high-density lipoprotein, non-HDL-C—non-high-density lipoprotein-cholesterol, LDL-C—low-density lipoproteins; * indicates the statistical significance of $p < 0.05$.

Cluster analysis calculated for boys based on their results achieved at HL and PL formed three characteristic homogenous groups. Cluster 1 consisted of participants who achieved low

results on HL and low results on PL (low PL—low HL; L-PL/L-HL). Participants who achieved high results on HL and average results on PL were grouped into Cluster 2 (average PL—high HL; A-PL/H-HL)). Cluster 3 was formed by boys who achieved average results on HL but high results on PL (H-PL/A-HL) (Figure 1).

For boys, ANOVA identified only one significant difference between clusters in indicators of CVHS, where the L-PL/L-HL group achieved the lowest results in PAL (F-test = 17.11, $p < 0.001$; significant post-hoc difference when compared to H-PL/A-HL group (Cluster 3).

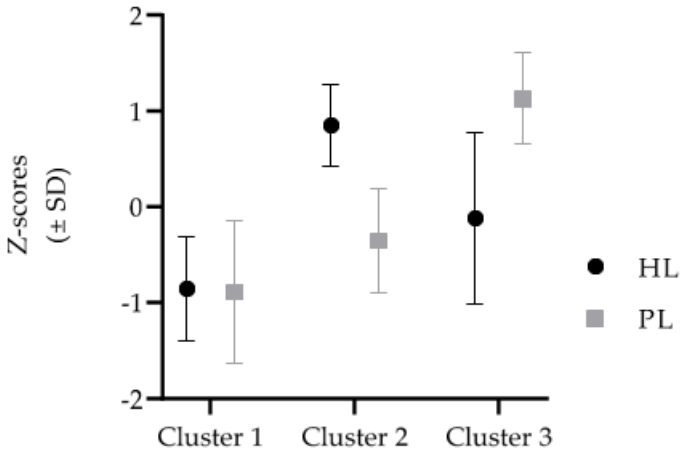

Figure 1. Multivariate clustering on the basis of health literacy (HL) and physical literacy (PL) for boys (results are presented in standardized values).

When cluster analysis was calculated for girls, Cluster 1 consisted of girls who achieved average results on PL and low results on HL (L-PL/L-HL). Girls who achieved high results on HL and high results on PL were grouped into Cluster 2 (H-PL/H-HL), while the Cluster 3 consisted of girls who achieved average results on HL and low results on PL (L-PL/A-HL) (Figure 2).

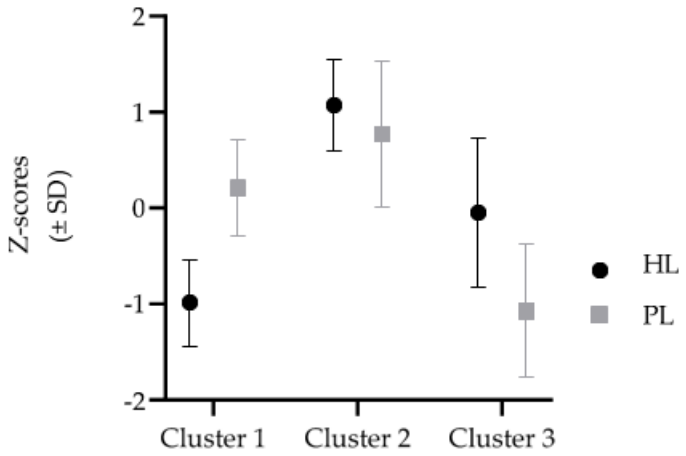

Figure 2. Multivariate clustering on the basis of health literacy (HL) and physical literacy (PL) for girls (results are presented in standardized values).

The ANOVA among clusters identified significant effects for PAL and non-HDL-C in girls (F-test = 13.11, and 11.12, respectively, both $p < 0.001$). Significant post-hoc differences for PAL were identified between Cluster 2 (H-HL/H-PL group) and Cluster 3 (L-PL/A-HL), with a better result on PAL for Cluster 1, indicating an association between higher PL with higher PAL in girls. Further, non-HDL-C was lowest in Cluster 1 (L-PL/L-HL group), with significant post-hoc differences when compared to Cluster 2 (H-HL/H-PL group), indicating an association between better HL and a more favorable lipid profile among girls.

2.3.4 Discussion

The aim of this study was to determine the gender-stratified associations between HL and PL and indices of CVHS (PAL and lipid profile). The study evidenced several most important findings: (i) HL was higher among girls with better lipid profile; (ii) PL was higher among adolescents with a higher PAL; (iii) HL was not associated with PAL, while PL was not associated with the lipid profile. Therefore, our initial study hypothesis was confirmed.

Health Literacy, Physical Literacy, and Lipid Profile

Results that adolescents with higher HL have a more favorable lipid profile are in accordance with several previous studies. Research on nursing students evidenced a positive association between HL and HDL cholesterol and a negative association of HL with cholesterol ratio (i.e., total cholesterol/HDL cholesterol), indicating a better lipid profile in students with

higher HL [46]. A study on adolescents from Taiwan indirectly confirmed such associations, as it evidenced that adolescents with high HL were less likely to be obese and have poor nutritional habits (high sugar-sweetened beverage, salt, and fat intake), which are one of the main factors of having a less favorable lipid profile [47]. Meanwhile, although a recent study on Croatian adolescents did not evidence an association between body composition (body fat percentage, muscle mass) and HL [11], the authors of that study concluded that some other and more precise health indicators (i.e., lipid profile) could be more associated with HL, which was actually confirmed here. The explanation for the association between HL and lipid profile could lie in the theory that individuals with better HL scores are able and willing to take actions that improve their health, leading to a better lipid profile [4]. Another possible explanation of this association could be that individuals with better HL skills can understand the results of their blood tests, including cholesterol screening [48]. Consequently, they are able to, with the guidance of health professionals, make appropriate changes in weight, diet, and exercise to control their lipid profile.

In our study, PL was not associated with the lipid profile, which is somewhat surprising if we consider previous studies that indicated a positive association between PL and health status indices [10]. For example, a study on Canadian children evidenced a positive relationship between PL and health indicators, including body fat percentage, aerobic fitness, blood pressure, and health-related quality of life [49]. Also, another study on Canadian children evidenced better cardiorespiratory fitness in children with higher PL scores [50]. However, even though previous studies evidenced associations between PL and health indicators, none specifically investigated lipid profiles. This altogether could point out that some other aspects related to the lipid profile are more important than PL, at least in adolescence. Namely, PL is mainly related to an increasing PAL (please see the following paragraph for a more detailed explanation) and probably has limited influence on other health-related behaviors (i.e., nutritional habits, substance use) that are known to be more influential on the lipid profile [51]. Thus, as more factors could have influenced the lipid profile, maybe PL alone cannot give a precise picture of the most important determinants of the lipid profile. No association between PAL and the lipid profile in our sample (please see results for more details) could be explained by numerous factors that influenced the lipid profile, and not only PAL. It has to be mentioned that the association between HL and the lipid profile differed by gender; HL was higher among girls with a better lipid profile. This can be explained by results from a recent study on a similar sample, where it was evidenced that PL and HL were associated only among girls [11].

Therefore, it could be theorized that HL has a greater influence on health status (i.e., lipid profile) among girls, as it is also associated with another health-promoting concept—PL.

Physical Literacy, Health Literacy, and Physical Activity Levels

A positive association between PL and PAL was expected, as PL is generally theorized to be the foundation of participation in physical activities [52]. Indeed, studies frequently reported correlations between PAL and PL in children and adolescents. Canadian children aged 8–12 that were meeting physical activity guidelines (i.e., had sufficient PAL) had higher PL scores (physical competence, motivation, and confidence domains) than children with low PAL [53]. Another Canadian study on children aged 7–14 noted a positive association between PL (movement competence domain) and objectively measured PAL [54]. A study on Chinese adolescents aged 12–18 years also recorded a positive relationship between perceived PL and PAL [55]. What is more, a recent review study reported that PL interventions led to increased PAL, supporting the association between PL and PAL [56]. Our results also confirmed that adolescents with higher PAL possess better PL, which can be explained by the following. First, physically literate individuals are deemed to possess movement competence, confidence and motivation, knowledge and understanding of the importance of engaging in physical activities [57]. Second, physically literate individuals are willing to participate (i.e., are action-oriented) in various movements, leading to lifelong participation in physical activities and overall increased PAL [58]. Putting it all together, physically literate individuals are more likely to be engaged in various physically demanding activities, which logically increases their PAL.

On the other side, HL was not associated with PAL, which contradicts some previous studies. Namely, a study on Finnish adolescents aged 13–15 reported that adolescents with higher HL levels were more likely to participate in sports activities, leading to increased PAL [59]. Moreover, a study on 8–11 year-old children from the Netherlands recorded a strong positive relationship between HL and PAL; children with higher HL had higher PAL [60]. Meanwhile, we did not record a correlation between PAL and HL. The first possible reason for this can be found in the age of the participants. Namely, previous studies where authors evidenced a correlation between HL and PAL examined younger subjects than we did herein (8–15 and 16–18 years of age, respectively) [59,60]. Meanwhile, it is well documented that PAL decreases after the age of 14 years, mostly due to drop-outs from sports [61,62]. Therefore, it is possible that these relationships, which are evidenced in childhood and younger

adolescence (i.e., higher PAL in those with better HL), are not characteristic for older adolescence simply because the HL logically increases (as a result of schooling and education), while PAL unfortunately decreases (as a result of various factors, mostly quitting sports). The indirect support for such an explanation could be found in the fact that HL and PL are actually independent qualities, at least in late adolescence [11]. Namely, even though both PL and HL are related to health behaviors (with engaging in physical activities being one of the most important ones), they are distinct concepts and evidently relate to different health behaviors. Precisely, physical activity is at the center of the PL concept, as PL is theorized to be the foundation of physical activity participation; hence it is logical that PL will have strong associations with PAL. On the other side, HL is the ability to make reasonable decisions regarding healthcare, disease prevention, and health promotion that positively influence health [4]. Therefore, it is evident that HL covers a larger area of health-related behaviors, altogether resulting in a lack of association between HL and PAL in our study.

Limitations and Strengths

The cross-sectional nature of the investigation is the main limitation of this study. Therefore, the cause–effect relationship between variables cannot be speculated. Moreover, HL, PL, and PAL were assessed via questionnaires, which could lead to collecting not completely honest answers. However, we tried to reduce this problem by anonymous testing, while self-selected codes were used for matching questionnaires with other variables. Moreover, another limitation can be the usage of the Mission Cholesterol Test Device, which might have analytical biases for some of the analyzed variables. Finally, lipid results were not confirmed using laboratory or additional analytical equipment, but this was a consequence of the testing protocol, which included testing in school settings and during school time. Namely, the study was done during COVID-19 pandemic, so we tried to avoid the possibility of participants being exposed to COVID-19 or any other disease in hospital/referent laboratory settings.

The main strength of this study is that it is one of the first studies that investigated HL and PL in relation to CVHS indices (lipid profile, PAL) in adolescents. Additionally, knowing that the studied indices vary across different geographical regions and cultures, it is important to note that this is probably the first study that has investigated this problem in southeastern Europe. This altogether makes the study of certain importance, as it can guide scientists and

public health authorities to investigate and promote HL and PL, which would hopefully lead to improved health of adolescents.

2.3.5 Conclusions

This study evidenced that HL was higher among adolescents with a better lipid profiles, while HL was not correlated with PAL. On the other hand, PL was higher among adolescents with a higher PAL, while PL was not associated with lipid profiles. Thus, it could be concluded that HL is more associated with direct health indicators, while PL is more related to PAL. Due to the cross-sectional nature of the study, the causality between variables cannot be speculated, and further longitudinal studies should evaluate the true nature of evidenced relationships. In brief, while higher PAL can be a consequence of better PL (i.e., participants who are better informed on physical activities (and have better PL) will be more physically active), the opposite direction is also possible (i.e., participants who spend more time in physically demanding activities will be more physically competent and will have better PL).

This study confirms that correlates of HL and PL are relatively independent and again confirmed that HL and PL cover distinct health-related behaviors. As the issue investigated in this study is of great importance for promoting health behaviors and health in general among adolescents, it can encourage scientists to more deeply explore such concepts and include public health authorities to implement them in health promotion strategies. Also, as this study included adolescents in the education system, this study points out the necessity of including HL and PL education in schools.

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M.P. and N.Z.; Methodology, M.G.K. and N.Z.; Project administration, N.Z.; Resources, A.J.S.; Software, A.J.S. and M.P.; Validation, B.G.; Writing—original draft, M.G.K. and B.G. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study, while parents signed the consent for underage participants.

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

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2.3.6 References

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2.4 Study 4: Analysis of the Association Between Health Literacy, Physical Literacy, and Scholastic Achievement; A Preliminary Cross-Sectional Study Among High-School Students From Southern Croatia

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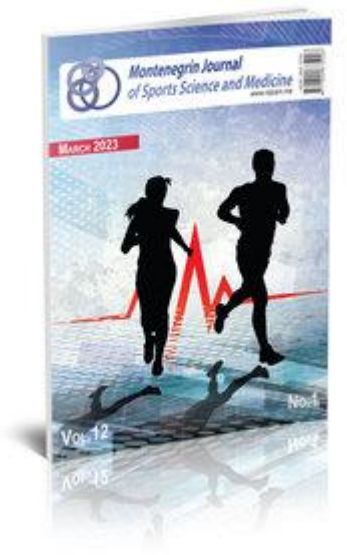

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ORIGINAL SCIENTIFIC PAPER

Analysis of the Association Between Health Literacy, Physical Literacy, and Scholastic Achievement; A Preliminary Cross-Sectional Study Among High-School Students From Southern Croatia

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Abstract

Theoretically, health literacy (HL) and physical literacy (PL) should be associated with overall education, but little is known about their association with scholastic achievement. The aim of this study was to investigate whether scholastic variables relate to HL and PL among high-school adolescents. We observed 268 high school students (202 females, 66 males) who were assessed on HL using the HLS-EU47 questionnaire and PL by PLAYself questionnaire. Scholastic variables included grade point average and excused and unexcused number of absences from school. Gender-stratified correlations, cluster analysis, and discriminant canonical analysis were calculated to establish the associations between study variables. The correlations between HL and scholastic variables were generally poor, while statistically significant correlations between grade point average and HL were noted only among girls ($R=0.16$, $p<0.05$). Cluster and discriminant analyses confirmed higher HL and PL among girls who were better at school. While associations between HL and PL with scholastic achievement were generally poor, our results point to the necessity of further investigation of a problem. Hence, specific types of knowledge should be explored as possible correlates of HL and PL in adolescence.

Keywords: *adolescents, health behavior, lifestyle, pedagogy, teachers*

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2.4.1 Introduction

High school students are in a sensible life period (i.e., adolescence), where they adopt behaviors that determine their adult habits (de Bruin, 2012). What is more, high school students are still in compulsory education, which means that teachers and other education agents can influence their behavior and teach them how to adopt behaviors that are good for their health (Olujić & Maras, 2021). Several concepts have been considered influential in the sense of adopting positive health behaviors, including health literacy (HL) and physical literacy (PL) (Buja et al., 2020; Cairney et al., 2019).

The most common definition of HL is "HL entails people's knowledge, motivation, and

competencies to access, understand, appraise and apply health information to make judgments and take decisions in everyday life concerning health-care, disease prevention, and health promotion to maintain or improve quality of life during the life course" (Sørensen et al., 2012). Indeed, numerous studies identified the link between HL and health-related behaviors and outcomes. Namely, it was found that adolescents with high levels of HL displayed good nutritional habits, appropriate physical activity levels, not consuming alcohol and tobacco, and having a good health-related quality of life (Guo et al., 2021; Klinker et al., 2020; Qiao et al., 2021). Supportively, a recent study conducted on similar participants (i.e., high school students from Croatia) evidenced that students with better HL have a preferable lipid profile, which is an indicator of cardiovascular health (Kesic et al., 2022).

On the other side, PL can be defined as "the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engagement in physical activities for life" (Martins et al., 2021). PL is mainly connected to health outcomes through fostering participation in physical activity, which is considered one of the most important habits that positively impact health status (Caldwell et al., 2020). Moreover, PL has directly been linked to several health indica- tors, such as cardiorespiratory fitness and health-related quality of life (Cairney et al., 2019; Cornish et al., 2020). Recent studies on high school students found that students with better PL have higher physical activity levels (Gilic et al., 2022) and better physical fitness (Gilic et al., 2022; Sunda et al., 2022).

As HL and PL can be taught (i.e., by high school teachers), it could be expected that scholastic achievement and other school-related variables would be connected to HL and PL. In other words, we can theorize that students with better grades and fewer school absences would have better developed PL and HL skills and better health habits. Indeed, studies evidenced that students with higher grades had higher diet quality (Whatnall et al., 2019) and physical activity levels (Nelson & Gordon-Larsen, 2006; Schmitz et al., 2002). Moreover, a study con ducted on adolescents from Bosnia and Herzegovina evidenced that students who are better in school (i.e., have better grades) managed to preserve their physical activity levels during the COVID-19 pandemic, which indicates that they had good PL skills and that they were aware of the health benefits of physical activity (Sekulic et al., 2021). Finally, scholastic achievement and health habits have been considered positively associated in a recent study that emphasized the importance of including HL interventions in the education system which would lead to better health outcomes of students (de Albuquerque et al., 2022).

Both HL and PL are skills that can be learned and are susceptible to changes during the educational processes in school. Considering that HL and PL are linked to positive health

behaviors and outcomes, it is important to investigate whether they relate to scholastic variables in order to emphasize the importance of including them in the school curriculum. However, studies that simultaneously investigated associations between HL, PL, and scholastic variables are lacking. Thus, the aim of this research was to determine whether HL and PL are related to scholastic variables (grade point average and school absences) in high school students. We hypothesize that students with higher grade point averages and fewer school absences will have higher HL and PL levels.

2.4.2 Materials and Methods

Participants and Study Design

In this cross-sectional preliminary study 268 high student (202 females, 66 males) from the Southern Croatia were in volved. The average age was 16.8 ± 1.3 years. The study was part of a wider research project previously initiated and approved by The Ethical Board of the University of Split, Faculty of Kinesiology, on 23rd September 2021 (EBO: 2181-205-02-01-21-0011).
The study permitted the inclusion of participants who were attending the school during the school years 2020/2021, and 2021/2022, and who were successfully tested for all variables observed (HL, PL). Students (or parents/legal guardians for those younger than 18 years of age) were invited to sign their consent to participate in the study on a form, successive to ethical approval.

Variables and Measurement

The variables in this study included gender and age (in years), HL, PL and variables of scholastic achievement.

The Croatian version of the European Health Literacy Survey Questionnaire 47 (HLS-EU-Q47) was used to assess the HL level as it was previously demonstrated to be valid among Croatian adolescents (Geets Kesic et al., 2022). The questionnaire asked 47 questions, relating to an individual's capability to acquire, process and understand basic health information and related services, and so allowing them to make appropriate health decisions or to obtain, understand, appraise, and act upon it/them. A general index of HL was constructed using a 4-point Likert scale, with responses from very difficult—1 to very easy—4. The score was calculated through the formula: index = (mean − 1) × (50/3). Scoring was made on a scale of 0-50 where 0 was considered the lowest score and 50 the highest. The scoring index was separated into four sections of HL: inadequate (from 0 to 25); problematic (26–33); sufficient (34–42); excellent (43–50).

PL was assessed using self-administered tool which is a part of the Physical Literacy

Assessment of Youth (PLAYself). PLAYself consists of four subscales: (i) affective and cognitive domain of PL; (ii) environment; (iii) literacy, numeracy and PL in different settings; and (iv) physical fitness (Jefferies et al., 2021). Maximum score is 100 (for subscales and for the total score) which represents the highest self-perceived PL. PLAYself was previously validated on the sample of Croatian adolescents (Gilic et al., 2022). To carry out all questionnaires (HLS-EU-Q47 and PLAYself) the platform SurveyMonkey (SurveyMonkey Inc., San Mateo, CA, USA) was used.

Scholastic achievement was assessed by academic achievement (grade point average - GPA) and school absences (excused and unexcused number of absences form school). The Constitution of the Republic of Croatia states that everyone is entitled to free compulsory education. The Ministry of Science, Education and Sport regulated the education process with the Primary and Secondary School Education Act, and the Ordinance on the Manner, Procedures and Elements of the Evaluation of the Primary and Secondary School Students (Žiljak & Baketa, 2019). Croatian education system defines two categories of grading: conduct grading – 3-point descriptive scale (poor, good, exemplary) and grade point average (GPA). GPA is calculated as the arithmetic mean of all numerical grades and it forms a scale from one to five as: insufficient/failing grade (1.00-1.99), sufficient (2.00-2.49), good (2.50-3.49), very good (3.50-4.49) and excellent (4.50-5.00). Overall school absence was the number of absences in school hours in one year.

All scholastic data was collected from the class register book in the electronic format: e-Dnevnik. E-Dnevnik represents a joint between ICT and the traditional class register book as web application. It was developed in 2011/2012 by The Croatian Academic and Research Network (CARNet) and its partners as the pilot-project "e-Schools". The idea was to implement ICT in education system in order to enable simpler access to different school data. One of major services developed and implemented by this project was e-Dnevnik. The advantage of use of e-Dnevnik in school practice is its simplicity to keep students' records, the monitoring of student progress, the possibility of analyzing collected statistical data and quick access to information about individual student or class. The ICT integrated in e-Dnevnik, easy gives to teacher or other school staff (e.g., pedagogue) GPA and calculated absence for the individual students or for the class (Vrkić Dimić & Vidov, 2019).

Statistical Analysis

All variables were checked for normality of the distributions by Kolmogorov-Smirnov test. As a result, parametric statistics were calculated, and descriptive statistics were reported by

means and standard deviations.

The analyses were done in several phases. As a preliminary first phase Pearson's correlation coefficients were calculated. Inthe second phase participants were grouped into homogenous groups on the basis of scholastic variables by multivariate clusteranalysis. Specifically, the Ward's method of clustering based on Euclidian distances was used. Each participant was consequently allocated to appropriate number of clusters (homogenous groups), which was used as categorical factor in the next phases. Analysis of variance was calculated to establish the characteristics of the formed clusters. Finally, discriminative canonical analysis (DISCRA) was calculated to evaluate the multivariate differences in HL and PL among established clusters. All analyses were gender stratified.

Statistica ver. 13.5 (Tibco Inc, Palo Alto, California, USA) was used for all analyses, and p-level of 0.05 was applied.

2.4.3 Results

Table 1 presents descriptive statistics for study variables as well as correlations among variables for the total sample ofsubjects. PL and HL were weekly correlated (5% of the com mon variance), while GPA was poorly but significantly correlated with HL (less than 2% of the common variance).

Table 1. Descriptive statistics (Mean, SD - standard deviation) and Pearson's correlations among variables - total sample

	Mean	SD	Age	PL	HL	GPA	U_Absence
Age (years)	17.03	1.39					
PL (score)	68.04	11.26	-0.02				
HL (score)	38.07	6.53	0.14*	0.25*			
GPA (score)	4.08	0.57	0.17*	0.08	0.12*		
U_Absence (school hours)	2.89	1.69	0.21*	-0.07	0.00	-0.29*	
T_Absence (school hours)	69.70	47.11	0.03	-0.03	-0.08	-0.41*	0.32*

Note: PL - physical literacy, HL - health literacy, GPA - grade point average, U_Absence - number of unexcused absences, T_Absence - number of total hours of absence, * denotes significance of $p < 0.05$

Descriptive statistics and correlations among variables for boys are presented in Table 2. In brief, apart from significant correlations among scholastic variables, no other coefficient reached statistical significance.

Table 2. Descriptive statistics (Mean, SD - standard deviation) and Pearson's correlations among variables - subsample of boys

	Mean	SD	Age	PL	HL	GPA	U_Absence
Age (years)	17.15	1.29					
PL (score)	68.05	11.04	0.05				
HL (score)	37.98	6.51	0.02	0.08			
GPA (score)	3.84	0.62	0.18	-0.07	0.01		
U_Absence (school hours)	3.55	2.40	0.35*	-0.12	-0.02	-0.22	
T_Absence (school hours)	71.32	48.70	0.05	0.23	-0.02	-0.33*	0.29*

Note: PL - physical literacy, HL - health literacy, GPA - grade point average, U_Absence - number of unexcused absences, T_Absence - number of total hours of absence, * denotes significance of $p < 0.05$

Table 3. Descriptive statistics (Mean, SD - standard deviation) and Pearson's correlations among variables - subsample of girls

	Mean	SD	Age	PL	HL	GPA	U_Absence
Age (years)	16.99	1.42					
PL (score)	68.03	11.36	-0.05				
HL (score)	38.10	6.55	0.18*	0.31*			
GPA (score)	4.16	0.53	0.19*	0.15*	0.17*		
U_Absence (school hours)	1.67	1.31	0.15*	-0.05	0.01	-0.27*	
T_Absence (school hours)	69.16	46.69	0.03	-0.12	-0.10	-0.46*	0.37*

Note: PL - physical literacy, HL - health literacy, GPA - grade point average, U_Absence - number of unexcused absences, T_Absence - number of total hours of absence, * denotes significance of $p < 0.05$

When calculated for girls, HL and PL were weekly but significantly correlated with GPA (less than 3% of the common variance). Generally, girls with higher GPA had better PL and HL (Table 3).

Figure 1 presents the hierarchical tree clustering of the boys according to their scholastic achievement. As evident, two homogenous groups were formed (Cluster 1 and Cluster 2), each containing a similar number of participants. Additional ANOVA evidenced better scholastic achievement in boys grouped in Cluster 1 ($p < 0.05$).

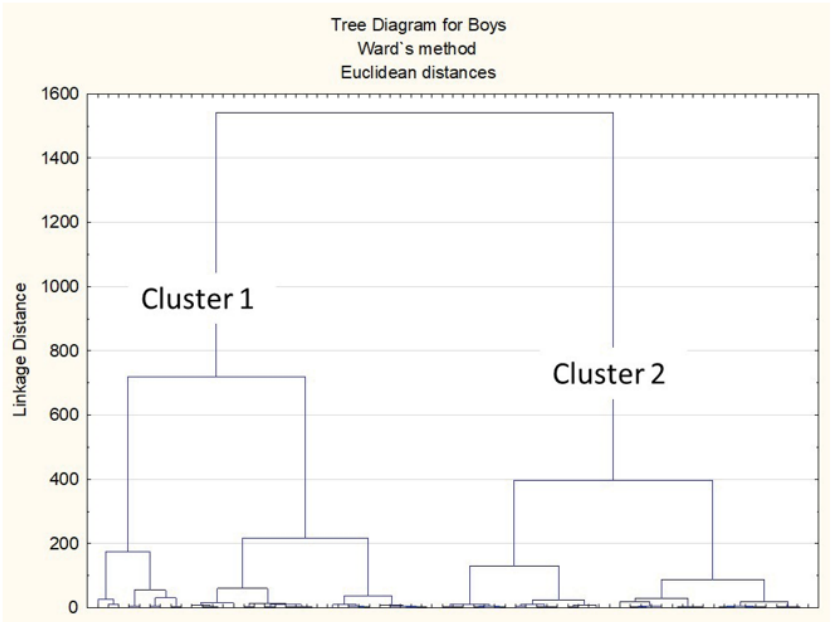

Figure 1. Multivariate clustering of boys based on scholastic variables.

Clustering of the girls on the basis of the scholastic variables is presented in Figure 2. In this subsample, three clusters were formed. ANOVA evidenced the best scholastic achievement in members of Cluster 1 ($p < 0.05$), with significant post-hoc differences between Cluster 1 and the remaining two clusters.

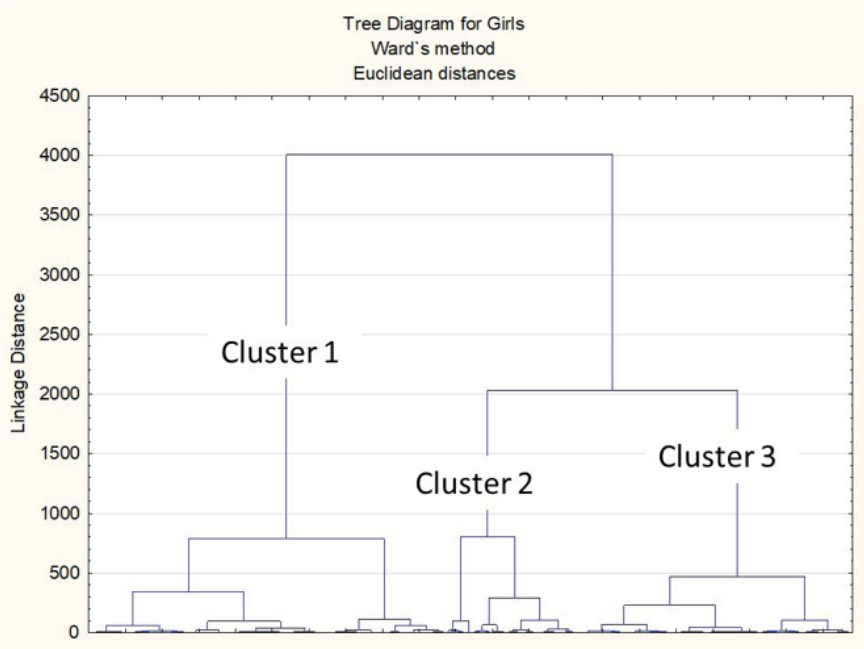

Figure 2. Multivariate clustering of girls based on scholastic variables.

DISCRA did not reveal significant differences between Clusters for boys (Table 4). However, DISCRA revealed multivariate differences among Clusters formed on the basis of scholastic achievement in girls (Table 5). In brief, Root 1 reached statistical significance, evidencing the highest PL and HL in girls grouped in Cluster 1 (note that Cluster 1 consisted of girls who achieved the best scholastic achievement; please see previously).

Table 4. Discriminant canonical analysis for boys - multivariate differences between clusters based on scholastic variables in health literacy (HL) and physical literacy (PL)

	Root 1
PL	0.65
HL	-0.55
Wilks Lambda	0.96
Canonical R	0.18
p-level	0.34
Centroid: Cluster 1	0.18
Centroid: Cluster 2	-0.16

Table 5. Discriminant canonical analysis for girls - multivariate differences among clusters based on scholastic variables in health literacy (HL) and physical literacy (PL)

	Root 1	Root 2
PL	-0.71	-1.00
HL	-0.93	-0.36
Wilks Lambda	0.94	0.98
Canonical R	0.20	0.10
p-level	0.03	0.13
Centroid: Cluster 1	0.26	0.01
Centroid: Cluster 2	-0.16	-0.10
Centroid: Cluster 3	-0.19	0.20

2.4.4 Discussion

The gender-stratified approach we applied herein was evidently appropriate. In brief, while scholastic factors were not significantly associated with PL and HL in boys, our analyses showed a significant association between these variables in girls. Although the correlation was generally low, the relative consistency of the associations (PL and HL were almost identically associated with scholastic factors in girls) deserves specific attention regarding study aims.

We initially hypothesized that scholastic factors would be positively associated with both observed types of literacy (PL and HL). Indeed, it was logical to expect that better scholastic achievement, despite the type of variable observed, would be an indicator of better HL and PL. To the best of our knowledge, this is one of the first investigations which directly observed mentioned relationships in southeastern Europe and almost certainly the first one on the territory of former Yugoslavia. However, previous studies in other regions support our findings (Nelson & Gordon-Larsen, 2006; Schmitz et al., 2002; Whatnall et al., 2019).

The positive association between scholastic achievement observed throughout school-grades (i.e., grade point average) with HL and PL is relatively straightforward. Namely, both PL and HL can be taught (de Albuquerque et al., 2022). Therefore, it is logical that students with better grades will have better knowledge incorporated in PL and HL questionnaires, either simply by better "general knowledge" obtained from various school subjects (i.e., biology, chemistry, physical education), or by specific learning about the topics evaluated in PL and HL questionnaires.

When it comes to a positive association between other scholastic variables we have observed (e.g., absences) with PL and HL, the explanation is relatively logical, although it doesn't seem so at first sight. Namely, scholastic factors are known to be intercorrelated. It means that students with better grades are less likely to be (frequently) absent from school. Although we didn't specifically discuss it in our study, previous research done in the territory of the former Yugoslavia consistently confirmed it (Idrizovic et al., 2015; Zubak et al., 2018). While the causality of the association between scholastic variables is not within this research's scope of this research, it will not be discussed in detail.

The findings that scholastic factors were correlated with PL and HL solely in girls is probably a result of several "mechanisms". First, the most logical explanation is related to the number of subjects and the fact that we observed three times more girls than boys. Simply statistically, the number of subjects increases the degrees of freedom and the probability and statistical significance (Huck, 2008). However, it seems that this was not the main mechanism of gender-specific associations since correlation coefficients in girls were somewhat higher than in boys (please see Results for details). Therefore, it is more likely the fact that we observed one specific educational program (vocational school, including future health professionals) resulted in (more) systematic development of all types of knowledge in girls than in boys. To support such a notion, we must mention that girls had better grades and better results in HL and PL than boys. This could imply that girls with better grades are more aware of the importance of health and have better health information.

Despite the previous discussion, the fact that studied correlations between scholastic variables with PL did not reach statistical significance among boys deserves certain attention. Once again, the most probable reason is the specificity of the sample of participants involved in our research. Precisely, students attending vocational high schools, such as the one studied here, are known to have worse health habits (e.g., increased sedentary time and lower physical activity levels) than academic high school students (Štefan et al., 2020).

Furthermore, as authors were directly involved in working with similar students (the study's first author was a teacher, and the second author was a school principal), we can state that only a few students (particularly boys) were actively involved in sports. It is important since the sport is one of the main agents that promote physical activity levels among boys, and directly and indirectly influences health habits by fostering the development of PL (Sunda et al., 2022). Additionally, sport is the primary source of physical activity, which is one of the paramount health promoting behaviors, and as such is also linked to HL (Buja et al., 2020). Thus, as boys included in our study didn't practice sports to a greater extent, it is somewhat

logical that the association between scholastic variables and literacies (HL and PL) did not reach statistical significance. This result deserves special attention from the perspective of a school and especially school pedagogues.

Namely, regarding adolescents not participating in sports activities which is the primary source of developing both HL and PL, those literacies should be embedded in the school curriculum. Indeed, school-based health promotion practices and embedding HL curricula are key agents for flourishing HL in young people (Schulenkorf et al., 2021). Schools are identified as venues for promoting health and health education as schools can reach all school-aged children without regarding their economic or social background (St Leger, 2001).

2.4.5 Conclusions

Although our results showed relatively weak associations between scholastic achievement with HL and PL, it seems that the problem of the influence of education on HL and PL deserves attention. Namely, while correlations were significant for girls, lack of association in boys could direct future studies in evidencing correlations between specific types of knowledge with HL and PL.

The main study limitation comes from the fact that we studied one specific sample of participants, students from a vocational school in one region of Croatia. Therefore, specific biases could exist and consequently could influence the results. Therefore, adolescents from other regions and schools should be observed in future studies.

It is globally accepted that both HL and PL should be developed, especially in adolescence. Consequently, it is necessary to evaluate its correlates and implement and evaluate programs to improve PL and HL as determinants of health. There fore, school authorities should be informed of results obtained herein, especially on the evident lack of associations between scholastic achievement, PL, and HL in high-school boys.

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3 GENERAL CONCLUSION

Health literacy (HL) and physical literacy (PL) are of great interest for public health professionals and the scientific world. It is well known that positive health behaviour in adolescence is related to adult health behaviour, and it could prevent different health outcomes and diseases. Two major concepts that have an impact on the health and health behaviour during adolescence are HL and PL. PL is a determinant of health and it is associated with favourable health indicators like body mass index (BMI), body weight, cardiorespiratory fitness, systolic blood pressure and muscular fitness. PL improves physical, social, and mental health through increases of physical activity (PA). Today, the decrease in levels of PA pose a global problem: 31.1% adults and 81% of adolescents worldwide are physically inactive. One of the leading modifiable health risk factors for global mortality is PA (Buja et al., 2020). HL enables individuals to be more critically responsible about their own health. It includes knowledge about healthy behavioural habits, healthy food, the importance of PA, and different prevention measures (like vaccination / immunisation). Individuals who possess such knowledge are classed as a "health literate" individual. Statistical data for the European Member States shows that Croatia is in first place regarding obesity; and second place in mortality, due to different sorts of cancer; and fifth place in terms of unhealthy behaviour (drinking, smoking…). This is caused by poor HL. A recent paper published by Bobinac et all. showed that the average level of HL for an adult in the Croatian population is between problematic and adequate. The same author showed that there are significant differences in level of HL within the population and that these differences are associated with class, economic, and social characteristics of individuals (Bobinac, 2023).

Two concepts and their relation to health indices are investigated in this research. The two concepts are HL and PL. Their relation to health indices was studied in a specific sample population from a vocational high school in the coastal county of Dalmatia of Croatia. Both these concepts influence health behaviour and health outcomes and as such could be taught as a general set of skills. Sometimes the terms HL and PL are used synonymously with some assuming that they represent the same concept. It was therefore important to explore the intercorrelation between HL and PL within an adolescent population. The resulting study showed poor intercorrelation between the two concepts. PL correlated with physical activity level (PAL) and physical fitness. On the other hand, HL correlated with health indicators such as lipid profiles and anthropometrics. The study also sought to find if there was any variance in HL and PL levels between the adolescent male and female populations. As there was no

conclusive evidence with regards to a difference in PL and HL between these two populations, a logical next step was to investigate how parental factors may influence HL and PL in adolescents. Parents are often considered role models for their children according to child development theory. As such children are often seen imitating the behavioural patterns of their parents. It was therefore considered that the level of parental education could be a factor. In other words, parents who are better educated possess a better level of HL and PL. Finally, considering that HL and PL could be taught as skills, and that this could be done in primary and secondary schools, it is feasible to surmise that the scholastic performance of adolescents along with other school-related variables, can be connected to HL and PL. It can be theorised that those students who achieve higher grades and have low levels of absenteeism, would be expected to have a more developed capability in terms of HL and PL skills along with better health habits.

This research generated the following conclusions:

(i) parental education (especially mother education/ level of HL) influences adolescents health-related behaviour and it is a protective factor against a decrease in PAL during COVID-19,
(ii) association between HL and PL is week in adolescent population,
(iii) HL and PL are associated with specific health indicators in the way that HL is more associated with direct health indicators, while PL is more related to PAL, and
(iv) association between HL and PL with scholastic achievement is generally poor.

These findings provide new knowledge on adolescent specific literacy such as HL and PL, and its impact on promoting/ improving health and health behaviour among adolescents, consequently highlining the need for establishing and evaluating HL and PL programs that will be included in both Educational and Public Health strategies to promote adolescent's health behaviour, health, and wellbeing. In the following text, each topic/conclusion is briefly explained.

(i) Parents and educational institutions as main educational agents can influence HL in adolescents, through the promotion of PA as a health enhancing behaviour rather than simply competitive sports. Findings from Study 1 indicated that in the group of older adolescents the maternal level of education (higher level of HL) is one of key component

influencing engagement in PA during COVID-19 pandemic. This can have direct repercussions in the ability of adolescents to maintain sufficient PAL in situations such as COVID-19 epidemic, where adolescents with higher HL and knowledge of the importance of PA as a health benefit will try to maintain sufficient PAL even in the absence of the regular conditions for practising sport.

(ii) Associations between HL, PL and health status are influenced by varying factors. Findings in Study 2 showed no gender differences in the level of HL and PL, and HL and PL were poorly intercorrelated. Thus, HL and PL should be evaluated both separately and using multiple indices in heterogeneous sample populations (other than body composition), in order to objectively evaluate the associations that may exist among HL, PL, and health status.

(iii) Lipid profiles can be a good parameter to use in the determination of HL in adolescents. Conversely lipid profiles are not always a good indicator of PL, which is more related to PAL. This suggests the independence of HL and PL as two specific branches of education that should be promoted by public health authorities and educational institutions to improve healthy behaviours in adolescents.

(iv) Insufficient data is available to determine whether there are correlates between scholastic results HL and PL. While this study showed significant correlations in girls, non-such correlations were found in boys. This may have been due to specific bias in the locality or the educational institution which was the focus of the study. It is therefore necessary that school authorities heed the information coming from this study and a more in depth and wider research activity is carried out to determine with more certainty if there are associations between scholastic results, HL, PL, and health status in adolescents.

Finally, it might be said that HL and PL are two key branches of education that should be developed and promoted by parents, educational institutions, and health authorities to directly impact on the health status of adolescents. More studies are required to find associations between HL, PL, health status and scholastic achievement.

3.1 Strengths and Limitations

Allbeit that participants in the studies answered anonymous questionaires which lead to a tendency to be more honest, it could be considered that the use of such self compiled questionaires are a limitation due to the possibility that participants provide socially acceptable answers as opposed to a true reflection of oneself.

A second limitation present concerned the cross-sectional nature of the investigation. In otherwords, because of cross-sectional nature of the investigation causality cannot be determined.

Finally, the fact that the studies were focused around a single vocational school in Southern Croatia could also be considered as a further limitation.

A strength of this study is that they are amongst the first investigations concerning the correlates of PAL during the COVID-19 lockdown in relation to diverse age groups of adolescents. Additionally, as far as the authors are aware, this was one of the first studies investigating HL in the Croatian adolescent population and, it is one of the first studies that investigated HL and PL in relation to CVHS indices (lipid profile, PAL) in adolescents. Additionally, knowing that the studied indices vary across different geographical regions and cultures, it is important to note that this is probably the first study that has investigated this problem in southeastern Europe. Indeed studies investigating the associations among PL, HL and body composition are generally lacking.

3.2 Perspectives for future research

From the public health perspective health literacy and physical literacy are of great interest, and therefore the author of this dissertation took liberty to highlight some directions for future investigations in the field. To the best of the authors knowladge this is one of the rare studies which investigated different aspects of health literacy in the region of the Southeastern Europe, and probably the first one that evaluated the associations between health literacy and physical literacy. Therefore, it is clear that in both areas there is a need for intervention studies where the effects of different educational programs on changes of helaht literacy and physical literacy can be evaluated. In doing so, special attention should be placed on children and adolescents since the eventual positive effects of intereventions would be hopefully continued in their later life.

One of the studies included in this dissertation (please see first published study) indicated a significant association between parental factors and factors of health literacy. Therefore, another important issue within the field would be the evaluation of the health literacy of the parents and the eventual association between parental and children's literacy-levels. Namely, it would allow, not only the identification of any correlation but also highlight the possibility of targeted interventions that could be provided to parents who would later transfer this knowledge to their children.

Finally, it is of utmost importance to identify possible effects of changes (e.g. improvement) of health literacy on changes in objective health-indicators. That is, although health literacy is known to be associated with health-indicators, there is a general lack of knowledge how changes in health literacy are transferred to health-indicators. Therefore, research where health inbidicators are observed prospectively over a certain time frame (e.g. pre- to post-measurement design) while participants are subjected to educational intervention aimed at the improvement of health litereacy would be of great interest and would provide valuable knowledge about the problem.

4 BIBLIOGRAPHY

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5 Biography

Marijana Geets-Kesić, MD; born on 06.09. in Split, Croatia. In 1996, she graduated at school of Medicine University of Zagreb. After two years of the internship in the Public Health for several years she worked for different NGOs in different countries in Africa and Middle East where she started to be interested in Medical Crisis Management. In 2006 she finished European Master's in Medical Disaster (EMDM) at Universita del Piemonte Orientale (Italy) and Vrije Universiteit Brussel (Belgium).

For more than 15 years she was senior teaching staff in Zdravsvena škola Split where she lectured medical group of subjects. She was active in different school projects. In 2019 she won mentors award in category Future Scientist Award for research project with title: "Antioxidant and antiproliferative characteristic of *Salvia officinalis* and *Hypericum perforatum* tea".

Currently she works as assistant at Department for Anthropological Kinesiology and Health - Faculty of Kinesiology at the University of Split. Her sphere of interest in research are: health literacy, physical literacy and health indices in adolescent population.

6 Curriculum vitae

Europass Curriculum Vitae

Personal Details

Name / Surname	**Marijana Geets-Kesić**
Address	Mostarska ulica 104
Telephone	021 368093 Mobile Telephone: 091 5740100
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E-mail	marijana_gk@hotmail.com;marijana.geets-kesic@skole.hr;markes@kifst.hr
Nationality	Croatian
Date of Birth	06.09.1969.
Sex	F

Work Experience

Date	From Jan 2021 - ongoing
Activity or Workplace	Assistant
Main Work and Responsibility	Assistant in the Institut for Anthropological Physiology and Health Faculty of Kinesiology, University of Split
Name and Address of Employer	Higher Education
Type of Activity or Sector	From September 2006 to January 2021
Date	
Activity or Workplace	Senior Vocational Teacher
Main Work and Responsibility	Organization and leading multiple subjects for vocational learning
Name and Address of Employer	College for Health Studies in Split, Šoltanska 15, Split
Type of Activity or Sector	Vocational teaching of students pursuing careers in health and social care sectors.
Date	From August 2004 to January 2006
Activity or Workplace	Medical Doctor

Main Work and Responsibility	Leading a team for emergency intervention and recovery in the UN Airport of Kinshasa (DR Congo)
Name and Address of Employer	PEA Inc.; 888 South Figueroa Street, suite 1700. Los Angeles, CA 90017-5466, USA.
Type of Activity or Sector	NGO (contracted to UN)
Date	From May 2004 to August 2004
Activity or Workplace	Medical Doctor
Main Work and Responsibility	Member of a medical team to supply first aid to workers and travellers in Split Airport
Name and Address of Employer	Heatlh Institute Split, Split Airport, Kavanjinova 2, Split
Type of Activity or Sector	Health and Welfare
Date	From December 2002. to September 2003.
Activity or Workplace	Medical Doctor
Main Work and Responsibility	Medical Doctor supporting a team carrying out de-mining operations in Croatia
Name and Address of Employer	VilaKol d.o.o. Nova Bila, Zagreb
Type of Activity or Sector	Humaitarian Support
Datei	From June 2002 to August 2002
Activity or Workplace	Medical Doctor
Main Work and Responsibility	Substitute Medical Doctor for ordinary medicine
Name and Address of Employer	Doctors Surgery Gordane Kovač-Prenc, Mosečka 65, Split
Type of Activity or Sector	Health and Welfare
Datei	From March 2000 to May 2001
Activity or Workplace	Medical Doctor
Main Work and Responsibility	Leader of the NGO clinic : United Methodist Health and Maternity Clinic
Name and Address of Employer	United Methodist church, 41E Kissy Bye-Pass Rd, PMB 883, Kissy, Freetown, Sierra Leone
Type of Activity or Sector	Humanitarian aid
Datei	From February 1999 to May 1999
Activity or Workplace	Medical Doctor
Main Work and Responsibility	Substitute Doctor in local surgery.
Name and Address of Employer	Doctors Surgery Gordane Kovač-Prenc, Mosečka 65, Split
Type of Activity or Sector	Health and Welfare
Date	From December 1996. do January 1999.
Activity or Workplace	Medical Doctor - Apprentice

Main Work and Responsibility	Work Experience
Name and Address of Employer	Institute of Health Split, Kavanjinova 2, Split
Type of Activity or Sector	Health and Welfare

Education

Date	From September 2009 to June 2010
Name of qualification	E-learning management
Main Subject / Professional Skills Acquired	Techniques and use of ICT technology in education
Name and type of organization providing the education and training	CARNet
Date	From october 2007 to jun 2008.
Name of qualification	Vocational teacher
Main Subject / Professional Skills Acquired	Pedagogy, Psychology, Metodology and Didactic
Name and type of organization providing the education and training	PMF - Split
Date	From January 2006 to jun 2008.
Name of qualification	EMDM
Main Subject / Professional Skills Acquired	Postgraduation in Management of Medical Disaster.
Name and type of organization providing the education and training	University of Eastern Piedmont Amedeo Avogadro, Piedmont, Italija
Date	from 1996. to 2006.
Name of qualification	n/a
Main Subject / Professional Skills Acquired	Biomedicine - immunology
Name and type of organization providing the education and training	PMF -Zagreb
Date	From October 1989 to March 1996
Name of qualification	Medical doctor
Main Subject / Professional Skills Acquired	Universityt of Zagreb – School of Medicine

Name and type of organization providing the education and training	
Date	From September 1984 to May 1988.
Name of qualification	Chemical assistant
Main Subject / Professional Skills Acquired	Chemistry Middle School -Split
Name and type of organization providing the education and training	

Additional Working Experience / Responsibilities

- From 2020 - lecturer for Medical subjects in the Health School in Split
- From 2018 - lecturer in Aspira College – adult education
- From 2018 - active participation in Lifelong Learning Week
- From 2016 - member of intervention team for CK Split
- 2000. – 2006. intermittent work in multicultural and multiethnic environments

Personal Skills and Competencies

Mother Tongue **Croatian**

Second Language (s) **English,French, Italian**

Self Assesment	Understanding		Speech		Writing
European Level (*)	Listening	Reading	Spoken Interaction	Spoken Reproduction	
English	C2	C2	C2	C2	C2
French	B2	B2	B2	B2	B2
Italian	A2	A2	A2	A2	A2

(*) EU Refernce for Language Levels

Social Skills and Competencies

- Communication, Systematic, Team Player, Leader, Coordinator, High energy

Organizational Skill and Competencies	- od 2006. – 2019 Active participant and coordinator E-medica. - od 2016. - 2018. President for practical activities in medicine for the Health School - od 2013. - 2014. - od 2007.- 2008..
Technical Skill and Competencies	- Quality Team Leader and Continuous Improvement - External Lecturer for Red Cross Split - Consultant for transporting dangerous materials.
IT Skills and Competencies	Proficient in working with computer packages e.g. Word Excel Passed all seven modules of ECDL. Passed CaARNet workshop : working with animation using flash tools. Working on line with Moodle, e-workshop for mentors. Communication and collaboration on the Internet, basic HTML and GIMP
Artistic Skills and Competencies	-- 2020 Mentor for iconographic work on the theme„ Corona – zaštiti sebe i druge“ Croatian Institut of Public Health - 2018 Mentor for Artwork competitition on the theme „Volunteering“ organized by HCK - 2017 organizacija preventivni programi - prevencija alkoholizma u mladih - 2011 organization of a public exhibition "We sailed 5000 years, and treated and ate…." and making posters about malaria for the purpose of educating the general population.
Driving Licence	B Category
Other Information	- Member of Croatian Medical Doctor Chamber (HLK), HLZ , EMDM Alumni, European facilitators - International Prize for Mentoring Students in the ISABSu competition / conference 2019.

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