UNIVERSITÀ DEGLI STUDI DI PALERMO

PhD Program in Health Promotion and Cognitive Sciences
Department of Psychology, Educational Science and Human Movement
Sport and Exercise Sciences Research Unit
Metodi e Didattiche delle Attività Sportive (M-EDF/02)

PHYSICAL ACTIVITY IN ADOLESCENCE: LEVELS, CHANGES, AND FACTORS OF INFLUENCE

Ph.D. CANDIDATE
MSc. Dora Marić

COORDINATOR
Prof. Massimiliano Oliveri

SUPERVISOR
Prof. Damir Sekulić

CO-SUPERVISOR
Prof. Antonino Bianco

CYCLE XXXIII
AA. 2020/2021

Acknowledgements

First of all, I would like to say that I am incredibly grateful for the opportunity to become a part of this Ph.D. program in “Health Promotion and Cognitive Sciences”. It provided me with great experience and education and made me more prepared, determined, empowered for future opportunities. If I think about things I cherish the most from this time, I would say people (colleagues), connections, friendships, great professors/mentors who supported me through this crazy, motivating, challenging, educative period full of opportunities to grow as a person and young scientist. This experience gave me a great opportunity to expand my knowledge and become even more motivated and hungry for learning, exploration, and self-improvement especially in the context of science in sport and physical activity. So I would like to express my sincere gratitude for this amazing opportunity to be a part of the UNIPA family and to fulfill my dream of becoming a future Doctor of Science.

I am deeply grateful to my supervisor-mentor, Professor Damir Sekulić and my co-supervisor, Professor Antonino Bianco for given time, knowledge, and guidance through this journey of becoming a Doctor of Science. I would like to extend my sincere gratitude to Prof. Nikola Foretić for invaluable advice, stimulating discussions, and encouragement.

Thanks to all of my professors from University of Palermo - Sport and Exercise Sciences Research Unit, from Faculty of Kinesiology in Split and from Faculty of Sport in Ljubljana and all of my colleagues supporting me during the course of my Ph.D. degree. Special thanks to all my coauthors for working on our publications.

Last but not least, I’m particularly appreciative of my family and friends for continuous and inexhaustible support and understanding, and most of all for believing in me when I needed it the most.

Abstract

Physical activity (PA) is considered a health imperative, so it is understandable that physical inactivity imposes a serious health threat. The fact that alarming decline in physical activity levels (PALs) occurs in adolescence is particularly concerning. Accordingly, the dissertation deals with PA issues among adolescents in regular conditions and during the COVID-19 pandemic. Generally, changes and correlates of the PALs in the period from 14 to 18 years of age and in the period of the COVID-19 pandemic are investigated. Four presented studies analyze the specified problems in adolescents from Croatia and Bosnia and Herzegovina and are among the first studies that examined this issue in Southeastern Europe. The results are, to some extent, clarifying PA changes and factors influencing PALs, indicating significant gender and environmental differences, the association between cigarette smoking and PALs, and the association between parental/familial factors and PALs. Apart from giving the insight into background of changes in PALs in adolescence, the results obtained provide guidance in developing preventive strategies intended to reduce the decline in physical activity progressively happening in adolescents.

Contents

Introduction **6**

Chapter 1 - Physical activity and adolescence **7**

1.1. Physical activity - benefits and recommendations 8

1.2. Inactivity - prevalence and consequences 10

1.3. Correlates of physical activity levels in adolescence 12

1.3.1. Environmental factors and physical activity in adolescents 13

1.3.2. Parental/familial factors and physical activity in adolescents 13

1.3.3. Cigarette smoking and physical activity in adolescents 15

1.3.4. COVID-19 pandemic and physical activity in adolescents 16

Chapter 2 - Overview of published papers **18**

2.1. Levels and Changes of Physical Activity in Adolescents during the COVID-19 Pandemic 19

2.1.1. Introduction 19

2.1.2. Materials and Methods 21

2.1.3. Results 25

2.1.4. Discussion 28

2.1.5. Conclusions 32

2.2. Parental and Familial Factors Influencing Physical Activity Levels in Early Adolescence: A Prospective Study 34

2.2.1. Introduction 34

2.2.2. Materials and Methods 37

2.2.3. Results 41

2.2.4. Discussion 46

2.2.5. Conclusions 51

2.3. Familial and Parental Predictors of Physical Activity in Late Adolescence: Prospective Analysis over a Two-Year Period 53

2.3.1. Introduction 53

2.3.2. Materials and Methods 56

2.3.3. Results 59

2.3.4. Discussion 62

2.3.5. Conclusions 67

2.4. Analysis of the Relationship between Tobacco Smoking and Physical Activity in Adolescence: A Gender Specific Study 69
2.4.1. Introduction 69
2.4.2. Materials and Methods 72
2.4.3. Results 74
2.4.4. Discussion 78
2.4.5. Conclusions 82
Chapter 3 - Contribution to the research field and practical application 84
3.1 Gender differences 85
3.2. Environmental factors and physical activity 86
3.3. Parental/familial factors and physical activity 87
References 88
Overview of the PhD activities and achievements of Miss Dora Marić 105
Appendix – Abstracts of accepted and published papers 109

Introduction

The present dissertation relates to one of the main research interests of the Ph.D. student Dora Marić. Miss Marić chose physical activity (PA) changes and factors influencing physical activity levels (PALs) as her main research topic, prompt and motivated by the continuous decline in PA, happening on the global level, which has been dangerously boosted by the outbreak of the COVID-19 pandemic in recent year.

Accordingly, the first chapter of the dissertation will provide theoretical insight into PA, a background that explains the importance of adequate and dangers of insufficient PALs. Additionally, through previous research most significant factors influencing PALs are going to be introduced.

In the second chapter, four papers published on the topic of physical activity during Miss Marić's Ph.D. study will be presented. The first research paper evaluates the adolescents' PALs changes that occurred as a result of social distancing measures imposed by COVID-19 and factors associated with PALs while considering the impact of the environment and community. The second paper prospectively examines the changes in PALs among adolescents (14 to 16 years of age) and evaluates the influence of socio-educational, socio-economic, and parent-child relationship factors on PALs. The third paper has a similar methodology, studying the influence of familial/parental factors on PALs in older adolescents (16 to 18 years of age). The fourth paper, has a prospective study design as well, however it focuses on the evaluation of the gender-specific relationship between smoking and PALs in adolescents.

The third chapter is dedicated to the author's contribution, conclusion, and implications for further research. The negative trend of physical inactivity is even more hazardous than the current COVID-19 pandemic, accordingly the author is of the opinion that contribution to the research field and suggestions for practical applications should be clearly presented.

Lastly, after references, an overview of Miss Marić activities and academic achievements acquired during three years of the joint international program in "Health Promotion and Cognitive Sciences". It is followed by an Appendix where all of Miss Marić published papers are listed and presented through abstracts.

Chapter 1 - Physical activity and adolescence

Physical activity (PA) includes every body movement, including time spent on activities such as active transportation, household chores, work, and recreational and sports activities, and it is categorized according to intensity levels, from low to moderate to vigorous [1]. Moreover, PA is considered to be any movement performed by skeletal muscle contraction, which results in an increase in energy expenditure or an increase in metabolic rate [2]. Given that the term PA is often mistakenly equated with exercise and is considered to be its equivalent, it is important to point out the differences.

Physical exercise is structured, planned, and repetitive bodily movement executed to maintain or improve one or more parameters of physical fitness defined as the ability/competence that people have or acquire, and is related to physical activity performance [3]. While physical exercise is oriented towards the movement for maintaining and improving parameters of physical fitness, PA can undertake many different forms including any form of exercise: running, cycling, walking, active forms of recreation (such as yoga, dance, aerobic) and sports [4]. Moreover, PA can also be undertaken as part of work (carrying, lifting, or other active tasks) and as part of unpaid or paid domestic errands/chores. Some activities may be done by choice and can provide enjoyment, other domestic or work-related PA may be necessary, or even obligatory, and may not provide equal social, mental, or health benefits in comparison with, for instance, active recreation [4]. Though all forms of PA can provide health welfares if performed regularly and of sufficient intensity and duration [4].

The importance of physical activity, and organized physical exercise, as a formal means of health promotion was emphasized throughout all human history [5]. Ancient Greeks promoted the importance of physical well-being through fitness and a healthy, active lifestyle. The Greek ideal of mental and physical health is contained in Plato's dictum 'Mens Sana in Corpore Sano.' Physical activity was a fundamental part of education in ancient Greece, and most of the education occurred at the Gymnasium. Also, medical treatments often involved daily exercise, diet, and temperate behavior in drinking, eating, sexual indulgence, and sleeping [5]. At the same time, one of the first written exercise prescriptions for a patient was provided by Hippocrates [6].

1.1 Physical activity - benefits and recommendations

It comes as no surprise that the benefits of PA and the direct and indirect influence that it has on the health status are recognized globally. The WHO proclaims PA as a health imperative and makes it one of the key priorities for optimizing health and well-being [1]. What's more, the health-promoting effects of PA are backed by numerous studies exploring the effect of PA on the prevention and treatment of chronic diseases [7-9]. The WHO emphasizes the importance of the regular physical activity of moderate intensity (e.g., doing sports, walking, cycling, etc.) for health benefits. While stating that at all ages, physical activity benefits are outweighing potential harm, such as accidents that are occurring during physical activity, and that any (some) physical activity is better than none.

Known benefits of adequate and regular PA are reduced risk of coronary heart disease, hypertension, stroke, various types of cancer, diabetes, and depression, improvements of bone and functional health, improvements of cardiorespiratory and muscular fitness, and it is fundamental to weight control and energy balance [1]. In general, the increase in PA leads to significantly better physical fitness, which has a positive impact on reducing premature death. Furthermore, scientific evidence highlights the benefits of PA in a broader socio-economic context, given that people who are physically inactive due to a wide range of health consequences represent a great burden for the health care system and thus a large financial expense for a state [10]. It is estimated that the cost of physical inactivity per year in direct health for 2013 is 54 billion international $, while the loss of productivity costs an additional 14 billion international $ [4, 11]. Therefore, it is generally accepted that PA is a core element for preserving health and leading a healthy life while protecting and improving the global socio-economic situation.

In October of 2020 the WHO provided the public with the newest guidelines on physical activity and sedentary behavior [12]. These guidelines are comprised of evidence-based public health recommendations for older adults, adults, adolescents, and children on the amount of PA (duration, intensity and, frequency) required for health benefits and health risks mitigation. More precisely, recommendations are provided on the relations between sedentary behavior and health outcomes, as well as for population subgroups, such as people living with disability and chronic conditions and postpartum and pregnant women [12].

When it comes to children and adolescents (5 - 17 years of age), WHO highlights cardiometabolic health (blood pressure, dyslipidemia, glucose, and insulin resistance), bone health, improved physical fitness (muscular and cardiorespiratory fitness), mental health (reduced symptoms of depression), cognitive outcomes (executive function, academic performance), and reduced adiposity as most important benefits of PA for this population [12]. Accordingly, WHO recommends an average of 60 minutes of moderate to vigorous-intensity physical activity (mostly aerobic) per day across the week, while vigorous-intensity aerobic activities and activities that strengthen muscle and bone should be incorporated for at least three days a week. Additionally, it is also recommended that adolescents and children should also limit sedentary time, in particular the amount of recreational screen time [12].

According to WHO, the most important contributions of PA when it comes to health outcomes in adults (18 - 64 years of age) are: improved all-cause mortality, cardiovascular disease mortality, incident site-specific cancers, incident hypertension, incident type-2 diabetes, cognitive health, mental health (reduced symptoms of depression and anxiety), sleep, and measures of adiposity [12]. WHO PA recommendations for health improvement comprise of at least 75–150 minutes of vigorous-intensity aerobic physical activity, or at least 150– 300 minutes of moderate-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity throughout the week [12]. In addition, muscle-strengthening activities at a greater or moderate-intensity that involve all major muscle groups should also be practiced per 2 or more days a week, given that they provide additional health benefits. Furthermore, reduction of sedentary time is advisable in order to reduce detrimental effects of a high level of sedentary behavior, while for further health benefits, it is recommended to strive for a higher PA level than suggested. Precisely, more than 150 minutes of vigorous-intensity aerobic physical activity, or more than 300 minutes of moderate-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity throughout the week [12].

Similarly, to adults, according to WHO most important contributions of PA when it comes to health outcomes in older adults are: improved all-cause mortality, cardiovascular disease mortality, incident site-specific cancers, incident hypertension, incident type-2 diabetes, cognitive health, mental health (reduced symptoms of depression and anxiety) sleep, and measures of adiposity, as well as prevention of declines in bone health and functional ability and the falls and falls-related injuries [12]. As for PA recommendations WHO states that Older

adults should do at least 75–150 minutes of vigorous-intensity aerobic physical activity, or at least 150–300 minutes of moderate-intensity aerobic PA; or an equivalent combination of vigorous- and moderate-intensity activity throughout the week, for significant health benefits [12]. For additional health benefits and fall prevention, muscle-strengthening activities at greater or moderate-intensity involving all major muscle groups should be practiced per 2 or more days a week, with additional multicomponent PA that accentuates functional balance. Moreover, limit and replacement of sedentary time with PA is advisable in order to reduce determinal effects of the high level of sedentary behavior, while for further health benefits, it is recommended to aim for a higher PA level than suggested [12].

1.2. Inactivity - prevalence and consequences

Despite the persistent and continuous promotion of guidelines for maintaining and optimizing health status over the last two decades, the trend of physical inactivity continues to increase rapidly on the global level (figure 1., figure 2.), and it has taken almost pandemic proportions [13, 14]. The decline in physical activity levels (PALs) is largely due to the modern way of life, which is strongly influenced by rapid economic development, changes in the living environment as well as increased use of technology for work and recreation [4]. Specifically, the increase of sedentarism, longer screen time, changes in transport patterns (relying more on motorized transportation), and the low necessity of physical work in everyday life caused by the transition towards sedentary occupations and leisure are the most recognizable reasons for the decrease of PALs [4]. Sedentary behavior can be defined as any awaking behavior with an energy expenditure lower than 1.5 metabolic equivalents, such as lying down or sitting [15]. The decline of PAL, as well as the increase in sedentary behavior, is alarming since it presents a risk for cardiometabolic morbidity, as well as leading risk factors for global mortality. Insufficiently active people have a 20% to 30% higher death risk in comparison to people who meet the PA recommendations [1].

However, the fact that a rapid decline in PAL and an increase in sedentarism occurs in early adolescence is particularly concerning. On the global level, 81% of adolescents (84% of girls, 78% of boys) aged 11 to 17 failed to meet the WHO recommendations in 2016 [1]. Furthermore, WHO statistics are supported by a great number of studies highlighting the fact that most adolescents and children worldwide do not meet the advisable PAL requirements [16-19].

Specifically, a global study reported that only 20% of children (13 to 15 years) exercise within the WHO recommendation levels [16]. These results differ among the studied populations; in particular, only 5.6% of Chinese between 9 and 17 years, 7% of Canadians between 6 and 19 years, and 15.9% of Americans between 14 and 17 years engage in at least 60 minutes of moderate activity six times a week [17-19]. In cross-sectional studies on youths in Europe and North America results indicate a clear decline of PA in adolescence [20, 21]. The trend of decreasing PALs in adolescents is also noted in few longitudinal studies [22]. In a longitudinal study, the authors followed changes in habits over five years from early to late adolescence and detected a significant decline in weekly hours spent in PA; at the same time, an increase in computer time was noticed, especially in boys [23]. Research conducted over a period of eight years (from 13 to 21) on young Norwegians reported a PA decrease between 13 and 19 years of age [24]. A more recent study on older adolescents (16 to 18 years old) from Bosnia and Herzegovina identified a significant decline in PALs, irrespective of gender [25]. It is obvious that there is an ongoing global trend of decreasing PALs in adolescence; this raises the question as to who will carry the future of the world if according to the data, newer generations will most likely pose a burden for health systems and further economic development. Given the circumstances, to change the negative trend and prevent negative outcomes, PA factors associated with such negative changes need to be elucidated.

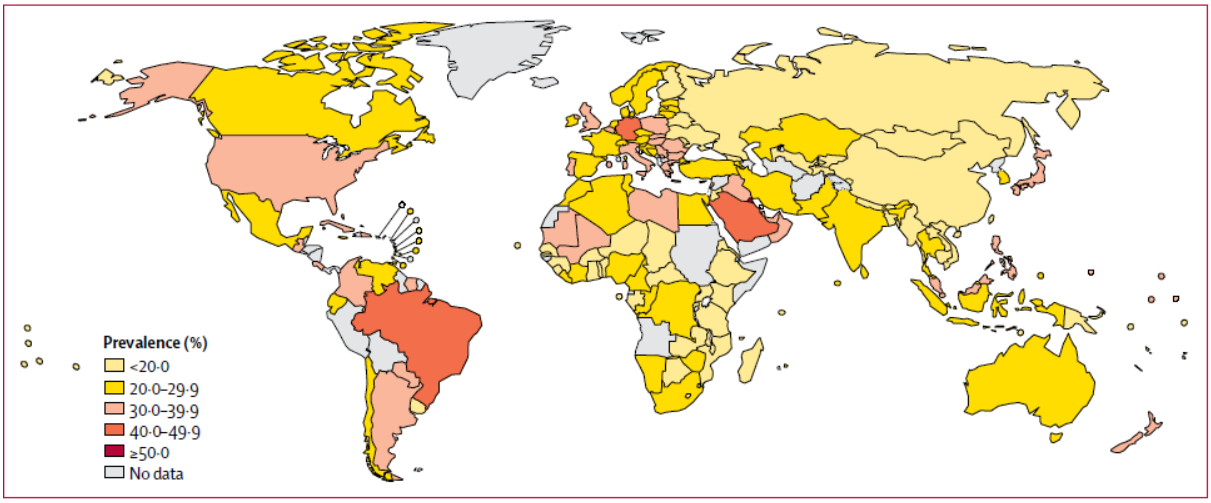

Figure 1. Prevalence of insufficient physical activity in men by country in 2016 [14]

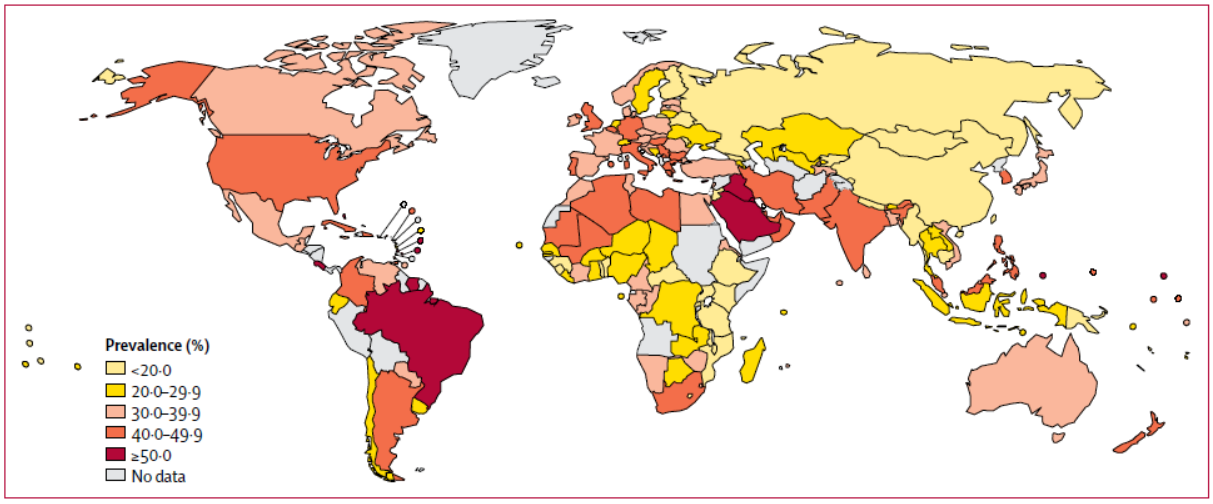

Figure 2. Prevalence of insufficient physical activity in women by country in 2016 [14]

1.3 Correlates of physical activity levels in adolescence

Adolescence presents a period of many changes and has often been characterized as a time of hardship and stress. It is a crucial period for the adoption and retention of future behaviors, including health and educational habits. The attitudes and habits that young people acquire during this period will most likely continue into the adult phase of their lives [26, 27]. Therefore, it is reasonable to conclude that physical activity in adolescence determines later levels of activity and thereby directly affects the overall health status of individuals in the future [28].

In order to resolve this burning issue, diverse interventions with the aim of promoting the greater involvement of adolescents and children in some form of PA have been developed [29-31]. One of the main preconditions for creating targeted and successful interventions is the identification of factors that affect PALs [32]. Not surprisingly, studies have frequently explored the factors associated with PALs in adolescence. Potential determinants can be generally classified into several sub-categories, including; (i) biological/ demographic (e.g., stage of puberty, body mass, sex, age), (ii) psychological/cognitive/emotional (e.g., cognition, attitudes, perceived competence, self-efficacy); (iii) behavioral attributes/skills (alcohol use, smoking, sedentarism, diet) (iv) socio/cultural factors (e.g., age, gender family structure, socioeconomic status, ethnicity, parent/peer/sibling/teacher/coach support); and (v) physical environment (e.g., urban/rural environment, time spent outdoors, weather) [33].

In brief, gender, participation in sports activities, living environment, level of education, self-efficacy, parental activity, and parental support are often positively correlated with PAL. In

addition, the consumption of substances (substance use and misuse—SUM) such as alcohol and cigarettes was often observed in relation to PALs, especially in adolescents. [34-37]. However, last year global population found itself upon another threat, and pandemic proportions of inactivity fell under the influence of another pandemic caused by the coronavirus. Accordingly, it should be acknowledged that with different living circumstances (social distancing, lockdown measures) a great number of new factors influencing PALs arises. Thus, it is also necessary to examine/explore factors influencing PA in the newly formed environmental situations of the COVID-19 pandemic if we want to adapt to the new circumstances and properly influence the PAL.

1.3.1. Environmental factors and physical activity in adolescents

A great number of studies established the importance of living environment on the lifestyle and consequently its impact on PALs [38, 39]. For instance, an international study identified differences between the lifestyle of adolescents who live in urban communities and adolescents who live a bit further from urban centers (few kilometers) [40]. This is supported by studies conducted with Austrian, Cyprus, Italian, Polish, Portuguese, Slovak, and Spanish children and adolescents [38, 41-46]. Adolescents and children living in rural vs. urban communities commonly differ not only in PALs (lower PALs in rural adolescents) but also in anthropometric/body built indices and fitness status [39, 45, 47, 48]. Even though it is well established that PALs are influenced by certain personal (individual) characteristics (i.e., conative facets, motivation, and self-esteem), considering the proven differences in PALs between urban and rural communities, it is expected the PALs among adolescents are also determined by some specific factors associated with a community [46]. Undeniably, the accessibility and availability of equipment and public areas for leisure activities (e.g., bike paths, playgrounds, and courts), time spent outdoors, perceived neighborhood safety, and participation in the labor market among other factors, were shown to be significant determinants of PAL [39, 49]. Reasonably, adolescents from rural communities are more engaged in unstructured outdoor physical activities (e.g., walking and free play). In contrast, those who live in urban communities are more involved in organized sports activities [43, 50].

1.3.2. Parental/familial factors and physical activity in adolescents

Of the sociological factors, parental factors stand out most frequently as positive influences on PALs due to the positive impact they have on the youth's involvement in PA [33, 51, 52]. More specifically, parents are proven to be more important agents of socialization when compared to teachers, peers, school, and other agents of socialization. This is probably because parents (caretakers in general) present one of the primary influences on youth and their behavioral patterns, including PA (e.g., outdoor play, sports and exercise) [33, 53-55]. Which is logical when we take into account that most young people spend approximately 18 years in close proximity to their parents [53, 56]. During that time, parents are usually serving as role models for future habits and behavior directly influencing, in this case, PA behavior, however not always with deliberate/conscious intention [53, 57]. Parents are also sometimes considered to be kind of "gatekeeper" by enrolling children in sports clubs, driving them to training, they are providing them with support even if they don't participate in the activity [29]. According to research so far, parental influence on PA can take many forms and generally can influence children PA both indirectly and directly [53, 58-62]. Studies investigating parental influence on children's PAL have identified a great number of predictors, including parental monitoring, parental expectations, parental support, and family connectedness [63-67]. Furthermore, children of active fathers and mothers are multiple times proven to be more active than children of inactive parents [63]. When it comes to overweight children and adolescents, higher levels of parental expectations, family connectedness, and moderate levels of parental monitoring were associated with the lower PALs [65]. Moreover, genetic and familial environmental factors have a significant influence on the familial resemblance in PALs [66]. However, Gustafson and Rhodes, in their review, reported some inconsistent results, more precisely, six studies found a moderate correlation between children's PA and parent's PA while seven studies did not support those findings. Additionally, parental support was almost consistently recognized as a positive impact on children's PAL, while this effect is more significant in younger children [52]. Similar outcomes were noted by Trost et al. reporting lack of association between children's and parent's PA while, indicating a positive impact of parental support on children's PA behavior [68]. Another systematic review by Jaeschke et al. reporting determinants of PA indicates that encouragement from significant others was associated with higher PALs in children and adolescents, whereas parental modeling and parental marital status were not correlated with PA in children [69]. Apart from that, research examining peer and parental influence on older adolescents (17 – 19 years) found no connection between adolescents' and parents'/peers' PA, however in accordance to previously mentioned studies

parents' encouragement was related to PALs [70]. Parental education is inconsistently associated with young people PALs, according to Sallis et al., which is also reported in other studies [71].

1.3.3. Cigarette smoking and physical activity in adolescents

The smoking prevalence is decreasing globally, however, smoking remains one of the leading cause of death worldwide, and even though the causal link between lung cancer and smoking was established more than fifty years ago, it is still the most commonly misused psychoactive substance in the world [72-74]. According to the statistics and international data, Southeastern Europe (including Bosnia and Herzegovina) is evidenced as one of the territories with the highest prevalence of smoking in Europe, especially in adolescence [75]. Particularly, >25% of high-school adolescents from Bosnia and Herzegovina reported daily smoking, while 20% stated they smoke cigarettes but not on a daily basis [76]. This can be explained by several facts including relatively low prices of cigarettes in the whole region (i.e., the territory of former Yugoslavia) (pack rarely costs more than 3 Euros), as well as the traditional orientation of tobacco growing in some parts of the country. Consequently, cigarette smoking is socially accepted in the country and in the rest of the region [77-79]. However, the fact that PALSsdecline in adolescence is commonly accompanied by an increase in the consumption of substances such as cigarettes is concerning. Knowing that both PALs and smoking are important determinants of health status, mainly since both low PALs and cigarette smoking have severe health consequences, sometimes even detrimental, makes the potential influence of smoking on PA particularly important [76, 78, 79].

Interestingly, although participation in sports (as the most important determinant of PALs in adolescence) and PA are traditionally considered as a way of supporting healthy habits and lifestyle in adolescence and in general, it is expected that higher PALs should be correlated with lower smoking, yet current research does not always support this thesis [80]. The research conducted on South Carolina high school students suggests that higher PALs are associated with a lower likelihood of cigarette smoking in male adolescents [37], which is in accordance with other studies on adolescents addressing this issue [34, 81, 82]. Conversely, a study conducted on African children aged 13 to 15 found no significant correlation between cigarette smoking and PAL [83]. Gender specific associations between smoking and PAL were also detected [84, 85]. Detected inconsistencies among studies are somewhat anticipated since it is well established that different populations depending on gender and sociocultural environment

can have different confounding effects on established relationships between observed variables in this context factors associated with PALs. Though most of these researches were cross-sectional, meaning they observe associations only in one time-point, and such study design provides limited evidence when it comes to the relationships which may exist between PAL and smoking in adolescence. Regardless of the associations between PAL and smoking, the causality between these variables can be interpreted in both directions. In particular, smoking can be observed as "the cause" of insufficient or lower PAL. For instance, more frequent cigarette smoking can have a harmful effect on physical capacities, and thus, it can reduce adolescents' willingness to engage in physically demanding activities. This is clearly evidenced and supported by studies confirming that adolescent smokers had a higher likelihood of quitting sports than non-smokers [86]. At the same time, it is possible that smoking is actually "influenced" by PAL. This is substantiated by the socio-psychological theory of self-categorization which implies that people adopt and accept norms, beliefs, and behaviors of members of their social environment [87]. Therefore, if adolescents embrace the socially acceptable "healthy behaviors" at younger age (including higher PAL due to participation in leisure time PA or sports), it will probably have a positive effect on cigarette smoking (lower smoking) [88].

1.3.4. COVID-19 pandemic and physical activity in adolescents

The current worldwide pandemic of Coronavirus disease 2019 (COVID-19), was recognized in March of 2020. According to the United Nations, "COVID-19 pandemic is the defining global health crisis of our time, and it is considered to be the greatest challenge we have faced since World War II". Based on detrimental health consequences, COVID-19 is perceived as a severe security threat. This ongoing global crisis happening due to the danger that COVID-19 presents for health forces countries that have a high number of confirmed COVID-19 infections cases to impose sooner or later certain measures of social distancing, including lockdowns [89, 90]. More particularly these measures include the closing of shopping centers, places of worship, schools, universities, and sports facilities (e.g., sport-clubs, gyms, and recreational centers, and) [91]. During this still current COVID-19 pandemic, schools are periodically closed depending on the number of active COVID-19 cases, and accordingly, physical education classes were inaccessible. That being said it is assumed that the decrease in PALs would be particularly evident in adolescents and children [92]. In general, a significant reduction in PAL was expected and detected [93]. The decrease of PALs as a consequence of

the COVID-19 pandemic was indirectly proven by Fitbit, the globally popular company which produces devices for activity tracking (Fitbit, Inc., San Francisco, CA), and has access to data from 30 million users. Briefly, the significant decline from 7% to 38% in PALs, measured by the average number of steps per day, was identified when compared to the same period for the previous year before the pandemic started [94]. Likewise, recent researches supports this numbers indicating PALs decline caused by implied restrictions measures [95-97]. It is expected that PALs changes happening during this quite peculiar and complex circumstance are influenced by numerous factors. Therefore, studies are exploring factors that have influenced adolescents PALs in line with PALs changes. Particularly, the latest studies have examined the influence age, gender, fitness status, and family factors have on adolescents PALs during the COVID-19 pandemic [98-100]. The study conducted on Croatian adolescents reported gender differences in PALs changes during the COVID-19 pandemic. PALs decline was more apparent among boys, most likely because recreational and sports facilities were closed during the lockdown, and these facilities are used for activities (i.e., team sports such as handball, basketball, football) that boys partake more regularly when comparing to girls. Moreover, higher PALs were associated with greater fitness status before and during the pandemic. The authors hypothesized that the explanation lies in the fact that adolescents with a higher fitness status have superior knowledge and better awareness of exercise and PA importance (i.e., better "physical literacy"), especially in these unfavorable circumstances/conditions [100]. This is indirectly supported by a recent study reporting the association between PALs and pre-pandemic sports factors, explained by better physical literacy and greater need for activity in sport participants [99, 100].

Chapter 2 – Overview of published papers

In this chapter, Miss Marić is going to present four papers selected for the final thesis. Regardless of the fact that physical activity is continuously highlighted and promoted as an important determinant of overall health status, the trend of physical inactivity continues to increase rapidly. The problem is particularly evident in adolescence because of the significant decline that occurs at this age. That being said Miss Marić decided to explore the issue related to physical activity and correlates of physical activity in adolescence. Papers presented are processing the topic of physical activity while examining different correlates. Besides the topic, papers also have a similar study design while also investigating a sample from the same region - Southeastern Europe. The prospective study design was selected given that it may provide a more comprehensive interpretation of the relationship and the cause-effect relation of variables examined.

1. Zenic, N., Taiar, R., Gilic, B., Blazevic, M., Maric, D., Pojskic, H., & B, D. (2020). Levels and Changes of Physical Activity in Adolescents during the COVID-19 Pandemic: Contextualizing Urban vs. Rural Living Environment. *Applied Sciences*, *10*(11), 3997. doi:10.3390/app10113997

2. Maric, D., Kvesic, I., Lujan, I. K., Bianco, A., Zenic, N., Separovic, V., Terzic, A., Versic, S., & Sekulic, D. (2020). Parental and Familial Factors Influencing Physical Activity Levels in Early Adolescence: A Prospective Study. *Healthcare* (Vol. 8, No. 4, p. 532). doi:10.3390/healthcare8040532

3. Sekulic, D., Maric, D., Versic, S., Zevrnja, A., Terzic, A., & Zenic, N. (2021, February). Familial and Parental Predictors of Physical Activity in Late Adolescence: Prospective Analysis over a Two-Year Period. *Healthcare* (Vol. 9, No. 2, p. 132). doi:10.3390/healthcare9020132

4. Maric, D., Bianco, A., Kvesic, I., Sekulic, D., & Zenic, N. (2021). Analysis of the Relationship between Tobacco Smoking and Physical Activity in Adolescence: A Gender Specific Study. Medicina, 57(3), 214. doi:10.3390/ medicina57030214

2.1. Levels and Changes of Physical Activity in Adolescents during the COVID-19 Pandemic

2.1.1 Introduction

Physical activity is described as the total amount of time spent engaged in daily life activities, work and school activities, recreational and sports activities, and other activities that increase the energy expenditure of the body [101]. Tracking the levels and correlates of physical activity levels (PALs) is one of the main research interests regarding public health [102-104], as having sufficient PALs is associated with higher health-related quality of life [105]. Despite the conclusive evidence of the importance of PAL at all ages, including youth, the PALs in youth over the past few decades have significantly declined [106]. More specifically, 81% of the youth aged 11–17 years do not meet the recommended daily physical activity guideline of 60 minutes of moderate-to-vigorous PA [106, 107]. PALs in adolescents' decline with age by a mean of –7% a year [108]. Similar trends in PAL decline are also evident in Croatian adolescents [109]. Collectively, there is a global consensus of the importance of tracking the changes in the trends of PAL and related influential factors, especially among the youth [110].

Numerous factors influence the PALs, with the emphasis on biological, psychological, social, and environmental factors [111]. Over the last decade, interest has risen in the investigation of the factors that directly or indirectly influence PALs in children and youth, irrespective of the living environment [112, 113]. Numerous studies confirmed the importance of living environment on lifestyle and consequently its influence on PAL [38, 39]. For example, an international study confirmed that adolescents who live only a few kilometers from urban centers have a significantly different lifestyle from their peers who live in urban communities [40]. This is indirectly confirmed in studies conducted with Italian, Polish, Austrian, Cyprus, Portuguese, Spanish, and Slovak children and adolescents [38, 41-46]. Children and adolescents living in urban vs. rural communities regularly differ not only in PAL (with higher PAL in urban adolescents) but also in fitness status and anthropometric/body built indices [39, 45, 47, 48].

Although PALs are generally known to be influenced by certain personal (individual) characteristics (i.e., motivation, self-esteem, and conative facets), considering the differences in PAL between rural and urban communities, it is expected that some specific factors associated with a community also determine the PAL among adolescents [46]. Availability of equipment and public spaces for leisure activities (e.g., bike paths, squares, and courts),

participation in the labor market, time spent outdoors, and perceived neighborhood safety, among other factors, were shown to be important determinants of PAL [39, 49]. Access to recreational and sports facilities, involvement in club sports, and physical education classes in school are positively correlated with PAL [113]. Adolescents from urban communities are more involved in organized sports activities, whereas those who live in rural communities are more engaged in unstructured outdoor physical activities (e.g., free play and walking) [43, 50].

COVID-19, which was recognized in December 2019, and later was classified as a worldwide pandemic. The United Nations stated that the "COVID-19 pandemic is the defining global health crisis of our time and the greatest challenge we have faced since World War II". Due to detrimental health consequences, COVID-19 should be observed as a serious security threat. Most of the countries with confirmed cases of COVID-19 infections imposed certain measures of social distancing, including lockdowns [89, 90]. In addition to other measures of social distancing (e.g., the closing of shopping centers, schools, universities, and places of worship), lockdown measures include the closing of sports facilities (e.g., gyms, centers, and sport-clubs) [89, 91].

Due to the social distancing and closing of sports facilities, a significant reduction in PAL are expected [93]. These claims were indirectly proven by the globally popular Fitbit company, which produces activity tracking devices (Fitbit, Inc., San Francisco, CA), where data from more than 30 million users were collected. In brief, the decrease in PAL (as measured by the average number of steps per day) was 7%–38% when compared to the same period for 2019 [94]. As physical education classes are currently inaccessible, the decrease in PAL would be particularly evident in children and adolescents. With regard to COVID-19 pandemic it is also important to note that recent review showed that physical exercise may increase the level of the enzyme extracellular superoxide dismutase (EcSOD), which is related to reducing oxidative stress in various tissues. EcSOD is induced by exercise and redistributed through circulation to the peripheral tissues as a molecular transducer of exercise to confer protection against oxidative stress and damage in various disease conditions, including various pulmonary diseases and ischemic heart disease [92, 114].

Despite the global projections for a decrease in PALs among adolescents due to the COVID-19 pandemic and related lockdowns and social distancing, studies empirically demonstrating this are lacking. To the best of our knowledge, no study examined this problem while also considering the community type (i.e., urban vs. rural environment). In this study, we aimed to explore the changes in PALs that occurred as a result of COVID-19 and social distancing measures in urban and rural adolescents from Croatia. We also examined the possible

associations between fitness status and PAL before and during the COVID-19 pandemic. We hypothesized that the decrease in PAL, as a result of the COVID-19 pandemic, will be lower in adolescents living in rural communities than those living in urban communities.

2.1.2. Materials and Methods

2.1.2.1. Participants and Study Design

The participants in this prospective study were 823 adolescents from a Croatian coastal region, the Split Dalmatia County. During the study, all participants were attending high school and, at the study baseline, they were 16.5 ± 2.1 years of age. All participants were healthy, meaning that they regularly participated in physical education, and some of them were involved in extracurricular sporting activities. Since the study was originally initiated as part of another investigation ("Physical activity, substance misuse, and factors of influence in adolescence"), all participants were previously informed about the study aims, risks, and benefits, and parental consent was obtained before the study baseline (the outline of the study is provided in later sections). The original study was approved by the Ethical Board of the University of Split, Faculty of Kinesiology (EBO: 2181-205-05-02-05-14-005), and changes in the study design related to the research presented here were additionally confirmed by the same Ethical Board (EBO: 2181-205-05-02-05-14-005-A1).

This prospective study included two measurements: baseline (done before the implementation of social distancing) and follow-up (done during the period of social distancing), as showed in Figure 1. Throughout baseline testing, participants were tested on anthropometrics, fitness status, and baseline PAL (PAL-BL; please see below for details on variables). For this study, in the PAL-BL period, the COVID-19 pandemic had not affected the school schedule and duties in Croatia. There were also no travel bans or limitations for sporting and social activities in the country, although people with a confirmed COVID-19 infection were placed in self-isolation, quarantined (detained), and/or hospitalized. Follow-up testing of PAL (PAL-FU) was conducted in April 2020 and included only online questionnaires of PALs. In this period, numerous measures related to the control of the COVID-19 pandemic were already implemented. Schools and universities were closed starting early March 2020, and as of 19 March, 2020, the government of Croatia implemented other extensive social distancing measures, including the banning of public gatherings, and the closure of cafes, restaurants, shopping centers, sports and fitness centers, cinemas, theaters, and places of worships (e.g.,

churches and temples). However, grocery stores, gas stations, pharmacies, and similar businesses remained open with the implementation of social distancing. At the moment of follow-up testing, local authorities were also able to close public playgrounds and parks, which was the case in the region from where the sample was drawn (Split-Dalmatia County). Figure 1 shows the study design and characteristics of the PAL baseline and follow-up periods.

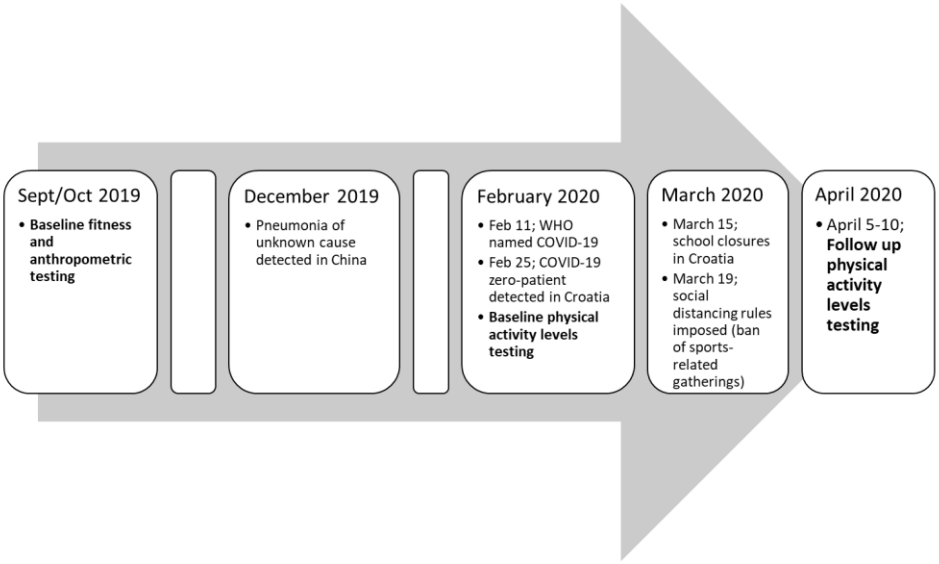

Figure 1. Study design and most important time frames.

2.1.2.2. Variables and Testing

Variables in this study were: age (in years), sex (male vs. female), community of residence (urban vs. rural), anthropometrics (body height, mass, and calculated body mass index), indices of fitness status, and PAL as measured by the Physical Activity Questionnaire for Adolescents (PAQA) [25, 115, 116].

The PAQA was used for measuring PAL-BL and PAL-FU. Participants completed the questionnaire on the online platform Survey Monkey (SurveyMonkey Inc., San Mateo, CA). Similar samples of respondents from Croatia and neighboring countries were assessed using the PAQA before, and it was shown to be a valid test for evaluating PAL. Participants had to recall the past seven days and report it through nine items in the questionnaire. The first eight sections included questions about types of physical activity (i.e., activities during free play, sports, physical education classes, and active transportation). The ninth item was not considered in the final score but was used for noting participants who had some injuries or illnesses that could cause reduced activity. The first eight items were scaled from 0 to 5, and the overall score ranged from 0 to 5, representing the minimum and maximum PAL, respectively. The scores

were categorized as baseline-PAL, follow-up-PAL, and the delta score (PAΔ), which represented the difference between baseline-PAL and follow-up-PAL and provided the range of change in PAL that occurred due to the regulations of social distancing during the COVID-19 pandemic. For statistical analyses (described later in detail), the baseline-PAL and follow-up-PAL were dichotomized. Specifically, scores below 2.73 were considered low-level-PAL, while scores above 2.73 were considered normal-level-PAL as suggested in previous studies [115, 116].

Measures of physical fitness, measured only during the baseline testing, included the standing broad-jump test (broad-jump), hanging on the bar with bent arms (bent-arm-hang), sit-and-reach (sit-and-reach), multilevel fitness test (multilevel-test), 400 meters run (run-400m), and performing sit-ups for 60-seconds (sit-ups). Tests are used in the Croatian educational system and were measured by experienced physical education teachers [117].

The standing broad-jump test was used to assess power (jumping) capacity. The test was performed using standardized equipment (Elan, Begunje, Slovenia) in the gym. Participants started from a standing position with feet placed shoulder-width apart and performed the test by bending their knees and swinging their arms to perform a maximal forward jump. Participants had three test trials with 20–30 seconds of rest in between, and the best (the longest) jump was used as the final score.

The bent-arm-hang test was used to measure static upper-body strength. The test was conducted once in the gymnasium. Participants were assisted to reach the position with bent arms and with their chin over the horizontal bar. Participants were instructed to hold that position as for long as they could. The maximal recorded time in seconds was the test result.

The sit-and-reach test was used to assess flexibility. It was performed in the gymnasium using a standardized box. Participants were sitting on the floor with both legs maximally extended at the knees and with soles of their bare feet placed flat on the box. Participants were instructed to reach forward as far as possible on the measuring line positioned on the box and to hold that position for 1–3 seconds. Participants had three trials, and the best score, measured in centimeters, was recorded.

The multilevel endurance test was used to test aerobic endurance [118]. Participants had to continuously run between two lines set 20 m apart according to the sound signals on the pre-recorded audio track. For the start of the test, participants were standing behind one line and facing the second line, and began to run on the sound signal (“beep”). Participants were instructed to turn after each signal and run back to the starting line until completion of the test. At the beginning of the test, the running pace was slower, and the first two beeps were nine

seconds apart. The interval between beeps progressively decreased each minute of the test. The participants had to increase their speed to reach the line before the beep sounded. The test was over when the participant failed to reach the line before the beep two consecutive times. The final result was the recorded time (in minutes:seconds) after the second missed beep.

The 400 m run was used to assess anaerobic capacity. The test was performed at a handball playground (40 × 20 meters) where participants had to run three full circles and an additional 40 meters. Each participant had one trial, and the result was recorded in seconds.

Sit-ups were used to evaluate the strength of the muscles in the abdominal region. The participants started the test by lying on their backs. They had their knees bent under 90 degrees, palms locked behind their neck, and feet fixed by a partner sitting on them and holding their legs with two hands. Participants had to lift their torso toward their knees. The result of the test was the number of correct repetitions in 60 seconds.

2.1.2.3. Statistics

Kolmogorov–Smirnov test was used to check the normality of the distribution. As a result, means and standard deviations were calculated for numerical variables (i.e., PAQA scores, fitness tests, and anthropometric variables).

Multifactorial analysis of variance for repeated measures (baseline testing vs. follow-up testing), with "sex" (male vs. female) and "environment" (urban vs. rural) used as grouping variables (ANOVA) to calculate and provide evidence for the effects of PAL changes that occurred as a result of the COVID-19 pandemic. Consecutive t-test analyses were calculated as post-hoc analyses when ANOVA results were statistically significant.

Pearson's product–moment correlation coefficients were calculated to evidence the associations between studied variables. The mixed model logistic regression (with gender as random factor) was applied to identify the associations between predictors and the binomial criterion (PAL observed as low-level-PAL (coded as "1") vs. normal-level-PAL (coded as "2")), logistic regressions were calculated, with an odds ratio (OR) and corresponding 95% confidence interval (CI) reported. The model fit was checked by the Hosmer–Lemeshow test (statistically significant test indicates that the model does not adequately fit the data). Two regression models were calculated: Model 0 (non-controlled for covariate environment) and Model 1 (controlled for covariate environment (urban vs. rural community)).

A p-value of 0.05 was applied and the statistical package Statistica ver. 13.0 (Statsoft, Tulsa, OK, USA) was used for all calculations.

2.1.3. Results

ANOVA results indicated a significant main effect for both main effects and significant interaction (Table 1).

Table 1. Factorial analysis of variance for repeated measures.

Variables	Main effects				Interaction	
	Environment		Measurement		Environment x Measurement	
PAL	F-test	p	F-test	p	F-test	p
	4.11	0.01	4.29	0.04	2.98	0.05

Post-hoc analyses revealed a decrease in PAL for the total sample (from 2.97±0.61 to 2.63±0.68, $p < 0.01$) and urban adolescents (from 3.11±0.78 to 2.68±0.73, $p < 0.001$). Significant differences ($p < 0.01$) between adolescents living in urban and rural environments were observed for baseline-PAL, with higher baseline-PAL in urban adolescents (3.11±0.78 and 2.80 ± 0.58, for urban and rural adolescents, respectively) (Figure 2).

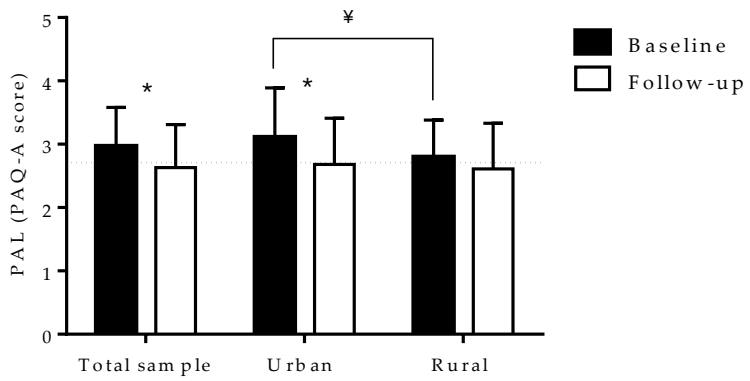

Figure 2. Descriptive statistics for physical activity levels at baseline (before COVID-19 pandemic), and at follow-up (during COVID-19 pandemic) with significance differences between-groups (indicated with symbol ¥), and within groups (indicated with symbol *).

Pearson product–moment coefficients reached statistical significance for associations between most of the anthropometric and physical fitness variables with baseline PAL. The number of significant coefficients was lower when anthropometrics and physical fitness variables were correlated with follow-up-PAL (Table 2). In general, better physical fitness was associated with higher PAL in both cases. The correlations between the anthropometric values

and physical fitness with differences in PAL were negligible, showing a low influence of baseline anthropometric values and physical fitness on changes in PAL that occurred as a result of COVID-19 and social distancing.

Table 2. Pearson's product moment correlation coefficients between anthropometric, physical fitness and physical-activity-level variables (* indicates significant correlation at $p < 0.05$).

	Total (n = 823)	**Rural (n = 381)**	**Urban (n = 442)**
Physical activity at baseline			
Body height	0.21*	0.28*	0.19*
Body mass	0.17*	0.19*	0.21*
Body mass index	0.13*	0.05	0.14*
Broad-jump	0.23*	0.35*	0.26*
Sit-ups	0.21*	0.28*	0.25*
Sit-and-reach	0.01	-0.03	0.06
Bent-arm-hang	0.28*	0.27*	0.35*
Run-400m	0.02	-0.31*	0.07
Multi-level-test	0.39*	0.32*	0.38*
Physical activity at follow-up			
Body height	0.06*	0.13*	0.01
Body mass	0.03	0.05	0.01
Body mass index	-0.04	-0.04	-0.01
Broad-jump	0.16*	0.05	0.16*
Sit-ups	0.19*	0.08	0.19*
Sit-and-reach	0.11*	0.09	0.05
Bent-arm-hang	0.11*	0.05	0.18*
Run-400m	0.09	-0.05	0.08
Multi-level-test	0.11*	0.04	0.17*
Physical activity difference between baseline and follow-up			
Body height	0.04	0.13*	0.20*
Body mass	0.05	0.13*	0.23*
Body mass index	0.10*	0.09	0.18*
Broad-jump	0.10*	0.17*	0.07
Sit-ups	0.05	0.08	0.03
Sit-and-reach	-0.05	-0.11*	0.00
Bent-arm-hang	0.16*	0.11*	0.12*
Run-400m	-0.04	-0.10*	-0.04

Multi-level-test	0.28*	0.25*	0.20*

The higher likelihood of normal PAL at baseline (baseline PAQA score above 2.71) was evidenced for urban adolescents (Model 0: OR: 1.41, 95%CI:: 1.23-1.87), adolescents who were taller (Model 0: OR = 1.54, 95% CI: 1.21–1.87; Model 1: OR: 1.65, 95% CI: 1.11–1.98), heavier (Model 0: OR = 1.34, 95% CI: 1.01–1.45), who had better aerobic endurance (Model 0: OR = 1.67, 95% CI: 1.44–1.95; Model 1: OR: 1.61, 95% CI: 1.20–2.01), anaerobic endurance (Model 0: OR = 0.61, 95% CI: 0.41-0.89; Model 1: OR: 0.71, 95% CI: 0.56–0.89), static strength (Model 0: OR = 2.01, 95% CI: 1.45–2.57; Model 1: OR: 1.97, 95% CI: 1.31–1.2.41), and dynamic strength (Model 0: OR = 1.87, 95% CI: 1.11–2.44; Model 1: OR: 1.88, 95% CI: 1.10–2.50) (Figure 3A and 3B for Model 0, and Model 1, respectively).

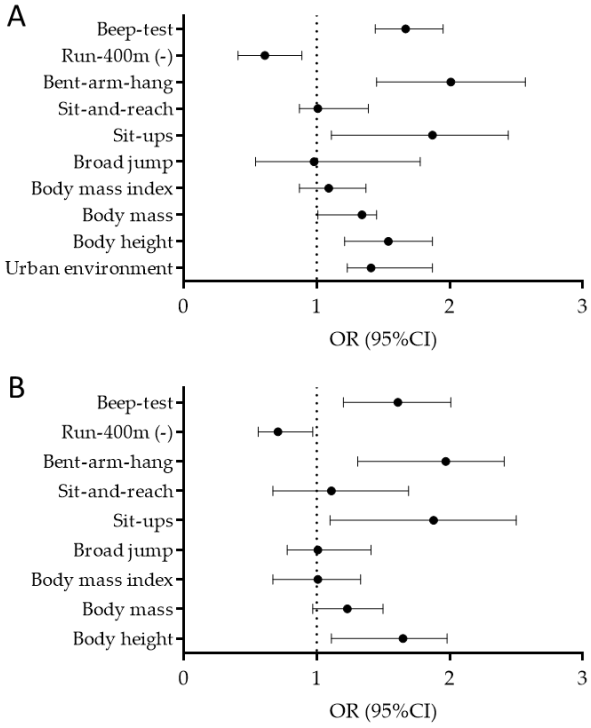

Figure 3. Correlates of baseline-PAL (A – crude logistic regression, B – logistic regression controlled for urban/rural environment as confounding factor).

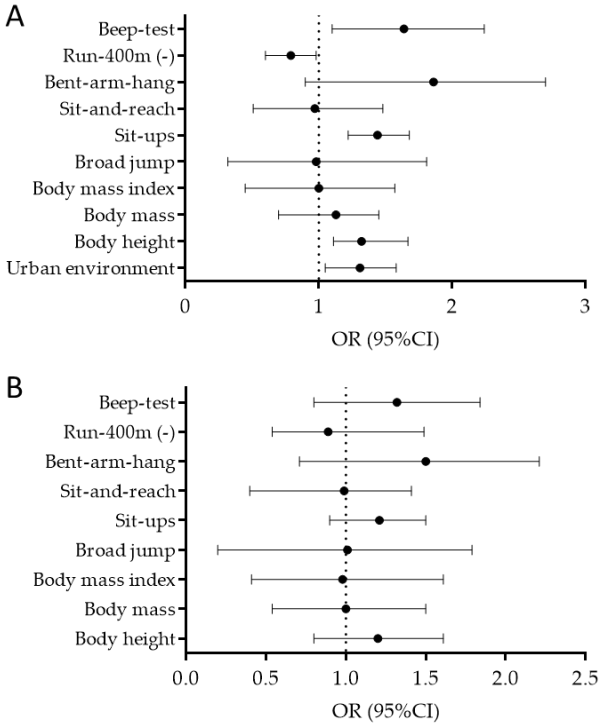

Figure 4. Correlates of follow-up-PAL (A – crude logistic regression, B – logistic regression controlled for urban/rural environment as confounding factor).

When logistic regression was calculated for follow-up-PALs, the results showed generally higher follow-up-PAL in adolescents of better physical-fitness status, but with a strong effect by the urban/rural living environment (Model 0: OR: 1.31, 95%CI: 1.05-1.58). Dynamic strength (measured by sit-ups; OR: 1.44, 95% CI: 1.22–1.68), aerobic endurance (measured by multi-level-test; OR: 1.64, 95% CI: 1.10–2.24), and anaerobic endurance measured by the 400 m run test (OR: 0.79, 95% CI: 0.60–0.980) were positively correlated with a normal-PAL at follow up in the logistic regression model non-controlled for urban/rural environment (Figure 4A). However, when urban/rural environment was included in the logistic regression calculation, no significant correlation between predictors and follow-up-PAL was evidenced (Figure 4B).

2.1.4. Discussion

This study aimed to detect the changes of PALs in adolescents as a result of the COVID-19 pandemic and produced several important findings. First, the PALs of studied adolescents significantly decreased, but this was mostly influenced by large decrease of PALS in urban

adolescents. Second, fitness status was related to baseline-PALs, while the associations between baseline fitness status and follow-up-PALs were strongly influenced by factor of living environment. Therefore, we may support our initial study hypothesis.

2.1.4.1. Changes in Physical Activity Levels among Rural and Urban Adolescents as a Result of the COVID-19 Pandemic

The PAL decreased significantly in the total sample, but we found an influence of the living environment (i.e., urban vs. rural community) on those changes, since the decrease in PAL as a result of social distancing due to COVID-19 pandemic was greater in urban than rural adolescents. Although these findings deserve attention, the following discussion is limited by a lack of accurate data on PALs in Croatian rural areas, especially concerning the adolescent population. Therefore, our results are mostly contextualized to findings of the studies where authors provided evidence for other indices (i.e., health-related, economic, and social factors) in Croatian rural areas.

Modern community development is focused on providing equal opportunities for rural and urban population in terms of income, living conditions, safety, health care, and other goods and services [119]. However, such intentions were not fruitful in Croatian rural areas, since studies showed that people living in rural areas regularly migrate to urban areas due to economic issues (e.g., lack of job opportunities and lower income) and the self-perception that living in rural areas means having a lower quality of life. Specifically, the perception of the quality of life among rural residents in Croatia is affected by dissatisfaction with social and health services and poorly developed infrastructure [119]. This results in an even lower likelihood of youth and adolescents engaging in organized sports in rural areas, which negatively influences the PAL among rural adolescents.

Studies previously reported that urban adults have a higher PAL compared to their rural counterparts in Croatian coastal regions, like the region observed in this study, which was at least partially associated with an increased risk for cardiovascular disease in rural areas [120]. Cross-sectional analyses showed better fitness status among Croatian urban children/adolescents than in their rural peers [121]. After considering the cross-sectional analyses, the results presented in this study that show a lower baseline-PAL among rural adolescents are not surprising and are generally consistent with global reports where similar conclusions were presented [113, 122, 123]. In brief, the U.S. data also conform to these findings, i.e., that rural adults are less physically active than their urban counterparts [113, 123].

Portuguese rural boys were also found to be less physically active than urban boys, but this was not confirmed in girls [122]. Although such differences have mostly been explained by considering physical and environmental factors (i.e., access to sports facilities and programs), other factors were also shown to be potentially important determinants of higher PALs among urban youth (e.g., parental educational level and socio-economic differences) [33, 122].

Considering the baseline-PAL status, it is not surprising that the PAL of urban adolescents decreased more than in rural adolescents. In general, social distancing measures influenced the opportunity to practice organized sports. The influence of social distancing measures was not so pronounced for competitive sports (please see later discussion on correlates of follow-up-PAL), but fitness centers, dance centers, and gyms were closed. This logically influenced the PAL of urban adolescents to a greater extent than rural adolescents, who are generally less engaged in organized recreation [43]. The result of a lower decrease in the PALs among rural adolescents should not be observed as being encouraging, but rather as alarming. The finding that PALs among rural adolescents were not (more) significantly reduced in circumstances such as imposed rules of social distancing, including closing the schools, is a problem in itself.

2.1.4.2. Correlates of Physical Activity Levels before and during the COVID-19 Pandemic in Urban and Rural Adolescents

Baseline PAL was correlated with most of the observed anthropometric and fitness variables, and there was no significant influence of urban/rural community on these relationships (i.e. no differences in associations between adolescents living in urban vs. rural environments). A higher baseline PAL was observed in adolescents who were taller, heavier, and had higher body mass index and who had better fitness. The baseline PAL being related to anthropometrics among boys is a consequence of the higher level of PA among boys involved in sports. Previous studies performed in Southeastern Europe confirmed that the majority of adolescents stop participating in competitive sports at the age of 16 years [85, 124].

This is the age when the most rigid selection of players in sports occurs, and only those predisposed to a high competitive achievement continue to train and compete [25]. For the sports that are the most popular among in the studied region (team sports such as soccer, handball, volleyball, basketball, water polo, etc.), the proper body build and height are among the main prerequisites for successful participation. Most of these sports favor adolescents who have a preferable physique and body type [125, 126]. In boys, this is additionally accentuated by body height and mass in adolescence often being a consequence of advanced maturity, which

directly results in better physical capacities, and a greater ability to physically train for any given sport [127]. As a result, the noted association between baseline PAL and anthropometrics among boys is understandable because it points to adolescents who are actively involved in sports being simultaneously: (i) advanced in observed anthropometric dimensions (i.e., they are tall and heavy) and (ii) physically active (because of the involvement in systematic sports training).

The associations between physical fitness variables and baseline PAL should be contextualized similar to the previously discussed association between anthropometrics and baseline PAL. However, in this case, no environment-specific correlations were seen, and physical fitness status was systematically correlated with baseline-PAL, regardless of the living environment. In general, positive correlations between baseline-PAL and fitness variables were almost certainly a result of better physical fitness status among those adolescents who practice organized and/or non-formal sports [128]. Here, we are not able to discuss the causality between baseline-PAL and physical fitness due to the cross-sectional nature of this part of the investigation, and it should be investigated in the future in greater detail. This study expands upon previous knowledge since the correlation between physical fitness status and (baseline) PAL is seen both in urban and rural adolescents, indicating that the benefits of increased PAL are likely to be similar both in urban and rural adolescents.

The correlations between baseline fitness and follow-up PAL were environment-specific. To summarize, adolescents who had better physical fitness status at study baseline were more likely to have higher follow-up PAL but with the living environment (urban vs. rural) as a strong confounding factor. To explain these findings, we must explain the specifics of the time frame when the study was conducted. The follow-up testing was performed when our participants were not under a strict lockdown. In Croatia, authorities provided social distancing guidelines but did not declare a rigid lockdown (i.e., an emergency protocol that prevents people from leaving the area). Schools, sports clubs, restaurants, and places of social gatherings were closed, and public transportation was limited and was exclusively for work and emergency transport. It was not formally prohibited to undertake some kind of physical training, such as walking, running, riding a bicycle, or even strength training in open spaces, while maintaining social distance. In this period, police officers patrolled and prevented social gatherings of more than a couple of people, including grouping for physical training. However, authorities did not strictly enforce stay-at-home policies under any circumstances, but rather supported and proclaimed such behavior [129, 130]. Collectively, if the measures of social distancing were

respected (maintaining a two-meter distance in public places), there were no strict boundaries regarding physical training, even in open spaces such as parks, forests, on the street, etc.

As we are actively involved in sports training, we are aware that most of the sport clubs and teams in the region organized some form of physical conditioning for their members and athletes. When the measures of social distancing were launched (the period we observed in the follow-up testing), physical training events for competitive athletes were still organized and coaches often joined or at least supervised their athletes. However, this opportunity for active involvement in organized training was limited to urban areas. Those adolescents who lived outside the urban areas could not participate in organized training due to the (i) distance and (ii) the limitation of public transportation.

2.1.4.3. Limitations and Strengths

The most important limitation of our study was that PALs were not directly measured but instead self-reported by participants. Next, physical fitness and anthropometric variables were collected almost three months before the baseline measurement of PAL. This study also only involved participants from one region in Croatia, and therefore the results are only generalizable to similar samples. The last limitation is particularly important given the climate in the studied region (Mediterranean region), and that during the observed time, the lowest temperature was rarely below 10 °C; as such, the weather was ideal for outdoor activities.

Our study is one of the rare studies where PAL and changes in PAL in the period during the COVID-19 pandemic are shown. The physical fitness variables were tested as a part of a well-organized project by experienced evaluators, and results may be observed as plausible and objective. Therefore, we think that our results will contribute to the knowledge in our field and encourage further research.

2.1.5. Conclusions

In conclusion, our data showed that adolescents from both urban and rural areas decreased their PAL as a result of imposed measures of social distancing during COVID-19 pandemic. A disturbing consequence of the measures was that both groups did not meet recommended NPAL during the crisis. Not surprisingly, results showed a significant influence of living-environment on the decrease of PAL, with larger negative effects in urban adolescents. Higher negative

changes were not observed in adolescents from rural areas due to their low baseline PAL. Additionally, the fitness status and body indices of urban adolescents predicted their PAL during COVID-19 pandemic, but such associations were not evidenced for rural adolescents.

In general, our findings accentuate the importance of encouraging adolescents to increase PAL irrespectively of living-environment, as PAL directly improves their fitness level. We believe that in the situation where the measures of social distancing might remain in place for a longer period of time, policy-makers should introduce strategies that would prevent negative impact on PAL in adolescents. As our findings indirectly suggested, the preventive strategies should include free access to training facilities for adolescents from rural areas and provide organized training activities in both rural and urban areas to avoid unintended consequences related to the decreased PAL (e.g. development of chronic diseases, obesity, anxiety, depression, etc.).

In line with the aforementioned, we suggest strategies that would provide adolescents to be physically active without risk to infect themselves or somebody else. The activities could be performed in smaller groups, without physical contact, keeping the recommended social distance, with constantly applied appropriate hygiene measures (e.g., using hand sanitizer to wash their hands regularly) and a permanent coach’s supervision.

2.2. Parental and Familial Factors Influencing Physical Activity Levels in Early Adolescence: A Prospective Study

2.2.1. Introduction

Physical activity (PA) represents an important segment of physical and mental health status [26, 131, 132]. Irrespective of importance of PA in all periods of life, reaching the appropriate PA level (PAL) is particularly important in childhood and adolescence, since regular PA is essential for the healthy growth and development during this life period for a number of reasons. Young people with high PALs are less prone to cardiovascular diseases and type 2 diabetes, control their weight better, maintain a healthy musculoskeletal system and respiratory capacities, and experience mental health benefits (i.e., self-confidence and reduced likelihood of depression) and also have higher level of self-perceived health status [22, 30, 133-138]. Moreover, a decreased PAL in adolescence can cause chronic health problems (e.g., cancer and cardiovascular and respiratory diseases) and obesity at a later age [139, 140].

Although debates over the amount and type of PA needed for health benefits continue, the World Health Organization (WHO) recommends at least 60 minutes a day of moderate-to-vigorous PA for children and adolescents aged 5 –17 years [107]. However, most children and adolescents worldwide do not meet the recommended PAL requirements [16-19]. Specifically, a global study found that only 20% of children between the ages of 13 and 15 exercise within the WHO recommendation levels [16]. These results differ among the studied populations; for example, only 15.9% of Americans between 14 and 17 years, 7% of Canadians between 6 and 19 years, and 5.6% of Chinese between 9 and 17 years engage in at least 60 minutes of moderate activity six times a week [17-19].

Adolescence is a critical period in an individual's development, in which young people form attitudes about many important life issues, including health and educational habits, and the habits and attitudes that young people gain during this period will likely continue into the adult phase of their lives [26, 27]. Despite the clearly emphasized and well-known importance of achieving appropriate PALs in young people, studies have shown that PALs significantly decline in adolescence [29].

In cross-sectional studies on youths in North America and Europe, research has indicated a clear decline of PA in adolescence [20, 21]. Longitudinal studies have also noted a trend of decreased PALs in adolescents [22]. In a five-year longitudinal study, the authors tracked

changes in habits from early to late adolescence and noticed a significant decline in weekly hours spent by young people engaged in PA; in contrast, they observed an increase in computer time, especially in boys [23]. Research on young Norwegians, conducted over a period of eight years (13–21 years of age), reported a decrease in PA between 13 and 19 years [24]. A recent study on older adolescents from Bosnia and Herzegovina detected a significant decrease in PALs between 16 and 18 years of age, irrespective of gender [25]. Obviously, there is a global trend of decreasing PALs; therefore, factors associated with such negative changes need to be elucidated.

Indeed, in order to solve this burning issue, a wide range of interventions have been developed with the aim of promoting the greater involvement of children and adolescents in some form of PA [29-31]. One of the most important preconditions for creating successful and targeted interventions is the identification of factors that affect PAL [32]. As a result, in recent years, a large number of studies have dealt with the analysis of the predictors of PALs in adolescents [29, 33, 63, 64, 141]. In general, PAL predictors can be divided into five groups: Demographic (biological) factors, psychological (cognitive) factors, behavioral characteristics, sociocultural factors, and the physical environment [142].

Globally, there are relatively consistent findings: (i) Boys are more active than girls, and (ii) PALs decrease during adolescence [143]. Furthermore, decreased PALs have been noticed in children from families with poorer socioeconomic status, simply because of the limited choice of physical activities/sports [144]. When it comes to psychological factors, studies have confirmed self-efficacy and motivation (which is primarily caused by perceived (sporting) competence and goal orientation) as the most important psychological predictors that positively affect PALs in young people [143]. Of the sociological factors, parental support stands out most consistently as a factor that positively influences PALs due to its positive influence on the involvement of youths in PA [33, 51, 52]. In this context, parents prove to be more important than other agents of socialization (colleagues, school, etc.) because, in addition to influencing young people as role models, they also serve as a kind of "gate keeper" by enrolling children in sports clubs, driving them to training, and so on [29].

Studies examining parental influence on children's PAL have identified a number of predictors, including parental support, family connectedness, parental expectations, and parental monitoring [63-67]. Children of active mothers and fathers are proven to be multiple times more active than children of inactive parents [63]. Parental support was consistently positively and significantly associated with child PA in numerous studies examining these factors [64, 67]. Among the overweight children and adolescents, higher levels of family

connectedness, parental expectations and moderate levels of parental monitoring were associated with the lower level of PA [65]. Also, familial environmental and genetic factors showed to have significant influence for the familial resemblance in PAL [66].

Despite all efforts, there is still no clear and definitive evaluation of the determinants of the PALs in adolescents [33]. On the one hand, this can be explained by the various measuring instruments used to estimate PA [33]. In brief, some authors used objective measurement techniques such as heart rate monitors, pedometers and accelerometers [145-148]. Meanwhile, most of the studies which analyzed PALs in children and adolescents used subjective technique methods including self-report questionnaires, interviewer-administered questionnaires, proxy-report questionnaires and diaries [149-155]. Self-report and interviewer-administered questionnaires rely on children's self-reported activity in past period, which can vary from past three days to whole year [149-152]. In proxy reports, parents and teachers provide information regarding children's PAL [153, 154]. Finally, diaries were used in only a few studies because it is very demanding for children to take regularly notes about their PAL [155].

The results of previous studies were undoubtedly determined by oftentimes homogenous samples of participants, so the same factors need to be investigated in subgroups of different ethnicities, socioeconomic statuses, and environmental characteristics [33]. Moreover, the researchers that have studied this topic have highlighted regularly in their conclusions the need for a systematic and longitudinal analysis of a number of factors that, due to their complexity, should be observed together, analyzing cause–effect relationships between them, in order to obtain a more realistic picture of the determinants of PA during adolescence [52, 69]. Although studies done so far provided evidence on decrease of PAL during period of adolescence on the territory of southeastern Europe, there is limited body of prospective evidence about: (i) changes in PAL which occur in younger adolescents, and (ii) factors which may influence such changes in this teritory. Specifically, to the best of our knowledge no study so far prospectively examined the changes in PAL, while examining the socio-economic, socio-educational, and factors of parent-child relationship as covariates of changes in PAL in younger adolescents from the territory of former Yugoslavia.

For these reasons, the main aim of this study was to prospectively evaluate the changes in PALs among adolescents from Bosnia and Herzegovina over the 2-years period, between 14 and 16 years of age. Further, we evaluated the influence of socio-economic, socio-educational, and parent-child relationship factors on PALs at the beginning of the 1st year of high school (approximately 14 years of age), and at the end of 2nd year of high-school (approximately 16 years of age). Authors hypothesized that decline of PAL will occur during the course of the

study. Additionally, we hypothesized that studied factors would influence PALs in both boys and girls.

2.2.2. Materials and Methods

2.2.2.1. Design and participants

The participants in this prospective cohort study were adolescents from Bosnia and Hercegovina, more precisely, from Tuzla county, Herzegovina–Neretva county, and Western Herzegovina county. The sampling was based on a multi-stage cluster sampling method including (i) clustering of all schools from selected counties into two cluster (based on school-size), (ii) random sampling of 50% of high schools from each cluster, and (iii) random sampling of 50% of 1st grades from each of the selected schools. During the baseline testing, a total of 701 participants were examined. Therefore, the inclusion criteria for this study was: (i) regular participation in the high-school education in selected high-schools, and (ii) participation in testing at both testing waves (please see later for details on testing). No specific exclusion criteria were specified. At baseline (September, 2017), the participants were at the beginning of the first grade of high school and were 14.3 ± 1.01 years old on average. The follow-up testing occurred 20 months later, in spring 2019, including 691 participants on the end of the second grade of high school. In this study, we included only those participants who were tested at both baseline and follow-up (n = 651; 50.3% females). Finally, the dropout rate was 12%. Included participants met the sample size criteria, since the required sample size for observed population, and a level of significance of $p < 0.05$ was 398. The sampling procedure, drop-out rates and locations of the study are presented in Figure 1.

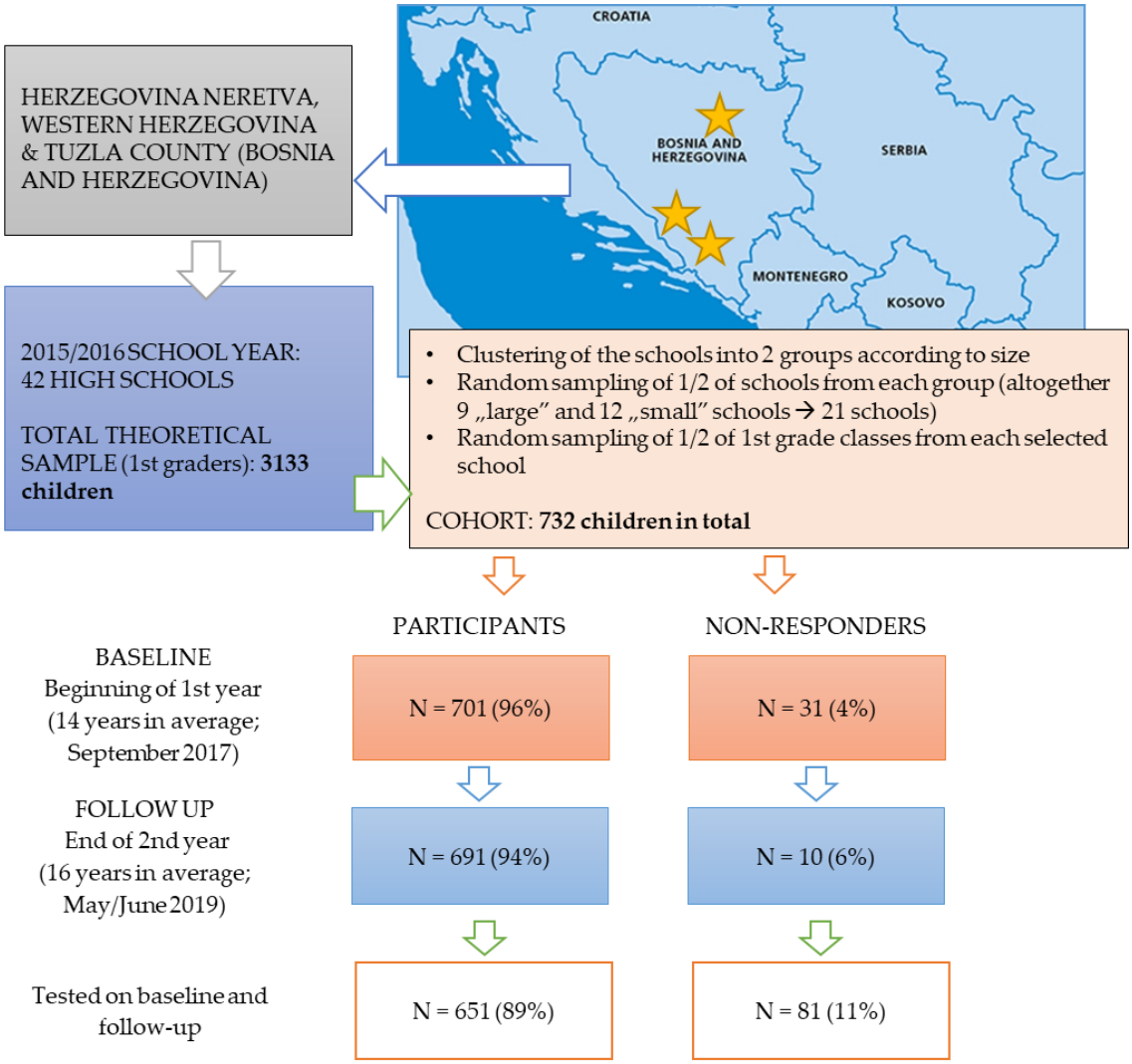

Figure 1. Study location, number of tested participants over testing waves, and drop-out rates.

2.2.2.1. Instruments

The variables in this study included: (i) Participants' sociodemographic characteristics, (ii) parental/familial factors, and (iii) PALs. Sociodemographic characteristics and parental/familial factors were evaluated by structured questionnaires which were previously confrmed to be valid and reliable in similar samples of participants, and results are presented in details elsewhere [76, 156, 157].The sociodemographic variables included age (in years), and gender (male and female). The parental/familial factors observed in the study consisted of socioeconomic status of the family (responded on a three-point scale: below average, average, and above average), paternal and maternal education level (elementary school, high school, and college/university degree), conflict with parents (almost never, rarely, periodically, and often), parental absence from home (always at home, rarely absent, occasionally absent, and often

absent), self-perceived parental care (parents do not care at all, do not care enough, good care, and very much care), and parental questioning about friends, school grades, problems, etc. (mostly never, rarely, from time to time, and often).

PALs were estimated with the Physical Activity Questionnaire for Adolescents (PAQ-A), which was previously validated and used in numerous studies [24]. The PAQ-A is a questionnaire form for which participants provide their self-reported PALs during the last seven days. The first eight questions contribute to the final score on a scale from 0 (minimum) to 5 (maximum PAL) refer to different forms of PA (e.g., sports, free play, and physical education in school). The last question was used only for detection of injuries and/or illness that could have possibly prevented participants from PA in the last seven days. Finally, the difference between the PAQ-A results at baseline and those at the follow-up for each participant was calculated as a measure of changes in PALs. For the purpose of this study participants were grouped according to their PAQ-A results into two groups; those with sufficient/appropriate PAL (PAQ-A score of 2.73 and above), and those with insufficient/inappropriate PAL (PAQ-A score <2.73).

2.2.2.2. Procedures

All high schools in the selected counties were divided into two groups according to the number of children, and one half of the first age classes were randomly selected from each of the groups. During the first school week (early September 2017), the examiners visited the schools and informed the children about the testing, as well as shared consent forms to participate in the research. The testing itself was conducted two weeks after, including only those students who brought a signed form by their parents. The study purposes and aims were explained to the students and their parents (in written form), and it was clearly indicated to them that the survey was strictly anonymous and that they could refuse to participate and/or not respond to any of the questions or to the whole questioning. Due to the specificity of testing at two time points and for the purpose of pairing the results, children were asked to choose personal anonymous code to use for both testing waves (i.e. last three digits of their e-mail password). The survey lasted approximately 15 minutes, and was performed on an online internet platform, using the school equipment and resources or private mobile phones. Second testing was performed over the last two weeks of school year 2018/19 (late May, early June 2019) using the same protocol. The entire testing procedure was performed in accordance with

ethical guidelines and was approved by the Ethical Committee of University of Split, Faculty of Kinesiology (approval number: 2181-205-05-02-05-14-005).

After conducting both baseline- and follow-up tests, analysis of the attrition bias was calculated No significant differences were evidenced in PAL between the children tested at both waves and the ones who dropped out. However, drop-out rate was higher in males than in females. By calculating intracluster correlation (with schools as clusters) we evidences the relatedness of responses within each cluster (school) [158]. Specifically, intracluster coefficient (IC) for the baseline PAL showed appropriate within-school variance (IC = 0.06).

2.2.2.3. Data analysis

Descriptive statistics included calculation of means and standard deviations for PAQ-A, and frequencies and percentages for remaining variables.

Second phase of statistical processing included calculation of the differences between groups (boys vs. girls; sufficient PAL vs. insufficient PAL), and within groups (PAL at baseline vs. PAL at follow-up). Namely, t-test for dependent samples was used to evaluate the differences for PAL obtained at baseline and follow-up for total sample, and stratified for gender. Differences between groups in raw PAL scores were evidenced by t-test for independent samples. Additionally, dichotomized PAL-values (insufficient-/sufficient-PAL) were compared between groups and this was done by Chi square ($\chi 2$) calculation. Mann Whitney test was used to compare ordinal variables between groups, while $\chi 2$ was used to evidence the differences between groups in categorical variables.

To define the influence of studied predictors on PAL at baseline and follow-up the logistic regression was applied. First, each predictor was correlated with dichotomized PAQ-A values (insufficient PAL was coded as “1”, and sufficient PAL was coded as “2”). In order to further evaluate the eventual co-variability of the predictors, and to identify/eliminate any possible causal relationship between predictors, in the last phase of the statistical analyses the multivariate logistic regressions were calculated for dichotomized criteria (PAL at baseline, and PAL at follow-up). For such purpose all predictors found to be significantly correlated to PAL were included in the multivariate logistic regression model. The final model was checked by Hosmer-Lemeshow test of model fit (with significant $\chi 2$ indicating inappropriate model fit). Negelkerke R square, p-values, Odds Ratio (OR) and corresponding 95% Confidence Interval (95%CI) were reported as indicators of association between predictors and criteria.

2.2.3. Results

PALs decreased significantly during the course of the study in total sample (from 2.26 ± 1.13 to 2.13 ± 1.06; t-test = 16.89, $p < 0.001$), and when observed separately for boys (from 2.42 ± 1.19 to 2.28 ± 1.01, t-test = 10.41, $p < 0.001$), and for girls (from 2.14 ± 1.07 to 2.01 ± 0.99, t-test = 13.42, $p < 0.001$). The PAL was higher in boys than in girls at baseline (t-test = 3.09, $p < 0.001$), and at follow-up (t-test = 3.4, $p < 0.001$).

The 31% of adolescents reached appropriate/sufficient PAL at baseline (38% boys and 26% girls), while only 26% of them had appropriate PAL at follow-up (31% girls and 22% girls) (Figure 2). When observed at categorical scale (sufficient/insufficient PAL) the differences between genders were significant at baseline ($\chi 2 = 9.54$, $p < 0.001$), and at follow-up measurement ($\chi 2 = 7.08$, $p < 0.01$), with higher prevalence of sufficient PAL among boys.

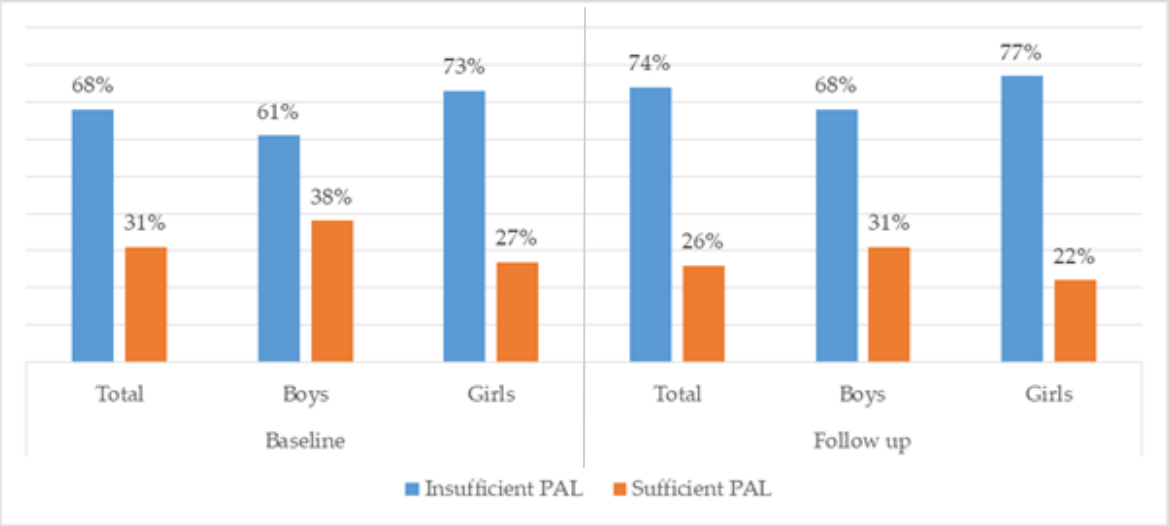

Figure 2. Prevalence of insufficient/sufficient physical activity level (PAL) in adolescents from Bosnia and Herzegovina at baseline (beginning of high school education) and follow-up (end of 2nd year of high-school).

The differences between adolescents who achieved, and those who didn't achieve sufficient PAL are presented in Table 1. Parental monitoring was lower in adolescents who with insufficient PAL at baseline (MW = 2.12, $p = 0.03$). The sufficient PAL at baseline was found in children whose fathers and mothers were better educated (MW = 2.74, $p < 0.01$ and MW = 3.3, $p < 0.001$ for paternal and maternal education, respectively).

Table 1. Differences between adolescents grouped according to sufficiency/insufficiency of physical activity level (PAL) at baseline.

	Baseline PAL				**Mann Whitney**	
	Sufficient		**Insufficient**		**MW**	p
	F	%	F	%		
Socioeconomic status					1.09	0.27
Below average	2	0.9	8	1.8		
Average	188	87.9	372	81.8		
Above average	17	7.9	55	12.1		
Paternal education					2.74	0.01
Elementary school	2	0.9	11	2.4		
High school	110	51.4	264	58.0		
College level	48	22.4	96	21.1		
University level	47	22.0	63	13.8		
Maternal education					3.3	0.001
Elementary school	3	1.4	14	3.1		
High school	103	48.1	265	58.2		
College level	51	23.8	91	20.0		
University level	50	23.4	68	14.9		
Parental/familial conflict					1.06	0.28
No. never	157	34.5	66	30.8		
Rarely	188	41.3	91	42.5		
From time to time	72	15.8	42	19.6		
Often	24	5.3	10	4.7		
Parental absence					1.42	0.15
Always at home	40	18.7	103	22.6		
Rarely absent	72	33.6	156	34.3		
Occasionally absent	76	35.5	136	29.9		
Frequently absent	21	9.8	42	9.2		
Parental care					0.61	0.53
Don't care at all	0	0.0	3	0.7		
Don't care enough	3	1.4	15	3.3		
Good care	43	20.1	85	18.7		
Very much care	163	76.2	333	73.2		
Parental questioning					2.12	0.03
Mostly never	4	1.9	12	2.6		

Rarely	18	8.4	41	9.0
From time to time	102	47.7	158	34.7
Often	84	39.3	228	50.1

Legend: Note that participants were not obligated to respond to all questions and therefore for some variables all responses summarized doesn't equal the total sample of participants (n = 651)

The higher maternal- (MW = 2.72, $p < 0.01$), and paternal-education (MW = 2.13, $p < 0.05$) was found in adolescents who had appropriate PAL at follow-up. No significant differences between groups based on PAL were evidenced for other predictors (Table 2).

Table 2. Differences between adolescents grouped according to sufficiency/insufficiency of physical activity level (PAL) at follow-up.

	Follow-up PAL				**Mann Whitney**	
	Sufficient		**Insufficient**		**MW**	p
	F	%	F	%		
Socioeconomic status					0.24	0.8
Below average	1	0.6	9	1.8		
Average	154	86.5	406	82.7		
Above average	16	9.0	56	11.4		
Paternal education					2.13	0.03
Elementary school	1	0.6	12	2.4		
High school	94	52.8	280	57.0		
College level	37	20.8	107	21.8		
University level	39	21.9	71	14.5		
Maternal education					2.72	0.01
Elementary school	2	1.1	15	3.1		
High school	89	50.0	279	56.8		
College level	35	19.7	107	21.8		
University level	45	25.3	73	14.9		
Parental/familial conflict					1.47	0.14
No. never	51	28.7	172	35.0		
Rarely	78	43.8	201	40.9		
From time to time	36	20.2	78	15.9		
Often	8	4.5	26	5.3		
Parental absence					1.24	0.21
Always at home	31	17.4	112	22.8		

Rarely absent	62	34.8	166	33.8		
Occasionally absent	65	36.5	147	29.9		
Frequently absent	15	8.4	48	9.8		
Parental care					0.32	0.75
Don't care at all	0	0.0	3	0.6		
Don't care enough	3	1.7	15	3.1		
Good care	36	20.2	92	18.7		
Very much care	134	75.3	362	73.7		
Parental questioning					1.44	0.15
Mostly never	3	1.7	13	2.6		
Rarely	16	9.0	43	8.8		
From time to time	81	45.5	179	36.5		
Often	73	41.0	239	48.7		

Legend: Note that participants were not obligated to respond to all questions and therefore for some variables all responses summarized doesn't equal the total sample of participants (n = 651)

Figures 3 and 4 present univariate relationships between baseline sociodemographic and parental/familial factor, and dichotomized PAL criterion at baseline (Figure 3) and at follow-up (Figure 4). At baseline, the higher likelihood for appropriate PAL was found in males (Negelkerke R square: 0.02; OR: 1.68, 95%CI: 1.21-2.34; $p < 0.001$), for those adolescents whose mothers- (Negelkerke R square: 0.02; OR: 1.38, 95%CI: 1.15-1.70; $p < 0.001$), and whose fathers- were better educated (Negelkerke R square: 0.02; baseline: OR: 1.35, 95%CI: 1.10-1.65, $p < 0.01$). At follow-up higher likelihood for appropriate PAL was found for boys (Negelkerke R square: 0.02; OR: 1.54, 95%CI: 1.11-2.03, $p < 0.001$), adolescents who reported better maternal- (Negelkerke R square: 0.02; OR: 1.35, 95%CI: 1.11-1.69, $p < 0.05$), and those who reported better paternal-education (Negelkerke R square: 0.015; OR: 1.29, 95%CI: 1.09-1.59, $p < 0.05$).

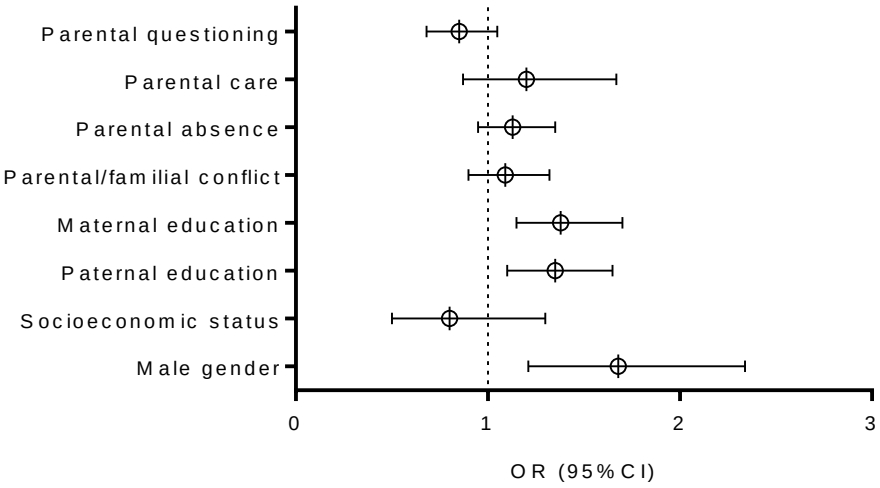

Figure 3. Correlates of sufficient physical activity level at baseline.

Multivariate logistic regressions were calculated while simultaneously including all variables evidenced as being significant univariate predictors of PAL at baseline and follow-up. Male gender (OR: 1.55, 95%CI: 1.11-1.91, $p < 0.001$), higher paternal education (OR: 1.35, 95%CI: 1.05-1.67, $p < 0.05$), and higher maternal education (OR: 1.34, 95%CI: 1.06-1.71, $p < 0.05$) were all significantly related to PAL-baseline (Negelkerke R square: 0.04). In total 67% of the participants were correctly classified according to specified regression function. Similar multivariate relationship was found when PAL at follow up was observed as criterion. Namely, higher paternal education (OR: 1.21, 95%CI: 1.01-1.44, $p < 0.05$), and higher maternal education (OR: 1.30, 95%CI: 1.05-1.57, $p < 0.01$), together with male gender (OR: 1.50, 95%CI: 1.05-2.15, $p < 0.01$) were positively correlated with appropriate/sufficient PAL at follow-up (Negelkerke R square: 0.05), with 71% participants being correctly classified. Results of the multivariate logistic regressions actually evidence the independent influence of paternal education and gender on PAL (Figure 5). Hosmer Lemeshov test evidenced appropriate model fit for multivariate logistic regression models calculated for PAL at baseline ($\chi 2= 7.37$ $p = 0.39$), and for PAL at follow-up ($\chi 2= 8.01$, $p = 0.31$).

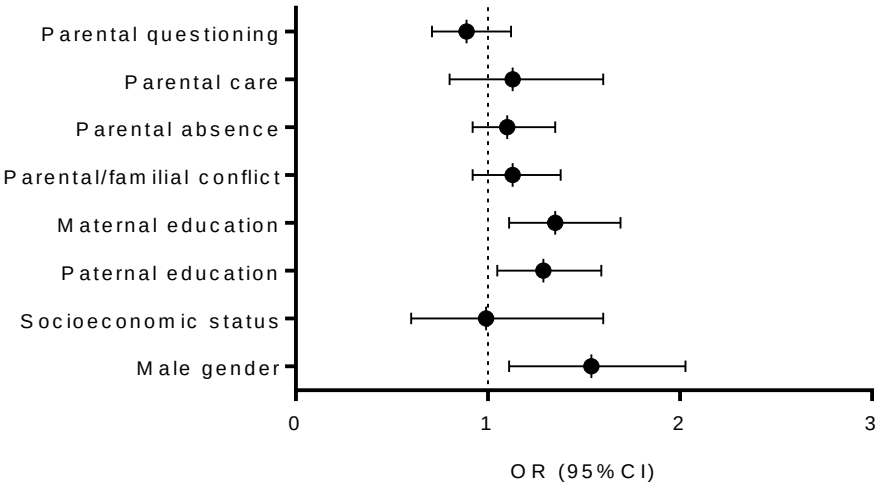

Figure 4. Correlates of sufficient physical activity level at follow-up.

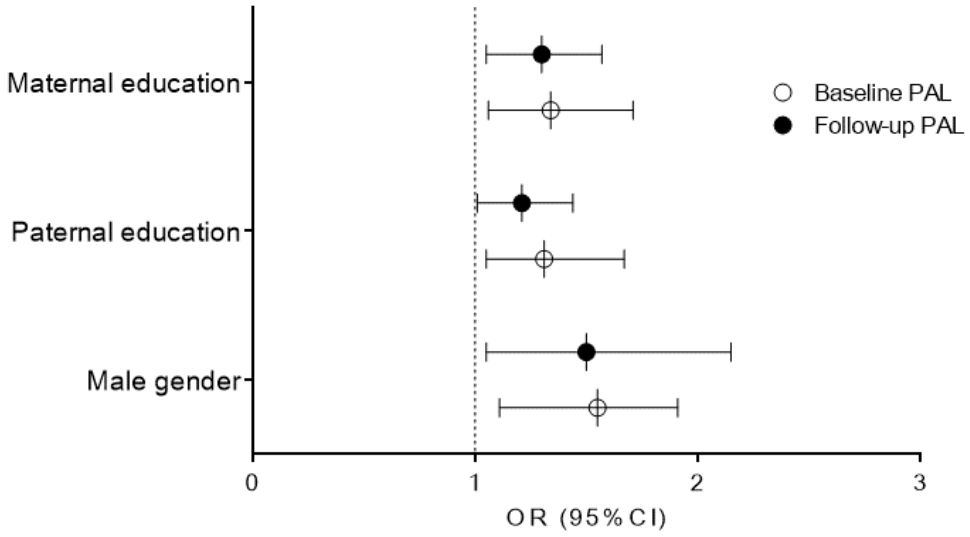

Figure 5. Multivariate logistic regression correlates of sufficient physical activity level (PAL) at baseline and at follow-up measurement.

2.2.4. Discussion

There are several important findings of this study. First, boys were more active than girls, PALs decreased over the study course, and the decrease was more evident in boys. As a result, we may support our initial study hypothesis. Second, parental education was evidenced as a positive influencing factor of PALs in both testing waves. Finally, no significant influences of

socioeconomic status, parental/familial conflict, parental absence from home, parental care, and parental questioning on PALs were found. Therefore, our second hypothesis may be partially accepted.

2.2.4.1. Changes and differences in PALs

Our results evidenced higher PALs in boys than in girls in early adolescence (between 14 and 16 years of age). Such findings are in line with previous research, which, almost without exception, reported higher PALs in boys [20-22, 33]. Specifically, an epidemiological review article that analyzed PALs and fitness levels in children and adolescents concluded that boys are approximately 14% and 25% more active than their female peers, respectively, and that over the school years, PALs decrease by 3%–7% [159]. Previous studies have highlighted three of the most common perspectives for explaining the important determinants of gender-differences in PALs: (i) Socialization, (ii) attitudinal factors, and (iii) organized sports [63, 160-163].

In the context of socialization, research has highlighted the significant impact of the environment (i.e., parents, peers, and teachers) on PALs in adolescents [63, 161]. This impact differs between genders, which is explained by an interaction between gender and parental or teacher involvement [160]. Additionally, a larger proportion of girls have negative experiences with practicing some form of physical activity and sports (e.g., feeling stupid or incompetent, being negatively evaluated, not having enough choice, and using inadequate facilities), which consequently reduces the level of their involvement in physical activity and sports [163].

An attitudinal explanation of the gender differences in physical activity and sports involvement assumes that gender roles foster differences in attitudes that contribute to differences in practicing sports and in physical activity in general [160]. Among other things, a greater association has been noticed between masculine identities and sports. In other words, boys are more competitive and generally more interested in sports than girls, which consequently contributes to their higher PALs [164, 165].

Irrespective of previous explanations, research has highlighted organized sports as a key factor in explaining gender differences in PALs [160]. This perspective is based on the fact that a large proportion of the PALs among young people refers to organized sports in sports clubs, where have much greater gender differences in inclusion compared to the overall gender difference in physical activity [162]. In short, the organized sports system favors men through organizational specifics, more competition, and more accessible sports facilities, and also the dropout rate for girls is much higher, especially taking into account girls' menstrual cycle and

more frequent absence from sports training in girls due to menstrual pain and/or hygienic reasons [166, 167]. Put altogether, the higher PALs among boys is understandable.

The decrease in PALs in our sample is in accordance with previous studies, where authors have regularly confirmed a decrease in PALs during adolescence [29, 159]. More specifically, a decline in PALs from the beginning of the first grade of high school to the end of the second grade was approximately 7%, and this was more emphasized in boys (8%) than in girls (5%). Several studies have analyzed longitudinal PAL changes during adolescence, and have evidenced various causes for the decrease in PALs [23, 168]. Collectively, authors most often point out the increase in school obligations, weight gain, and increased screen time, as well as decline in active transport.

Although not entirely consistent, previous research has more often identified a higher rate of PAL decline in boys during younger adolescence [169, 170]. However, it must be observed in light of the higher PALs in boys than in girls at the beginning of the observed period [160, 171]. The reasons for this stands in the fact that girls drop out from sports earlier (between 9 and 12 years). Therefore, during younger adolescence, girls generally have a lower baseline level of PA and thus less of chance of an additional decline in PALs than boys, who, during this period (13–16 years), start to drop out from organized sports [170].

2.2.4.2. Parental education and physical activity during adolescence

Thus far, much research has analyzed the influence of parental and familial factors on PALs in children and adolescents [51, 52, 172]. Above all, family support has been consistently shown to be a positive predictor of PALs in adolescents [51]. Specifically, parents have been proven to be one of the most important predictors of PALs, because they serve as role models and they finance and actively participate in the organization of sports activities for their children [29]. However, previous studies have not consistently highlighted parental education as a predictor of PALs in adolescence.

Some studies have shown that there is no significant influence [51, 172], while others have indicated a positive influence of a higher educational level of parents on their children's PALs [173]. In studies that have confirmed a positive influence, this fact was primarily explained by the relationship between the level of education and familial socioeconomic status and income [173]. For example, a longitudinal study on 1213 African-American and 1166 Caucasian girls found a significant impact of parental education on PALs, which was explained by the negative

impact of a low socioeconomic status and a potentially stressful home environment on PALs in children, highlighting the need to solve social disparities that potentiate health disparities [173].

In contrast, although parental education was positively correlated with PALs in children, we found no significant effect of socioeconomic status on PALs, and therefore our results are not absolutely consistent with previous findings [52, 174]. Before discussing it must be noted that data on socio-economic status for adolescents observed herein could be observed as plausible since results are comparable to data reported in previous studies where somewhat older adolescents from the same country were included [156, 175]. Most likely, in the region where the study was conducted, the financial status of the family does not have a strong influence on sports involvement as in some other regions of the world. Specifically, in studied counties, as well as on the whole territory of Bosnia and Herzegovina, the majority of sports are available to all children (i.e., participation is mostly free), the distances between home and sports facilities are relatively short (i.e., children do not depend on parental transport), and most popular sports do not require specific and expensive sports equipment, and are practiced in school facilities and gyms (i.e. team sports like football, handball, basketball) [76]. Taken together, even the influence of socioeconomic status on the participation in sports and PA in the studied adolescents was reduced. Therefore, the cause of the connection between parental education and the children's PALs in our study should be found in something else.

Mainly, it is reasonable to assume that parents with a higher level of education are generally better informed and are more aware of the importance of PA on the health status of their children [32]. Therefore, better educated parents more likely encourage their children to engage in some form of PA or sports. This explanation is in accordance with a recent discussion offered in a study where maternal education was positively correlated with PALs in somewhat older adolescents, and where the authors highlighted mothers as being more involved in their children's life in later adolescence, even in the domain of physical activity, irrespective of the known influence of fathers on sports participation, which is more evident in earlier adolescence [32]. Interestingly, even in our study the effect size (based on R square from univariate logistic regressions) for PAL at follow-up was higher for maternal education, than for paternal education (Nagelkerke R square = 0.02 and 0.015, for maternal- and paternal-education, respectively) which indicate stronger influence of maternal education on PAL of the children at the age of 16. Meanwhile, based on same statistical parameter, maternal- and paternal-education are equally important predictors of PAL at baseline (i.e. 14 years of age).

2.2.4.3. Familial variables and physical activity in adolescence

Parental and familial factors are known to be important determinants of various health-related behaviors in adolescents, and previous studies have regularly confirmed the direct influence of family cohesion, parent–child relationships, and parental involvement in children's daily activities on PALs [176, 177]. These dimensions of parental influence may be a reflection of an authoritative parenting style, which generally includes reaction, in the form of providing emotional support and involvement, but also demanding in terms of providing an appropriate level of parental control [177]. Studies find that authoritative parenting styles are often associated with higher levels of student achievement [178]. Furthermore, a study examining PALs and sedentary lifestyles in girls identified an authoritative parenting style as a significant positive predictor of PALs [179].

Similar findings have been found in studies of some other issues, such as smoking [180]. Specifically, it has been shown that parents with an authoritative parenting style who have anti-smoking household rules and who do not smoke themselves are more likely to have adolescents who do not consume cigarettes [180]. Additionally, in the study examining optimal parent–child relationships parental warmth and strictness was highly associated with child's well-being [181]. However, in our study, the variables examining parent–child relationships, familial conflict, parental absence from the home, parental care, and parental questioning were not significant predictors of PALs.

The most likely reason for such relative inconsistency in our results (i.e., non-significant influence of parental control and monitoring variables on the PALs of their children) compared to those reported previously, where the authors regularly confirmed significant correlations between similar sets of variables that could be found in the differences between the established "magnitude" of parental control/monitoring. Namely, in our study, a minority of the children reported "low levels of parental control/monitoring" (see Results for details). Meanwhile, when using an identical measurement tool and studying somewhat older adolescents, previous reports from the same region (i.e., southeastern Europe) have shown a considerably larger variance in their results [157]. It could simply mathematically result in a higher possibility of reaching a statistically significant association between variables [182].

2.2.4.4. Limitations and strengths

The first limitation of the study is the subjective nature of the measurement tool, since data were collected by a questionnaire. Therefore, there is a possibility that the participants did not answer honestly and/or tended to provide socially desirable answers. However, the authors strongly believe this possibility was reduced due to the testing protocol, the experience of the researchers, and the strict anonymity of the testing. Moreover, PALs were evidenced by questionnaire and were not objectively measured. However, the use of an objective measures of PALs (e.g., accelerometers, pedometers) was limited because of the large sample size and the prospective nature of the study. Next, the observed sample did not represent the whole country, so the results should be generalized only for specific regions. Finally, this study did not take into account biological maturity, but only chronological maturity of the adolescents. Considering the well-known influence of maturity on multiple factors, future investigations should pay attention on it, and include the biological age in analyses of such kind.

This is one of the first studies that systematically examined the parental/familial predictors of PALs in adolescents from southeastern Europe. Additionally, this is probably the first prospective study of PAL changes and the predictors of PALs in young adolescents in this region. One of the strengths of this study is the fact that the tested sample was twice as large as that theoretically required for a high statistical power, with a minor dropout rate. Finally, given that decreased PALs are highlighted globally as a major public health concern because of their association with the leading causes of death, illness, and disability, the authors believe that the findings of this research can be used in the global fight against the pandemic of physical inactivity, and that they will initiate further research. Findings of this study suggest practical interventions on children with parents of a lower educational level and the need to further examine decline in PAL for girls in earlier age than analyzed here. Also, additional factors related to decreased PAL in boys between 14 and 16 years of age should be evaluated.

2.2.5. Conclusions

The results of this study showed that boys are generally more active than girls in the period of younger adolescence (14–16 years). With a prospective follow-up over a two-year period, a declining trend in PALs was observed, and this negative trend was larger in boys. Given that previous researchers have found an earlier dropout from organized sports in girls (between 9

and 12 years old), it is obvious that the period between 14 and 16 years of age is particularly important for boys. Future studies should certainly investigate all of the factors that lead to dropouts from sports in younger male adolescents and the predictors of PAL decline in girls should be studied in younger years.

This study analyzed parental factors as possible indicators of PALs in younger adolescents, and especially emphasized the education of parents in both testing waves as a positive predictor. Therefore, in order to prevent a decrease in PALs in early adolescence, there is an evident need to specifically focus on children whose parents are of a lower educational level. This will hopefully improve their awareness of the importance of PA in this period of life. Such efforts will consequently have an important positive impact on the overall health status both in adolescence and later life.

Additionally, the established influence of the parental education on PAL of their children should be observed out of the context of relationship. Namely, we can anticipate that specific education of the parents about the benefits and importance of physical activity would be directly translated to PAL of their children. Therefore, we may encourage studies that will investigate the effects of education of the parents (i.e. responsible adults) on their children's PAL. In doing so special attention should be placed on parents of lower educational status and health-related topics of physical activity.

Parental/familial variables explaining socioeconomic status, as well as parental/familial control and monitoring, were not shown to be important predictors of PALs in the studied period (between 14 and 16 years of age). Most likely, the fact that the studied adolescents evidenced low levels of parental conflict and high parental control reduced the possibility that these variables significantly influenced PALs. Moreover, it the studied region, sports activities are relatively available to all children, which reduced the possibility that the socioeconomic status of the studied adolescents significantly contributed to PALs.

2.3. Familial and Parental Predictors of Physical Activity in Late Adolescence: Prospective Analysis Over a Two-Year Period

2.3.1. Introduction

Despite the globally known benefits of physical activity (PA) and the negative health outcomes of an inadequate (PALs) physical activity levels, physical inactivity indicates a trend of pandemic proportions, with almost no improvement since 2001 [4]. Guthold et al. reported a slight decrease in boys insufficient PA since 2001, while there were no changes over time in girls, and in the general adolescent population [106]. Trends of PA decline in adolescence are repeatedly highlighting in Southeastern Europe as well [25, 32, 183, 184]. It is evident that on-going technological development and economic growth have a strong influence on the global population lifestyle [185]. More precisely, changes in transport patterns (relying more on motorized transportation) and the transition toward sedentary occupations and leisure, which implies a more frequent use of technology for recreation and work, leads to an increase in sedentary behaviors and decrease in PALs across the world [4]. Additionally, advances in technology are changing the way modern-day youths think, play, socialize, and entertain, which often leads to the replacement of time spent engaging in PA with screen time [186].

The widespread problem of physical inactivity threatens the future of the world as we know it, especially considering the fact that 81% of adolescents (11–17 years) fail to meet the WHO recommendations of at least 60 min of moderate-to-vigorous-intensity physical activity per day [4]. This is particularly concerning, since an inadequate PAL is known to have a negative impact on health systems, economic progress, the environment, community well-being, and quality of life. Therefore, the question arises as to who will carry the future of the world if, according to the data, the younger generations will most likely pose a burden on the health systems and further economic development. Given the circumstances, in order to prevent negative outcomes and to change the negative trends in PALs, it is important to identify the social and environmental factors associated with PA, especially during adolescence [64].

Adolescence presents a period of many changes and has often been presented as a time of hardship and stress. It is a crucial period for interventions aiming to promote the greater involvement in some form of PA, leading to improvement of regular PA, which is known to have a positive impact on cardio-metabolic health (glucose and insulin resistance, blood pressure, and dyslipidemia), physical fitness (muscular and cardiorespiratory fitness), adiposity

reduction, bone health, mental health (reduced symptoms of depression), and cognitive (executive function, academic performance) outcomes [4]. In general, adolescence is an important time in a young person's life for the adoption and retention of future habits and for forming attitudes about various life matters such as health and educational habits. Therefore, it is reasonable to assume that physical activity during adolescence defines activity levels later in life, and thus directly affects an individual's overall health status in the future [28].

Consequently, the factors associated with PALs in adolescence have been frequently explored. Faigenbaum et al. stated that "physical activity is a learned behavior and is influenced by a variety of socio-ecological factors including, facilitators (e.g., friends, teachers, coaches, fitness specialists, and health care providers), facilities (e.g., schools, playgrounds, and sport fields) and family (e.g., parents and siblings)" [26, 186]. Sallis et al. put forward sex, age (inverse relationship), ethnicity, depression (inverse relationship), perceived activity competence, previous physical activity, sibling PA, opportunities to exercise, parental support, and direct help from parents as the most consistent correlates of PA in a review of the literature. Although most studies show consistency when it comes to the impact of the abovementioned variables, many authors have pointed out the existence of studies with an inverse relationship or no impact of the discussed variables [33]. Furthermore, according to the vast majority of studies, participation in sport activities, level of education, self-efficacy, parental activity, and parental support are often positively correlated with PALs [52, 187].

It is well established that families have a strong influence on children's and adolescent's health behavior, including PALs [33, 68, 177]. More precisely, parents (caretakers in general) are one of the primary influences of youth behavioral patterns, including PA-related actions (e.g., outdoor play, sport, and exercise) [33, 53-55]. This is understandable if we take into consideration that most young people spend approximately 18 years of their life in close proximity to their parents [53, 56]. During this period, parents usually serve as a model for future behavior and habits, directly influencing, in this case, PA behavior, although not always with conscious/deliberate intention [53, 57]. According to the research conducted thus far, parental influence on PA can take many forms and, generally, can influence children's PA, both directly and indirectly [53, 188]. However, despite the wide consensus that parental factors are important determinants of children's PALs, the results of studies thus far inconsistent.

Gustafson and Rhodes, in their review, presented some inconsistent results; more specifically, six studies found a moderate correlation between parents' PA and children's PA, while seven studies did not support these findings. However, parental support was almost consistently recognized as a positive impact on children's PALs, while this effect was more

significant in younger children [52]. Similar outcomes were noted by Trost et al., who reported no support for the link between parents' and children's PA, while indicating a consistent positive association for parental support and children's PA behavior [68]. Another systematic review, by Jaeschke et al., which reported on the determinants of PA, pointed out that encouragement from significant others was associated with greater PA in children and adolescents, whereas parental marital status and parental modeling were not associated with PA in children [69]. Furthermore, research examining parental and peer influence on older adolescents (17–19 years) found no association between adolescents' and parents' PA; however, in accordance with the previously mentioned studies, parents' encouragement was related to PALs [70]. Parental education is inconsistently associated with young people's PALs according to Sallis et al., which has also been reported in other studies [71]. A recent prospective study examining younger adolescents found a positive influence of paternal education level on PALs, yet no significant influence of maternal education, parental care, parental/familial conflict, parental absence from home, and parental questioning were found [183].

The previously presented inconsistencies in results are not surprising if we take into account the fact that previous studies were conducted on different populations varying in terms of socioeconomic status, ethnicity, and environmental characteristics. Besides this, they often differed in their measures of parental PA influence and modes for estimating PA levels. Moreover, it is important to emphasize the fact that there is a lack of information on changes in perception of parental support and influence on PA over time, since it has rarely been investigated. To acquire a clearer picture of these changes, especially regarding adolescents, longitudinal and systematic analysis of diverse factors is required. A prospective study would provide a clearer perspective and a more complete interpretation of the cause–effect relationship of the observed variables [52, 69].

In a previously presented study, the authors provided prospective information about the influence of parental/familial variables on PALs in adolescents from Bosnia and Herzegovina between the age of 14 and 16 years [183]. In brief, parental education was significantly associated with PALs, but no association was found for the variables explaining parental/familial support and conflict with PALs in this period of life. For a more profound understanding of the problem, further analyses are needed in the in the next period of life (e.g. in older age). Therefore, this study aimed to prospectively determine the parental and familial factors associated with PALs and changes in PALs between 16 and 18 years of age. We were particularly interested in eventual changes in the relationships between variables that may occur

in the observed period of life. Additionally, we evidenced changes in PALs that occurred in the study period.

2.3.2. Materials and Methods

2.3.2.1. Design and participants

Adolescents from three counties in Bosnia and Herzegovina participated in this prospective study. The research was conducted across three testing waves, with baseline testing at the beginning (September) of the 2017/2018 school year, when participants were approximately 16 years old and were starting the third grade of high school. The first follow-up testing occurred at the end of the 2017/2018 school year (May/June 2018), while the second follow-up testing was conducted at the end of high-school education (May/June 2019), when the participants were approximately 18 years old. The sampling was done across several phases. In the first step, all high schools in selected counties were grouped into two clusters according to their size (number of students). After this, we randomly selected one-half of the schools from each cluster, and finally, one-half of the third grades from the chosen schools. Considering that some high school programs last three years, in our study, we included only classes participating in four-year high school programs. A total of 856 participants were tested at the study baseline, but the final analysis included 766 participants (347 females) who carried out the testing on all three occasions (the drop-out rate was 15%). The sample used in this study met the theoretical required sample for the observed population in studied counties (341 required participants for a theoretical sample of approximately 3000 adolescents aged 16 years, and a level of significance of $p < 0.05$) (Figure 1).

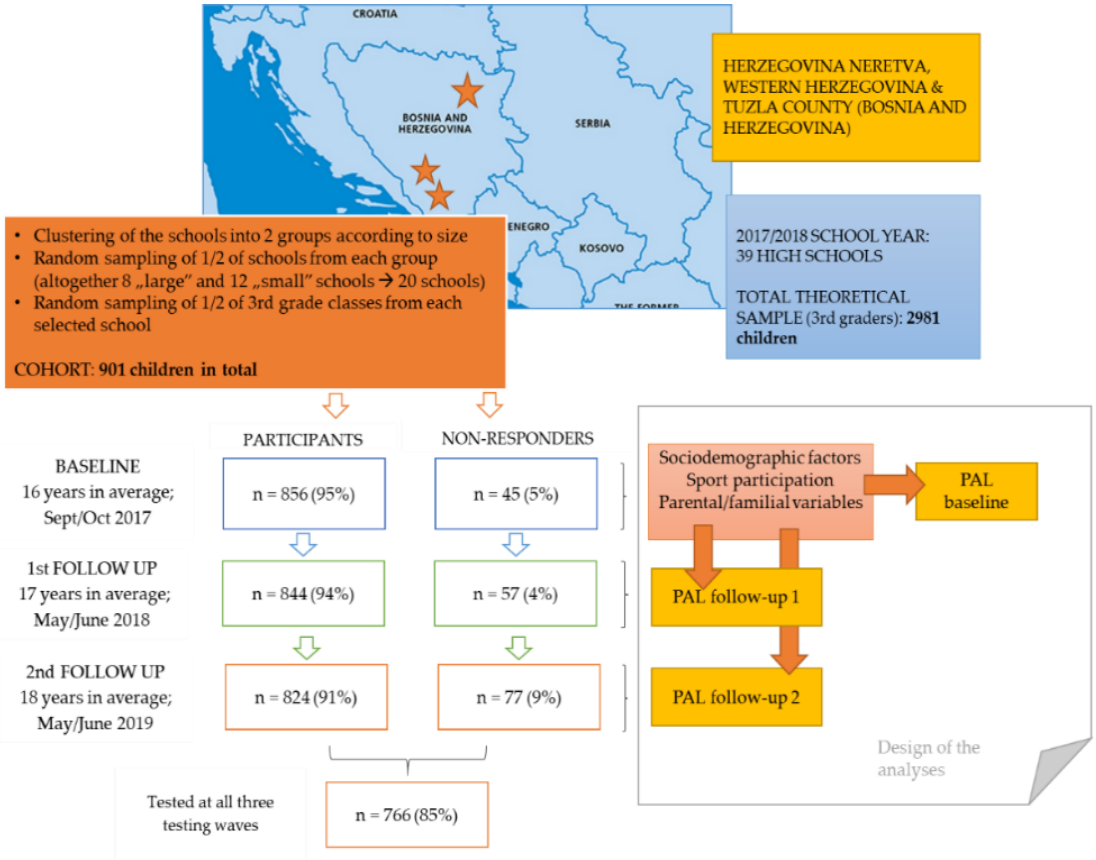

Figure 1. Study location, design, and testing sequences.

2.3.2.2. Instruments

In both testing waves, the participants were examined with questionnaires that included sociodemographic characteristics, sport factors, parental/familial factors, and PALs. The questionnaires used were previously validated on a similar sample of participants, and details on testing are presented elsewhere [76, 183].

The sociodemographic variables were age (in years) and gender (male and female). The parental/familial variables included: (i) Socioeconomic status (self-reported as below average, average, and above average), (ii) parental education level (elementary school, high school, and college/university degree—reported separately for mothers and fathers), (iii) conflict with parents (almost never, rarely, periodically, and often), (iv) parental presence at home (always at home, rarely absent, occasionally absent, and often absent), (v) evaluation of parental care (parents do not care at all, do not care enough, provide good care, and care very much), and (vi) level of parental questioning about school, friends, and similar problems (mostly never, rarely, from time to time, and often). The sport participation at baseline was evidenced by one question

with three possible answers (participating, participated but quit, never participated—later categorized as participation vs. non-participation).

PALs were evidenced at baseline, at first follow-up measurement (FU1), and at second follow-up measurement (FU2) by the Physical Activity Questionnaire for Adolescents (PAQ-A), which was previously used and validated with similar samples of participants [25, 189, 190]. This tool consists of nine questions that examine participants' PALs over the previous seven days. While the last question is of an open type and serves only to record possible injuries and illness, the first eight relate to various types of PA (e.g., free play, sport at school, and sport at sport clubs), and all together, they form the final grade on a scale from 0 (minimum) to 5 (maximum PAL). Apart from the raw scores, for the purpose of this study, the results were categorized as previously suggested [183]. In brief, participants were stratified into groups with sufficient (score of 2.71 and higher) and insufficient (scores <2.71) PALs.

2.3.2.3. Procedures

Before conducting the testing, the examiners visited the schools and informed the students about the aims, purposes, and procedures of the examination. The students were given consent forms for participation in the study, and only those who brought back forms signed by their parents or guardians were included. The baseline testing was held two weeks after the first meeting. The questionnaires were completely anonymous, but because of study design (testing at three time points and the need to compare the results), students were instructed to use their private password for baseline and follow-up testing. The testing itself was conducted using an online survey platform, and participants filled in the questionnaires for approximately 15 min during school hours using their mobile phones. The study was approved by the Ethics Committee of the Faculty of Kinesiology, University of Split, and was completed in line with the proposed ethical guidelines.

The intra-cluster coefficient of 0.05 for the PALs at the baseline (with schools as clusters) indicated proper within-school variance. With regard to the drop-out rate, we found no significant differences in the baseline PALs between those adolescents who dropped out from the study and those who were tested at all three testing waves (t-test = 0.87, $p > 0.05$), but significantly more females were retained in the study ($\chi^2 = 1.1$, $p < 0.05$), which was attributed to the regularly reported more frequent absence from school among boys [191].

2.3.2.4. Data analysis

The Kolmogorov–Smirnov test was used to test the normality of the distribution. Accordingly, the means and 95% confidence intervals (CI) were calculated for the PAQ-A, while for the other variables, the descriptive statistics included frequencies and percentages.

To estimate the differences in PALs among the testing waves, factorial analysis of the variance was used for the repeated measures (ANOVA), with "gender" and "measurement" as the main effects and interaction (gender × measurement). Additionally, consecutive Scheffe post-hoc tests were calculated in order to evidence between-groups and between-measures differences. To compare groups in the categorical variables, chi-square ($\chi 2$) was calculated, while the Mann–Whitney test was used to examine the possible differences between groups in the ordinal variables.

The final phase of statistical analyses included calculation aimed to identify the predictors of PALs in the three testing waves. To identify the associations between the predictors and PAQ-A as a binomial criterion, with insufficient PALs coded as "1" and sufficient PALs as "2," logistic regressions were calculated, with the odds ratios (ORs) and corresponding 95% CIs reported. However, since previous studies have regularly confirmed sport participation and male gender as being significantly associated with PALs in adolescence, before calculating the logistic regressions for the parental/familial predictors, we chanced associations between gender and sport participation with the PAL criteria and evidenced significant associations in our participants as well (please see later results). Accordingly, sport participation and male gender were included as covariates in the later logistic regressions calculated for the parental/familial variables as predictors of PALs in the three testing waves. Multivariate regression models were additionally calculated when more than one predictor was evidenced as being significantly related to the criterion. The model fit was checked using the Hosmer Lemeshow test (with a statistically significant $\chi 2$ indicating that the model did not adequately fit the data). For all analysis, Statistica ver. 13.0 (Statsoft, Tulsa, OK, USA) was used and a p-value of 0.05 was taken as being statistically significant.

2.3.3. Results

The results of the factorial ANOVA with gender and measurement as the main effects and a gender × measurement interaction are presented in Table 1. The significant main effect for

measurement evidenced that PALs significantly decreased over the course of the study ($F = 94.17$, $p < 0.001$). Meanwhile, the significant interaction effect (gender × measurement) pointed to differential changes in PALs for boys and girls ($F = 6.61$, $p < 0.001$).

Table 1. Results of the factorial analysis of variance for repeated measurements.

	Main effects				**Interaction**	
Variable	Gender		Measurement		Gender x Measurement	
	F-test	p-level	F-test	p	F-test	p-level
PAQ-A	94.17	0.001	83.05	0.001	6.61	0.001

Figure 1 evidences the changes in PALs for boys and girls, as well as the significance of the post-hoc differences between and within genders. The boys had higher PALs than the girls at baseline, FU1, and FU2. The PALs of the girls decreased continuously from 16 to 18 years, with non-significant differences between 17 and 18 years. Meanwhile, the PALs among the boys decreased between baseline and FU1, but slightly increased from FU1 to FU2.

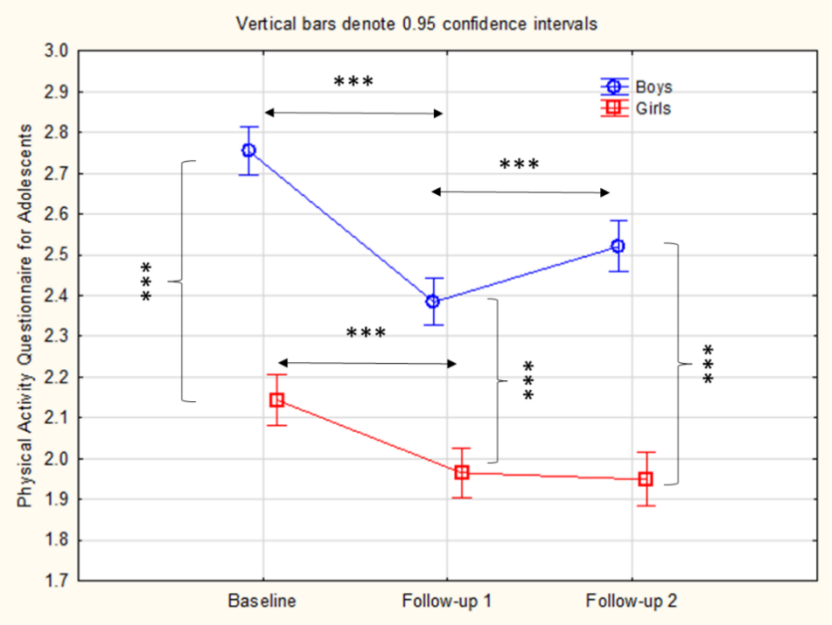

Figure 2. Descriptive statistics (Mean ± 95% CI) and statistical significance of the differences between and within groups/genders obtained by post-hoc Schefee test (*** indicates *p-level* of 0.001).

As could be expected based on the previously presented ANOVA results, the boys were more likely to achieve sufficient PALs than the girls at baseline (OR = 5.84, 95%CI: 4.24–8.06), FU1 (OR = 4.55, 95%CI: 3.07–6.71), and FU2 (OR = 4.78, 95%CI: 3.31–6.89).

Moreover, sport participation at baseline was a significant predictor of PALs in all three testing waves, with a lower likelihood of reaching appropriate PALs in adolescents who were not involved in sport (baseline: OR = 0.33, 95%CI: 0.27–0.40, FU1: 0.28, 95%CI: 0.22–0.37, FU2: 0.33, 95%CI: 0.26–0.41). Therefore, the logistic regressions calculated for the parental/familial variables as predictors of PALs were controlled for gender and baseline sport participation as covariates.

The logistic regression calculated for the dichotomized PAL criterion at baseline (16 years of age), with gender and sport participation as covariates, evidenced better PALs among adolescents whose fathers were better educated (OR = 1.42, 95%CI: 1.17–1.84). Additionally, a lower likelihood of appropriate PALs was found in adolescents who reported a higher level of parental conflict (OR = 0.72, 95%CI: 0.58–0.88). The multivariate logistic regression, controlled for sport participation and gender, evidenced both predictors as being independently associated with PALs at baseline (paternal education: OR = 1.54, 95%CI: 1.23–1.94; conflict with parents/family: 0.69, 95%CI: 0.56–0.85). When logistic regression was used to calculate PALs at FU2 (17 years of age on average), no association was evidenced between the variables of parental education and PALs. Meanwhile, parental conflict remained significantly associated with the criterion, with a lower likelihood of being sufficiently active for adolescents who reported a higher level of conflict (OR = 0.83, 95%CI: 0.63–0.98). Finally, parental conflict was the single significant predictor of PALs at FU3 (OR = 0.75, 95%CI: 0.60–0.94) (Table 2).

Table 2. Correlates of physical activity levels at baseline, and two follow-up measurements; results of the logistic regression analysis controlled for gender and sport participation as covariates (N = 766).

	PAL baseline		PAL follow-up 1		PAL follow-up 2	
	OR	95%CI	OR	95%CI	OR	95%CI
Socioeconomic status	0.79	0.44-1.41	0.89	0.48-1.67	0.65	0.35-1.21
Paternal education	1.42	1.17-1.84	1.16	0.98-1.49	1.23	0.97-1.56
Maternal education	1.16	0.95-1.43	1.18	0.88-1.41	0.90	0.71-1.13
Parental/familial conflict	0.72	0.58-0.88	0.83	0.63-0.98	0.75	0.60-0.94
Parental absence	1.13	0.97-1.32	1.06	0.88-1.28	1.14	0.96-1.36
Parental care	0.80	0.62-1.04	1.09	0.81-1.47	1.01	0.76-1.33
Parental questioning	1.16	0.93-1.44	1.09	0.87-1.38	1.20	0.98-1.47

Additional data and univariate differences between groups based on physical activity levels at three testing waves are presented in Supplementary tables S1-S3.

2.3.4. Discussion

Our study aimed to prospectively examine the influence of parental/familial factors on PALs in adolescents aged 16–18 years. There are several important findings of this study. First, a significant decrease in PALs was evidenced during the observed period, and female gender was associated with a greater risk of being insufficiently active. Second, paternal education had a positive impact on children's PALs only at baseline (i.e., when participants were 16 years of age), while such an influence was lost after the age of 17. Third, parental/familial conflict had a negative impact on PALs during the study period.

2.3.4.1. Gender and changes in PALs

A decrease in PALs during adolescence has been evidenced globally [183, 184]. Therefore, the decrease in PALs that we evidenced in adolescents herein was actually expected. However, this study, to some extent, fulfilled the picture regarding the trends in PAL changes during adolescence. In brief, when observing our results together with those previously reported using the same instruments, we can highlight the fact that the decrease in PALs in girls was actually continuous, at least in terms of the period between the age of 14 and 18 years. Specifically, Maric et al. recently evidenced a significant decrease in PALs between 14 and 16 years of age (first to third grades of high school) [183]. Meanwhile, the study of Stefan et al. indicated a decline between the second and third grades of high school [184], while in this study, we evidenced a decrease in PALs between the third and fourth grades.

Collectively, this negative trend in PAL for the total sample (including boys and girls) can be explained by a great number of factors typical for this period of life, such as: (i) Changes in time requirements and life priorities (longer sitting time during school hours, during leisure activities, and at home), (ii) an increase in school duties, (iii) a stronger focus on academic achievement [192, 193], and (iv) a decline in active transport . Additionally, we can highlight quitting sport as one of the most important factors for the evidenced decrease in PALs found here. Namely, although we did not evidence the problem here, previous studies in the region evidenced large decrease in sport participation particularly for the late adolescence [79, 194]. While an explanation of the different facets of the decline in PALs in adolescence is beyond the scope of this research, we instead focused on information provided directly throughout our investigation.

Irrespective of the results which point to negative trends in PAL for total sample, when our results are combined with results of previous study done in Bosnia and Herzegovina trends in PALs for boys are inconsistent [183]. Most specifically we can highlight variable changes in PALs among adolescent boys from Bosnia and Herzegovina (2.42, 2.28, 2.75, 2.40, and 2.51 for 14-, 16-, 17- and 18-years of age, respectively) [183]. Possible explanations are provided in the following text.

First, there is a certain possibility that selection of the participants influenced such results. Namely, in this study we included adolescents who finalized 4-year high-school education program (please see subsection Design and participants for details). The 4-year educational programs are known to be more challenging with regard to scholastic obligations than 3-year education programs, and children involved in 4-year programs are known to be better in educational achievements, including further educational plans (i.e. continuing education at College/University levels) [85]. While scholastic achievements are known to be associated with PALs, it is possible that initial selection of the study participants in this investigation resulted in specified discrepancies in trends of PALs to some extent, at least for boys.

Second, the fact that PALs in boys slightly increases between the 2nd and 3rd testing wave may be a result of the fact that 2nd testing wave was organized at the end of the 3rd school year. Previous studies noted that this period is specific due to large drop-out from organized sports among boys [175], which consequently reduces even the PALs. In the following period (during the 4th year of high-school education), boys could re-organize their duties and interests, including initiation in some form of recreational physical exercise (in fitness and recreational centers), which could result even in increase of the PALs between 2nd and 3rd testing wave.

A lower level of PALs in adolescent females than in boys is regularly reported [20, 184]. Specifically for Southeastern Europe, a study conducted with students from Bosnia and Herzegovina indicated lower PALs among girls between 14 and 16 years of age [183]. Supportively, research conducted on adolescents from the territory of Croatia showed gender differences in the period between the third and fourth grades of high school, with higher PALs among boys [32]. Such differences are supported by the latest WHO data, stating that 84% of girls and 78% of adolescent boys do not meet the global PA level recommendations [1]. According to research to date, a few explanations are most commonly underlined as a cause of gender differences in PALs: (i) Social factors, (ii) attitudinal factors, and (iii) factors related to participation in organized sport [160].

When we talk about social factors in the context of gender differences, we are referring to the influence that the social environment (i.e., peers, teachers, and parents) has on PALs in

adolescents [161]. More specifically, social factors—considering social–cultural and generational aspects—influence the modeling of PA involvement in males and females [195]. Specifically, PA through recreation and sport is often presented as an important element of masculinity in mass culture, resulting in higher social expectations toward men being physically active [195]. However, this actually means that girls often receive less support from the immediate environment related to participation in PA, while boys are exposed to a much larger number of social structures that encourage and influence PA and participation in PA [52, 196]. This at least partially reflects the differences in PALs between genders during adolescence, resulting in higher PALs among boys.

On the contrary, when we talk about the attitudes that affect PALs, we cannot ignore the simple fact that so-called "gender roles" define differences in attitudes, and therefore additionally contribute to the differences in PALs between adolescent boys and girls [160]. For instance, the competitive nature of sport is unappealing to a substantial number of today's adolescents, but there is no doubt that such unattractiveness is more common in females. Girls therefore often feel incompetent/incapable of participating in sport and PA in general [192, 197]. As a result, girls are generally less interested in PA, which certainly contributes to a their lower PALs in the end [164, 165].

Finally, irrespective of the previously explained social and attitudinal factors related to PALs, we cannot ignore the sport factors that also directly contribute to differences in PALs between genders [160]. It cannot be ignored that PALs among children and adolescents mostly refers to organized sport in sport clubs, where the level of support and opportunity is not equal for both genders. Briefly, it is evident that the organized sport system, through organizational specifics, more accessible sport facilities, and more competition, undoubtedly favors males, leading to lower sport participation rates and much higher dropout rates in girls [171]. As direct support for previous discussion, we can highlight: (i) Higher levels of sport participation in boys than in girls observed herein (please see Supplementary Table S1 for details), and (ii) a significant influence of sport participation on the PALs in all three testing waves.

2.3.4.2. Parental education and PALs

Physically active parents inspire their children to develop healthy physical behaviors [198]. Logically, parental influence is one of the primary factors influencing the behavior of young people, and thus the habits associated with PALs [33, 54, 55]. Accordingly, a large number of studies to date have examined familial and parental influence on PALs in children and

adolescents [51, 52]. However, the results are inconsistent. While some studies have indicated a positive impact of higher parental education on children's PALs, others show conflicting results [69, 197]. This is consistent with our results, given that: (i) Maternal education was not identified as a factor influencing PALs, and (ii) the influence of paternal education on PALs was significant only at the study baseline. Interestingly, the positive influence of paternal education on PALs at baseline (when participants were 16 years of age) is consistent with a recent report where Maric et al. highlighted a positive relationship between same variables in adolescents over the period of 14–16 years of age [32, 183]. The background of this relationship is discussed below.

Even though studies show conflicting findings when it comes to maternal or paternal influence on PAL and sports involvement, we may assume that our finding is in accordance with studies highlighting fathers as one of the most important factors influencing PALs and involvement in sport [199, 200]. Therefore, we can assume that the significant impact of (exclusively) paternal education on PALs at baseline is partly due to the greater impact they generally have on the PALs of their children. The reason for this relationship is probably based on the social perception that men are more competent in terms of PA and sport than women. The authors of the current study are of the opinion that this is particularly noticeable in the area of Southeastern Europe, where sport represents one of the most common topics of socializing in male environments [201]. However, it is also possible that fathers with a higher educational level, knowing the benefits of PA, actively encourage their children to participate in PA and sport, as it has been recently suggested [183]. However, for the moment, we cannot clearly define which of the factors mentioned above significantly affects the established correlation at baseline; hence, it should be studied in more detail in the future.

To the best of our knowledge, this is the first study to report the time points at which parental education is no longer a factor of influence on children's PALs. Evidently, the age of 17 years should be considered a certain "critical point," at least for adolescents from Bosnia and Herzegovina. The authors believe that the reason for this is related to maturation, which similarly affects PALs, but also the sociocultural determinants of PALs. More specifically, it is assumed that through this period, parental supportive behavior decreases in accordance with the maturation of adolescents. During the reported period, adolescents go through social change and the opinions of their peers become far more important than the opinions of their family members [69, 202].

At the same time, the perceptions of adolescents themselves change accordingly [69]. Thereby, previously appreciated parental influence changes in the eyes of adolescents. The

assumption is that parental input creates repulsion, since adolescents feel mature enough to make their own decisions and form their own conclusions about individual behaviors, which they could feel deprived of because of parental interference [69]. Adolescents strive for emotional autonomy from their parents so that they can have the opportunity to develop into an independent person [203]. Although further studies are needed in order to examine this issue in more detail, we may assume that the previously discussed information at least partially explains the lack of influence of parental education on PALs after 17 years of age. Moreover, this probably explains the non-significant association between parental monitoring and parental care with PALs in the studied adolescents herein.

2.3.4.3. Parental conflict and PALs

Parental/familial conflict evidenced at baseline had a negative impact on PALs during the whole study period. Interestingly, a recent study conducted in the same country showed no association between the same parental/familial variables and PALs in younger adolescents (12–14 years of age) [183]. It is particularly important to note that the previous study used identical measurement tools to those used here. Therefore, it seems that such relationships and the possible influence of parental/familial conflict on children's PALs are characteristic of older adolescents (e.g., from 16 to 18 years of age). Explanations should be sought for the possible causes of the conflict itself.

Older adolescence is marked by a series of rebellious behavior [204]. Adolescents of such an age are often prone to thinking that they know and understand more than they objectively do, trying new things, taking risks, and testing boundaries [205]. Therefore, it is possible that the conflict between children and parents/family is a result of too directive and/or restrictive parental behavior. This would naturally jeopardize the autonomy of adolescents, which is known to be extremely important during this period [69]. Altogether, this may result in the rebellion of children against all "pro-social behaviors," including those associated with PALs (i.e., participation in sport, active transportation, and recreational activities with family and friends).

Supportively, previous studies have indicated that controlling and directive parental behavior in some cases have a negative impact on adolescents' PALs. For instance, Wing et al., in a sample of 594 adolescents from Canada, pointed to the negative impact of parental control on self-efficacy beliefs and youth enjoyment of PA, which the authors highlighted as the two main determinants of PA-related behavior [206]. Therefore, it is important to take into account

the fact that conflicts between parents and adolescents are one of the most characteristic/common features of adolescence. Therefore, although such conflict is most often characterized by mild arguments, disagreements, and conflicts over everyday issues, it is necessary to pay attention to the negative effects that these conflicts can have on young people's behavior, including the behavior related to PA.

2.3.4.4. Limitations and strengths

This study has several limitations. First, physical activity was not directly measured but was evidenced by self-administered questionnaires. However, knowing that the PAQ-A has been repeatedly validated in similar samples of participants, we believe that the results obtained herein are plausible. Furthermore, this study did not observe some of the important covariates of the predictors and outcomes (i.e., scholastic factors and physical literacy), which limits the possibility to discuss the established relationships more profoundly. Third, we observed participants from one specific country and location; therefore, the results are generalizable only to similar regions.

This study is one of the first where PA was observed across a relatively short time span off approximately six months. Therefore, it allowed us to better understand the complex and dynamic relationships between the parental variables and physical activity among adolescents. Additionally, this study is a continuation of previous research conducted with younger participants from the same country. Such an experimental approach, together with a prospective design, allowed us to identify and explain the trends in PALs changes, as well as to discuss the relationships between the studied predictors and the PALs from 14 to 18 years of age.

2.3.5. Conclusions

The results of this study point to a significant decline in PALs in the period between 16 and 18 years of age. Knowing that previous studies conducted in the same region have evidenced a similar decline in the previous two years, we may highlight the continuous decline in PALs from 14 to 18 years Therefore, in order to prevent a decline in PALs in this period of life, public health authorities should target all ages with similar respect and attention. In other words, there is no evidence that a specific age only should be considered as “critical” in terms of a more rapid decline in PALs.

However, there are certain evidences that negative trends in PALs among adolescent boys are not continuous between the age of 14 and 18. There is certain possibility that changes in sport participation (i.e. quitting organized competitive sports, involvement in fitness/recreational physical exercising) during adolescence influence such results. Therefore, this issue should be more precisely studied in future investigations.

This study also evidenced a significant influence of paternal education level on children's PALs at the age of 16, with no association between parental education and children's PALs after the age of 17 years. This information is important from the perspective of the development of a targeted intervention aimed at the prevention of a decline in PALs. Namely, while children whose parents (fathers) are better educated should be observed as being "protected" against a decline in PALs until the age of 16 years, this "protective mechanism" seems to disappear in older adolescence.

Contrary to the association between parental education and PALs that exists in younger adolescence, this study brought evidence of parental conflict as a significant risk factor of lower PALs later in adolescence (i.e., >17 years of age). As a result, when targeting older adolescents at risk of lower PALs, special attention should be placed on those who self-report higher parental/familial conflict. Meanwhile, it seems that factors of parental conflict do not correlate with PALs in younger adolescence.

Lastly, this study evidenced differential dynamics of the changes in PALs between boys and girls in the observed period. Specifically, while the PALs among the girls decreased continuously, the boys experienced variable changes in PALs, with a decrease between 16 and 17 years and a slight increase between 17 and 18 years of age. Therefore, further analysis is needed in order to better understand such differences between and within genders.

2.4. Analysis of the relationship between tobacco smoking and physical activity in adolescence: a gender specific study

2.4.1. Introduction

Physical activity (PA) includes every body movement, including time spent on activities such as transportation, household chores, work, and recreational and sports activities, and it is categorized according to intensity levels, from low to moderate to vigorous [1]. The PA is considered to be any movement performed by muscle contraction which results in an increase in energy expenditure or an increase in metabolic rate [2]. Due to its direct and indirect influence on health status globally, the WHO proclaims PA as a health imperative, and makes it one of the key priorities for optimizing health and well-being [1].

The health-promoting effects of PA are backed by numerous studies exploring the effect of PA on the prevention and treatment of chronic diseases [7-9]. Some of the known benefits of regular and adequate PA are: improvements of bone and functional health, improvements of muscular and cardiorespiratory fitness, and reduced risk of coronary heart disease, hypertension, stroke, various types of cancer, diabetes, and depression, and it is fundamental to weight control and energy balance [1, 207, 208]. Furthermore, scientific evidence highlights the benefits of PA in a broader socio-economic context, given that people who are physically inactive due to a wide range of health consequences represent a great burden for the health care system and thus a large financial expense for a state [10].

Despite the persistent and continuous promotion of guidelines for maintaining and optimizing health status over the last two decades, the trend of physical inactivity continues to increase rapidly on the global level [13]. The decline in physical activity levels (PAL) is largely due to the modern way of life, which is strongly influenced by rapid economic development and changes in the living environment. Specifically, the increase of sedentarism and screen time, lack of active transportation, and the low necessity of physical work in everyday life are the most recognizable reasons for decrease of everyday PAL [209]. However, the fact that a rapid decline in PAL occurs in early adolescence is particularly concerning. On a global level 81% of adolescents (84% of girls, 78% of boys) aged 11 to 17 failed to meet the WHO recommendations in 2016 [1]. It is important to emphasize that adolescence is a crucial period for the adoption and retention of future habits, and thus it largely determines the future of the individual. Therefore, it is reasonable to conclude that physical activity in adolescence

determines later levels of activity, and thereby directly affects the overall health status of individuals in the future [28]. As a result, it is necessary to evaluate factors influencing PA in this population in order to design more effective interventions [28]. One of the factors which is particularly important with regard to PAL in adolescence is substance misuse, including tobacco smoking [34-37].

The smoking prevalence is generally decreasing globally, smoking is still a sixth leading cause of death worldwide, and the most frequently misused psychoactive substance in the world, despite the fact that the causal link between lung cancer and smoking was established more than 50 years ago [72-74]. Statistics and international data evidenced southeastern Europe (including Bosnia and Herzegovina) as one of the territories with the highest prevalence of adolescent smoking in Europe [75]. In particular, for Bosnia and Herzegovina daily smoking is reported for >25% of high-school adolescents, while an additional 20% of adolescents misuse cigarettes but not on a daily basis [76]. This is explained by several facts including traditional orientation of tobacco growing in some parts of the country, as well as relatively low prices of cigarettes (pack rarely costs more than 3 Euros). Consequently, cigarette smoking is socially accepted in the country, and in the whole region (i.e. the territory of former Yugoslavia) [77-79].

Knowing that both smoking and PAL are important determinants of health status, studies have analyzed the smoking prevalence as correlate of PAL in adolescence [76, 78, 79]. Interestingly, although PA and participation in sports (as the most important determinant of PAL in adolescence) are traditionally considered a way of supporting healthy habits in adolescence, and therefore higher PAL should be correlated with lower smoking, current research does not always support this thesis [80]. The research conducted on high school students in South Carolina suggests that higher levels of physical activity are correlated with lower likelihood of cigarette smoking in male adolescents [37], which is consistent with other studies done on adolescents that addressed this issue [34, 81, 82]. Conversely, an African study conducted on children aged 13 to 15 found no significant association between cigarette smoking and PAL [83]. Gender specific associations in associations between smoking and PAL were also detected [84, 85]. Observed inconsistencies among studies are expected since it is well established that studies investigating factors associated with PALs are indicating differences among different populations depending on sociocultural environment and gender caused by different confounding effects on established relationships between studied variables. However, most of these studies observed associations only in one time-point, and such a design provides

limited evidence on the relationships which may exist between smoking and PAL in adolescence.

Irrespective of the associations between smoking and PAL, the causality between these variables can be interpreted in both directions. More specifically, the smoking can be observed as "the cause" of lower PAL. For example, the higher smoking negatively influences the physical capacities and therefore reduce adolescents' willingness to participate in physically demanding activities. This is clearly evidenced in studies where authors confirmed that adolescent smokers were more likely to have quit sports than non-smokers [86]. Meanwhile, it is possible that PAL actually "influence" the smoking. This is backgrounded in socio-psychological theory of self-categorization which states that people accept and adopt the beliefs, behaviors, and norms of members of their social-environment [87]. As a result, if adolescents embrace the socially acceptable "healthy behaviors" in childhood (including higher PAL due to participation in sports or leisure time PA), it will probably transfer in lower smoking [88]. Although both mentioned directions of cause-effect relationships deserve attention, for a moment we were particularly interested in the possible influence of smoking as predictor of PAL.

The rapid decline in PAL and the increase in smoking that occur in adolescence indicates the need for prospective studies that would give us a better perspective and a more comprehensive interpretation of the relationship and the cause–effect relation of these variables. To the authors' knowledge, there is only one prospective study done on the territory of Southeast Europe that investigated smoking as a predictor of PAL during adolescence [25]. The study reported no significant influence of smoking on PAL in the period between 16 and 18 years of age. However, given that most of the studied adolescents initiated smoking before the age of 16 (the age of study baseline), the authors of that study highlighted: (i) the need for further research examining younger children, and (ii) gender-stratified analyses due to significant differences in smoking prevalence and PAL between genders [25]. Therefore, the aim of our study was to examine the gender-specific relationship between smoking and PAL in adolescents aged 14 to 16 years. We hypothesized that smoking will be negatively correlated to PAL at the first testing wave (beginning of high school education; 14 years of age), and at second-testing wave (end of 2nd grade of high school; 16 years of age) both in boys and girls.

2.4.2. Materials and methods

2.4.2.1. Participants and design of the study

This study is part of larger investigation where different types of predictors were observed in relation to PAL in adolescents from Bosnia and Herzegovina, and results of other analyses with other samples of participants are recently published elsewhere [183]. In this investigation we observed 650 participants (337 (48.2%) females) aged 14.7 ± 0.5 years at the first testing wave. The sample included adolescents from Herzegovina Neretva, Western Herzegovina, and Herzeg Bosnian County/Canton 10 (Figure 1). For the purpose of the investigation and this study we used multistage cluster sampling method, including (i) random selection of 1/4 of high schools in the observed Cantons and (ii) random selection of 1/3 of the first-year classes. With the population of 2662 first year high-schoolers, previously reported prevalence of smoking for somewhat older adolescents (30%), Type I/II error rate of 0.05, and statistical power of 80%, necessary sample size was 311 participants. In all schools observed in this study children participated in physical education classes twice a week during the school-year, which was mandatory school requirement for all healthy children. Some children participated in out of school sports, and other physically demanding activities and programs (i.e. dance), but for the purpose of this investigation these data were not collected (please see later for details).

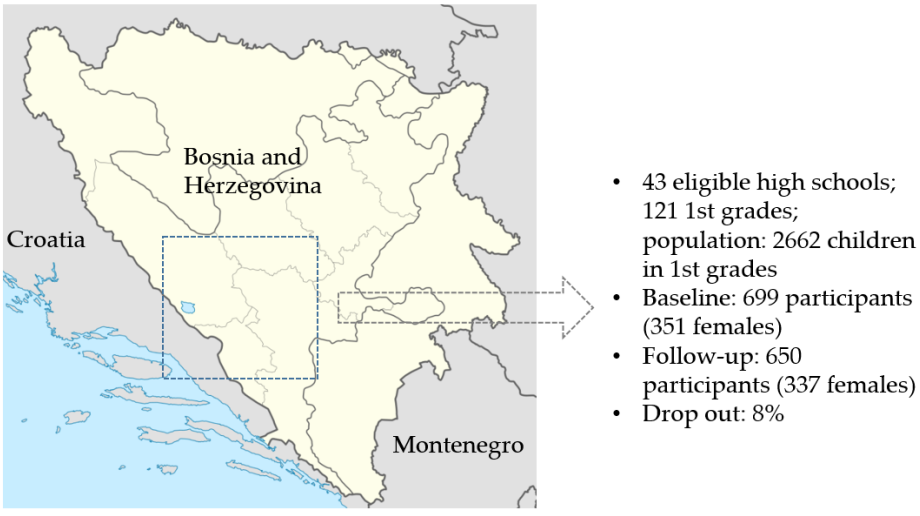

Figure 1. Study location, eligible participants and number of participants tested at each testing wave

The sample was tested at two testing waves. First testing wave was done when participants were 14 years old on average and started with their second-wave(approximately 20 months later). At first-wave, 699 participants were tested, however only those participants who were tested at both testing waves were included in the. Prior to investigation, study was approved by Ethical board of corresponding's author Institution, and then authorized by school authorities. The location, time frame and number of participants across testing waves is presented in Figure 1.

Before the first-wave testing, consent form was collected from children's parents/responsible adults. At both the testing, the participants were informed that the survey was strictly anonymous, and that they can refuse to participate, they could leave some questions or the entire questionnaire unanswered. The participants were asked to use self-selected codes in order to track the responses. The testing was performed through an internet-based application. Testing was done in schools, using the originally designed online survey. Participants used their private smart phones, but one of the investigators was present at each testing and provided smart phone if it was necessary.

2.4.2.2. Variables

Participants were tested using the structured questionnaires that were previously found to be reliable and valid measuring tools: the Questionnaire of Substance Use (QSU), and the Physical Activity Questionnaire for Adolescents (PAQ-A) [77, 115].

The QSU evaluates sociodemographic factors, and data on substance misuse, including smoking prevalence. The sociodemographic factors included the participants' age (in years) urban/rural living environment (later derived on the basis of specified living community), gender (male - female), and socioeconomic status of the family (SES; above average – average – below average). One query was used to evaluate prevalence of cigarette smoking with four possible answers (never smoked, ever tried, smoking but not daily, daily smoking). For the purpose of this study and later statistical analyses answers were grouped in nonsmokers vs. smokers) [77, 88].

PAQ-A was used for PAL assessment. The PAQ-A consists of 9 items. In brief, participants are asked to report their PAL based during last seven days (one week). The first 8 items are scored on a 5-point scale and include questions on different types of PAL (i.e., active transportation, activity during physical education classes, free play, sports), and as a result the PAQ-A provides a summary PA score derived from 8 items. The ninth item does not contribute

to the total score, it is used simply for selection (i.e., illness, injury,). The final score at PAQ-A ranges from 0 to 5. For the purpose of this study, we observed the total score of the PAQ-A, but additionally categorized data as "insufficient PAL" (scores <2.73), and "sufficient PAL (scores of 2.73 and above) [115, 116].

2.4.2.3. Statistics

To test the normality of the distributions, Kolmogorov–Smirnov test was calculated. For numerical variables (age, PAQ-A raw scores) the means and standard deviations were calculated, while frequencies and percentages were reported for the remaining variables.

The t-test for independent samples was used to identify differences between groups in parametric variables (PAQ-A raw scores, age). The $\chi 2$ test was used to identify differences between groups in ordinal variables, and to test the associations between ordinal variables (i.e. gender and PAQ-A observed at categorical scale (sufficient vs. insufficient PAL). Changes in PAQ-A raw scores during the study course were evaluated by t-test for dependent samples.

Binary logistic regression was used to estimate relationships between studied predictors observed at first-testing wave and dichotomized PAQ-A criteria (e.g. insufficient vs. sufficient PAL, please see previous text for details), and the odds ratio (OR) and the corresponding 95% confidence intervals (95%CI) were reported. Since preliminary indicated strong influence of gender on PAL, the logistic regressions were controlled for gender as covariate. Finally, gender was observed as an effect modifier, and all variables were additionally checked for correlations in logistic regressions stratified for gender. Hosmer Lemeshow test (HL) was calculated to test the model fit.

Statistical significance was set at 95%, and all analyses were done by software Statistical ver. 13.5 (Tibco Inc., Palo Alto, CA, USA)

2.4.3. Results

The 80.1% of boys and 80.9% of girls never tried to smoke cigarettes, with no significant difference between genders ($\chi^2 = 0.26$, $p = 0.60$).

Figure 2 presents PAL at testing waves. PAQ-A decreased significantly for total sample (2.40 ± 0.81 vs.2.25 ± 0.77, t-test = 22.19, $p < 0.001$), for boys (2.56 ± 0.86 vs. 2.34 ± 0.81, t – test = 16.75, $p < 0.001$), and for girls (2.25 ± 0.76 vs. 2.15 ± 0.72, t-test = 13.04, $p < 0.001$).

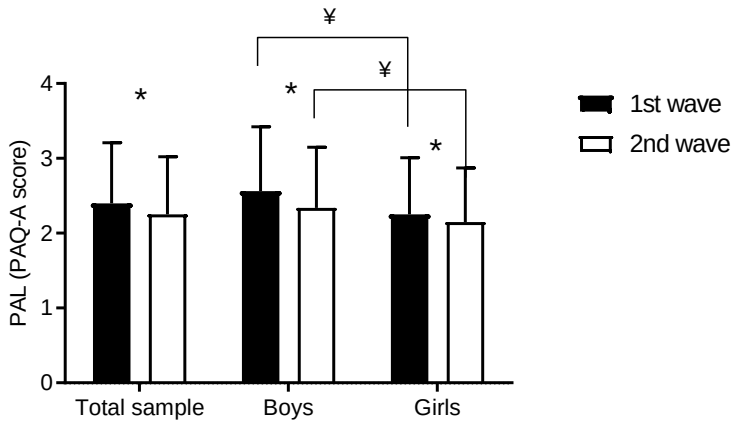

Figure 2. Changes and difference in physical activity levels for studied adolescents (¥ denotes significant ($p < 0.05$) t-test calculated between groups; * denotes significant ($p < 0.05$) t-test calculated within groups)

Adolescents who had sufficient PAL were of similar age as their peers with insufficient PAL at first-wave (14.79 ± 0.22 and 14.81 ± 0.42 years, respectively; t-test = 1.24, p = 0.21). At second-wave, those adolescents who achieved sufficient PAL were younger than those with insufficient PAL (14.76±0.42 and 14.83±0.41, respectively; t-test = 2.26, p = 0.03).

Differences between adolescents according to their PAL observed at categorical scale (e.g. insufficient vs. sufficient PAL) at first-wave are presented in Table 1. Supportively to t-test where genders were compared in PAQ-A raw scores (please see previously for results of t-test for independent sample), boys are more likely to achieve sufficient PAL than girls at first testing wave ($\chi^2 = 7.55$, $p < 0.001$).

Table 1. Descriptive statistics (F – frequency, % - percentage), and differences (Chi square test - $\chi 2$) between adolescents according to their physical activity levels at first-wave

	Total		**Insufficient PAL**		**Sufficient PAL**		**χ^2**	
	F	**%**	**F**	**%**	**F**	**%**	**χ^2**	**p**
Gender							7.55	0.001
Boys	313	48.2	192	44.3	121	55.8		
Girls	337	51.8	241	55.7	96	44.2		
Socioeconomic status							1.01	4.47

Below average	17	2.6	9	2.1	8	3.8		
Average	560	86.3	372	85.3	188	88.3		
Above average	72	11.1	55	12.6	17	8		
Urban/Rural							0.17	0.67
Urban	296	45.6	200	46.2	96	44.2		
Rural	353	55.4	233	53.8	120	55.3		
Smoking							1.28	0.25
No	523	80.6	340	79	183	82.8		
Yes	127	19.4	89	20.6	38	17.2		

Differences between groups of adolescents according to their PAL observed at categorical scale (insufficient vs. sufficient PAL) at second-wave are presented in Table 2. As could be expected from t-test results (please see previous text), boys are more active than girls ($\chi^2 = 7.54$, $p < 0.001$), while smoking is lower in those adolescents who achieved sufficient PAL (Mann Whitney test = 6.46, $p = 0.02$).

Table 2. Descriptive statistics (F – frequency, % - percentage), and differences (Chi square test - $\chi 2$) between adolescents according to their physical activity levels at second-wave

	Insufficient PAL		**Sufficient PAL**		**χ^2**	
	F	**%**	**F**	**%**	**χ^2**	**p**
Gender					7.54	0.001
Boys	192	44.3	121	55.8		
Girls	241	55.7	96	44.2		
Socioeconomic status					1.01	0.6
Below average	13	2.7	4	2.3		
Average	406	85.1	154	8.9		
Above average	56	11.7	16	9.1		
Urban/Rural					0.48	0.48
Urban	141	46.5	152	43.8		
Rural	162	53.5	195	56.2		

Smoking					6.46	0.02
No	231	76.2	292	84.2		
Yes	71	23.5	54	15.6		

Logistic regression calculated for "Gender" as predictor of PAL evidenced higher likelihood for sufficient/appropriate PAL among boys at first- (OR = 1.68, 95%CI = 1.21-2.35), and at second-wave (OR = 1.59, 95%CI = 1.12-2.26).

Table 3 presents correlations between studied predictors and PAL at first-wave. When calculated for total sample, while including "Gender" as confounding factor, lower likelihood for sufficient PAL was found for adolescents who smoke (OR = 0.55, 95%CI: 0.36-0.83, HL = 0.56, p = 0.90). In gender-stratified models significant relationship was found between smoking and PAL in girls, with lower PAL among girls who smoke (OR: 0.75, 95%CI: 0.55-0.95; HL = 0.04, p = 0.84).

Table 3. Logistic regressions between sociodemographic variables and cigarette smoking (predictors) and physical activity levels at first-wave

	Total sample*		**Gender stratified**			
			Boys		**Girls**	
	OR	95%CI	OR	95%CI	OR	95%CI
Cigarette smoking	0.55	0.36-0.83	0.76	0.50-1.01	0.75	0.55-0.95
Urban environment	0.97	0.75-1.23	1.09	0.81-1.42	0.95	0.67-1.36
Age	0.74	0.41-1.14	0.7	0.41-1.03	0.73	0.40-1.10
Socioeconomic status [int]	0.99	0.81-1.14	1.00	0.71-1.29	0.99	0.75-1.24

* Model included "Gender" as confounding factor, [int] – observed as interval for the purpose of logistic regression calculation (below average-average-above average socioeconomic status)

Correlates of PAL at second-wave are presented in Table 4. Smoking was correlated to PAL (OR = 0.59, 95%CI = 0.37-0.92; HL = 0.13, p = 0.98), with lower likelihood for sufficient PAL in adolescents who smoke (for total sample with "Gender" as confounding factor). When gender-stratified logistic regression were calculated, the lower likelihood for sufficient PAL was evidenced in girls who smoke (OR = 0.73, 95%CI: 0.51-0.96 HL = 0.12, p = 0.72).

Table 4. Logistic regressions between sociodemographic variables and cigarette smoking (predictors) and physical activity levels at second-wave

	Total sample*		**Gender stratified**			
			Boys		**Girls**	
	OR	95%CI	OR	95%CI	OR	95%CI
Cigarette smoking	0.59	0.37-0.92	0.79	0.54-1.03	0.73	0.51-0.96
Urban environment	1.00	0.79-1.23	1.11	0.80-1.46	0.98	0.64-1.40
Age	0.80	0.40-1.16	0.65	0.38-1.07	0.76	0.36-1.08
Socioeconomic status [int]	1.01	0.81-1.17	1.02	0.70-1.31	1.01	0.70-1.31

* Model included "Gender" as confounding factor, [int] – observed as interval for the purpose of logistic regression calculation (below average-average-above average socioeconomic status)

2.4.4. Discussion

The study aimed to examine the impact of smoking on PAL in adolescents 14 to 16 years of age. With regard to study aims, we can highlight following results. First, male adolescents were more physically active than females. Next, cigarette smoking negatively affects PAL in girls. Finally, no association between smoking and PAL was found in boys. Therefore, our initial study hypothesis can be only partially accepted.

2.4.4.1. Gender and physical activity levels in adolescence

The decline in PAL in adolescents is not surprising and is consistent with a large number of previous studies [108, 184, 210]. This phenomenon is explained by numerous factors, including changes in life priorities and time requirements (longer sedentary time at school and home), focusing on academic achievement [195], and a lack of support from friends, teachers, and families [192, 193]. Furthermore, it is generally believed that the decline in PAL is largely due to the modern way of life, which is strongly influenced by rapid economic development and changes in the living environment. Finally, it is important to emphasize that the decrease of PAL in this period is significantly influenced by cessation of organized sports [25].

We evidenced lower PAL among girls than in boys at both testing waves, and this is in accordance with studies done globally [211]. We can assume that this is actually a result of significant decrease of PAL among girls in earlier age, given that the changes caused by puberty occur earlier in girls [184]. Although the authors are currently unable to offer clear evidence for such statement, we may support it based on previous research that states that biological factors significantly contribute to gender differences in PAL [169, 210, 212]. In short, differences in PAL between boys and girls decrease after adjustment to sexual maturity, in which case we can assume that lower PAL in girls could be associated with maturation at an earlier chronological age [171, 213].

Another explanation for higher PAL in boys is related to sport participation. Although in this study we didn't specifically observed the level of sport participation, recent studies with somewhat older adolescents in the region evidenced significant influence of participation in organized sports as important determinant of PAL in adolescents [32]. Also, investigations regularly confirmed higher sport-participation in adolescent boys, than in girls [25, 79]. Together with previously mentioned differences in maturation stages between boys and girls, this may result in gender-differences in PAL we evidenced in this study.

2.4.4.2. Smoking and physical activity levels in girls and boys

Research to date brought inconsistent results when it comes to association between smoking and PAL in adolescence [37, 80, 214]. For instance, US study with high school students evidenced higher PAL in male adolescents who don't smoke [37], and similar findings are reported in some other studies [34, 81, 82]. In the meantime, African study reported no significant association between PAL and cigarette smoking [83], which is consistent with recent report from Bosnia and Herzegovina with older adolescents . As a result, we may say that gender-specific associations between smoking and PAL we have evidenced herein are not surprising. That being said we may assume that differences in results occur due to dissimilarities among populations which leads to the occurrence of different confounding effects on established relationships between studied variables. Accordingly, we discussed our results in the context of gender specifics and the socio-cultural environment of the tested sample.

In our study cigarette smoking was negatively correlated with PAL in girls, and we can highlight several explanations for such finding. Firstly, the negative effects of smoking on the cardiovascular and respiratory systems are well known. Smoking leads to a decrease in oxygen uptake and transport, which leads to the reduced functionality of the cardiovascular and

respiratory systems during exercise [25, 37]. Negative effects that often manifest immediately, such as breathing difficulties, are logically more familiar to physically active individuals, which explains the association between lower smoking and higher PAL among girls in our study.

It is important to highlight that such negative relationship between smoking and the ability to be physically active is particularly evident for girls. Namely, previous experimental studies confirmed a dose-response relationship between smoking and reduced lung function (i.e. lower physical capacity) only in girls [215]. It actually means that girls should be observed as more vulnerable than boys to the impact of smoking on lung function and respiratory symptoms, which additionally may explain the established relationship between smoking and PAL (exclusively) in girls. It altogether probably resulted even in relatively consistent relationship between smoking and PAL in girls.

Smoking status observed as first testing-wave was not significantly related to PAL in boys. Although this result is in certain disagreement with findings on higher PAL among girls who don't smoke, it can be explained taking into account the context of PAL in studied boys. Namely, previous studied noted that PAL in Bosnian and Herzegovinian boys is mostly a result of their participation in competitive sports (i.e. soccer, handball, basketball) [88, 115]. Meanwhile, this is not the case for adolescent girls from the same country since girls' PAL is more a result of participation in recreational activities in fitness centers, and in nature (jogging, walking, etc.). It is also important to note that girls' participation in competitive sports is much lower than in boys of the same age [124].

The explanation for such gender-specific context of the PAL during adolescence is related to the existence of generational, cultural, and social influences on sports involvement in men and women [195, 216]. Briefly, competitive sport is presented as an important determinant of masculinity in many cultures, and thus the social expectation for men to play sports is higher than that for women [195]. Accordingly, boys unite their sports identity with their masculine identity relatively easily, which is not easy for the girls who often lack the support of their social environment (parents, teachers, and friends) [217]. Finally, studies clearly indicate that the competitive nature of sport is unattractive to great number of females who often feel that they do not have the adequate level of competence required to participate in a team [192, 197].

Further, previous investigations in the region noted alarmingly high prevalence of smoking in boys who participate in organized competitive sports (among athletic boys aged 16-18 years more than 30% were daily smokers), and studies indicated even the earlier initiation in smoking in athletic- than in non-athletic boys [76, 79]. This was explained the socio-cultural phenomenon of competitive sport, especially regarding the regular post-sport gatherings in bars

and clubs where smoking is allowed. It actually could result even in "negative" correlations between smoking and PAL even in here observed boys (i.e. boys who smoke are more likely to be involved in sports, and consequently will have higher PAL).

Collectively, all previously discussed issues probably led to non-significant relationship between smoking and PAL among boys in our study. Figuratively speaking, while the higher PAL should be logically influenced by non-smoking (and will result in correlation similar to one evidenced among girls), the specific context of previously explained factors (post-sport gatherings, high-prevalence of smoking and early initiation in smoking among athletic boys) caused opposite relationship, finally resulting in non-significant relationship between smoking status, and PAL among adolescent boys observed herein.

Finally, there is additional possibility that the lack of association between smoking and PAL in boys could be aggravated by low vulnerability of boys when it comes to negative impact of smoking on their physical capacities [215]. Specifically, in the study which examined sex-specific effect of adolescent smoking on respiratory symptoms and lung function, authors confirmed dose-response relation between smoking and reduced lung function only in girls [215]. In other words, boys were generally more resistant to the impact of smoking on respiratory symptoms and lung function. Together with all previously specified factors, this could at least partially influence our findings as well.

2.4.4.3. Limitations and strengths

The most important limitation of our study is the fact that this study is based on self-reports. Meaning that PALs and cigarette smoking were not directly and objectively measured, but were rather evidenced throughout participants' self-report. The questionnaires were used because of a relatively large sample of participants, testing of the cigarette smoking data, and prospective study design which altogether limited the usage of more accurate measurement tools (i.e. accelerometers and pedometers). However, used questionnaires were reported to be valid and reliable measuring tools. Moreover, even though there is a certain probability that participants may choose socially desirable answers, particularly when it comes to cigarette smoking, authors believe that strict anonymity of the investigation and previous experience from similar studies conducted in the past are decreasing this possibility. Next, in this investigation we observed only tobacco smoking, and no information was provided about other types of smoking (i.e. e-cigarettes, water pipe). However, knowing the situation in the region where the study was performed, and relatively low prevalence of types of smoking other than "cigarette smoking"

we believe that this limitation did not influence our findings to a greater extent. Furthermore, our study lacks the detailed evaluation of smoking history. This information would certainly make a discussion stronger since it would provide a better understanding of obtained results. Alsothis problem should be considered in future research, as well as the examination of the predictors of change from non-smoking to smoking (and vice versa).

This is one of the first prospective investigations which examined the influence of smoking on PAL in younger adolescents, and probably the first one in southeastern Europe. Knowing the negative trends in PAL and alarmingly high prevalence of smoking in adolescents from the region, this is important strength of the study. Also, usage of the previously validated questionnaires allowed us to objectively compare the obtained results with those previously reported for similar sample. Therefore, we believe that although not the final word, the investigation will contribute to knowledge and initiate further research.

2.4.5. Conclusions

Authors believe that detailed investigation of PA should be one of the priorities for optimizing health and productivity on the global level, given the fact that PA has a wide variety of positive outcomes, while inadequate PALs is one of the leading risk factors for global mortality. Unfortunately, regardless of the WHO appeal interventions aimed at increasing PALs are still not prioritized on the global level, which is quite obvious given the fact that the decline in PALs is an ongoing trend. Hence it is logical that a detailed investigation of PA and PA issues should also be an ongoing trend and highly prioritized. Investigations should proceed with exposing PA benefits/dangers of physical inactivity and identification of factors influencing PA levels since they present the most important preconditions for creating targeted and successful interventions aimed at fighting this negative trend which took pandemic proportions.

Future investigations should provide additional information that will finally encourage changes of global populations PALs and bring more concrete and quality solutions for solving the problem of physical inactivity. We believe that our results support this by providing information for future research and interventions since it provides insight and thus a better understanding of the relationships between smoking and PAL on the territory of Southeastern Europe. More specifically, the correlation between smoking and PAL in girls is promising from the viewpoint of development of public-health educational politics. Specifically, it may be

suggested that the increase of the PAL in this age group may have multiple positive effects, including those directly related to higher PAL (i.e., prevention of non-communicable diseases, positive influence of PAL on psycho-social health), but also on prevention of smoking.

Smoking was not correlated to PAL in boys, but this finding is understandable considering the broader socio-cultural perspective. It seems that socio-cultural environment in studied country, as well as reported orientation of boys toward competitive sports, resulted in non-systematic relationship between smoking and PAL. However, for more detailed analysis further studies are needed, where different facets of PAL (i.e. physical education, free-time activities in nature, recreational activities in fitness centers, competitive sports) will be specifically examined and correlated to PAL.

Finally, our results suggest that boys and girls in younger adolescence do not follow the equal trajectories when it comes to the relationships between smoking and PAL. Therefore, in developing promotional public health actions related to decrease of smoking and increase of PAL, gender specific approach is highly recommended.

Chapter 3 - Contribution to the research field and practical application

The research papers included in the dissertation studied changes in PALs and correlates of PA in adolescence [183, 218, 219], a major global problem given the downward trajectory of PA curve since 2001. Therefore, identifying the factors influencing PALs is an important step in fighting this negative trend and it is necessary for the preparation and development of quality interventions aimed at increasing the PALs. The author - Miss Marić believes that there are a few significant contributions to this research filed. This dissertation will contribute to the knowledge in our field and encourage further research, while also improving and promoting PA interventions. Therefore, in the following text the authors' contribution to the field and practical application will be more thoroughly explained and described.

Above all results of the research confirmed the initial assumption of a continuous decline in PALs [183, 219, 220] but also PALs decline during lockdown and social isolation imposed by the COVID-19 pandemic [218]. This is important to point out since low PALs are already one of the more severe problems affecting the population of adolescents, which is supported by all four studies herein presented [183, 218-220]. Factors that disrupt and interfere with initially low PALs should be identified, and their negative impact should be eliminated as efficiently as possible. In this case, we must emphasize the fact that the COVID-19 pandemic has multiple adverse effects in addition to potentially severe consequences of virus infection [218]. It also threatens freedom to move, socialize and engage in PA, which consequently reduces the ability to maintain PALs, leading to potential health threats caused by non-communicable diseases that develop as a result of inactivity. According to that, it is our responsibility as a sports scientist to address "the elephant in the room" and, through our research, remind everyone that COVID-19 is not the only pandemic that has affected the world. Physical inactivity is a pandemic that has been rapidly spreading around the world over the last few decades, and it shouldn't be neglected just because of another one, and especially in the circumstances like this. The author believes that all four research papers presented herein provide a great reminder of how severe the problem of physical inactivity in adolescence is while emphasizing the need for further action and a call for further research.

Studies presented as a part of this dissertation are probably among the first prospective studies exploring PAL changes and the predictors of PALs in adolescents in Southeastern Europe

region. Therefore, identified determinates of PA provide a meaningful source of information since they have the potential of clarifying cause-effect and pointing out risk groups. Information's acquired should be used for the preparation of future studies but also targeted interventions intended for positive changes in adolescents PALs. Accordingly, factors influencing PALs identified in the presented studies are going to be highlighted, considering the fact they could contribute to both future research and practical application. Additionally, author will briefly present the practical implications of the obtained data.

3.1. Gender differences

Significant gender differences were identified, implying lower PALs in girls in both tested periods, younger (14 – 16 years) and older adolescence (16 – 18 years). Despite lower PALs in girls, a significant decline in activity was detected in both genders. However, prospective follow-up over a two-year period from 14 to 16 years of age detected a greater negative trend of PALs decline in boys. Furthermore, PALs were negatively influenced by cigarette smoking in girls, while there was no association between smoking and PALs in boys.

Gender differences are quite common when it comes to PALs, but also in factors influencing PALs. Previous researchers have found an earlier dropout from organized sports in girls (between 9 and 12 years old), while in herein presented studies, the period between 14 and 16 years of age was identifying as particularly critical for boys PA changes. Additionally, PALs decline was also reported for the period between 16 to 18 years of age. Accordingly, we may conclude that decline of PALs is continuous throughout adolescence, with differences in "critical point" when it comes to a sudden drop of PALs for boys and girls. This leads to the conclusion that PAL decline in girls should be explored in more detail in younger years, while in boys, a more thorough investigation should be conducted between 14 and 16 years of age. This should also be taken into account when it comes to the execution and implementation of future interventions to combat physical inactivity and campaigns to encourage increased physical activity.

Additionally, gender differences were also detected in the association between PALs and cigarette smoking. The negative correlation between PALs and smoking in girls is promising from the perspective of the development of public-health educational interventions and politics. In particular, interventions aiming to increase the PALs in girls (14 to 16 years old) may have

several positive effects. Firstly, those directly related to higher PAL, such as the positive influence of PAL on psycho-social health and prevention of non-communicable diseases, and secondly smoking prevention. What's more, our results suggest that girls and boys in younger adolescence do not follow identical trajectories when it comes to the relations between PAL and smoking. Therefore, when developing public health actions targeted at promotion and intervention to increase PAL or decrease smoking, the author strongly suggests gender-specific approach.

3.2. Environmental factors and physical activity

Research results provided a clearer picture of the relationship between the living environment and PA. Meaning it is evident that PALs are significantly higher in the urban environment, and also decline of PAL during COVID-19 were more significant in adolescents living in the urban environment. This is implying the importance of influence that environmental factors have on PALs in the population of Croatian adolescents.

The author is of the opinion that it is necessary to start with adapting infrastructure and developing and creating environments that would make PA accessible and attractive for both younger and older generations. Study findings are indirectly suggesting, that the preventive strategies should provide adolescents from rural areas with free access to training facilities, and in general, provide adolescents from urban and rural areas with organized training activities to avoid consequences related to the declined PALs (e.g., obesity, development of chronic diseases, anxiety, depression, etc.) whether it's because of COVID19 pandemic, or in general. However, since the circumstances (COVID19 pandemic) affecting the decline in PALs have not yet changed, it would be good to start from the development of strategies that would prevent a negative impact on PAL in adolescents caused by prolonged measures of social distancing. In line with the above-mentioned, the author proposes strategies that would promote the physical activity of adolescents without the risk of infecting themselves or someone else. Therefore, it is suggested for activities to be performed in smaller groups, while keeping the recommended social distance and avoiding physical contact, while retaining appropriate hygiene measures (e.g., using hand sanitizer, disinfection of used exercise equipment) and all of this with a permanent coach's supervision. Despite everything, this is, unfortunately, easier said than done since it depends on the state authorities' actions. Therefore, in order to encourage

initiatives for more physically active youth and the population in general, especially in today's time of social distancing caused by COVID-19, we should appeal to the state authorities to get actively involved and make an active effort in suppressing the inactivity pandemic.

3.3. Parental/familial factors and physical activity

Systematically examined familial/parental predictors of PALs in adolescents from Southeastern Europe between 14 to 16 years of age identified parental education as a positive predictor of PALs in both testing waves. On the other hand, when tested older adolescents (16 – 18 years), paternal education positively influenced their PALs only at baseline (i.e., when participants were 16 years of age), while the influence was lost in the follow-up proceeded after two years. Furthermore, familial/parental conflict was evidenced as a negative influence on PALs only in older adolescents (16 – 18 years) through the whole study period.

Better education of parents should be observed as a protective factor against PAL decline. Yet, if comparing research conducted on younger and older adolescents presented within this dissertation we may conclude that parental influence and thus the influence of the level of education weakens over the years and ultimately disappears completely. Therefore, in order to prevent a decrease in PALs in early adolescence, there is an evident need to specifically focus on children whose parents are of a lower educational level. This will hopefully improve their awareness of the importance of PA in this period of life. Such efforts will consequently have an important positive impact on the overall health status both in adolescence and later life. Furthermore, another comparison between these two researches examining association between the same parental/familial variables and PALs in younger and older adolescents leads to the conclusion that the impact of parental/familial conflict on children's PALs are characteristic of older adolescents (16 to 18 years of age) since the influence wasn't determined in younger adolescents. Thereby, presumably, that explanations should be sought for the possible causes of the conflict itself. That being said, this is definitely something that should be more thoroughly examined in the future.

References

1. WHO. *Physical activity*. 2018 [cited 2020 August 17]; Available from: https://www.who.int/news-room/fact-sheets/detail/physical-activity.
2. Bouchard, C., S. Blair, and W. Haskell, *Why study physical activity and health.* Physical activity and health, 2007. **1**: p. 3-20.
3. Blair, S.N., et al., *How much physical activity is good for health?* Annu Rev Public Health, 1992. **13**: p. 99-126.
4. WHO, *Global action plan on physical activity 2018-2030: more active people for a healthier world*. 2019: World Health Organization.
5. MacAuley, D., *A history of physical activity, health and medicine.* J R Soc Med, 1994. **87**(1): p. 32-5.
6. Tipton, C.M., *The history of "Exercise Is Medicine" in ancient civilizations.* Adv Physiol Educ, 2014. **38**(2): p. 109-17.
7. Warburton, D.E., C.W. Nicol, and S.S. Bredin, *Health benefits of physical activity: the evidence.* Cmaj, 2006. **174**(6): p. 801-809.
8. Goh, T.L., et al., *Children's Physical Activity Levels Following Participation in a Classroom-Based Physical Activity Curriculum.* Children (Basel), 2019. **6**(6).
9. King, A.K., et al., *Go Girls!-Dance-Based Fitness to Increase Enjoyment of Exercise in Girls at Risk for PCOS.* Children (Basel), 2019. **6**(9).
10. Pratt, M., C.A. Macera, and G. Wang, *Higher direct medical costs associated with physical inactivity.* The Physician and sportsmedicine, 2000. **28**(10): p. 63-70.
11. Ding, D., et al., *The economic burden of physical inactivity: a global analysis of major non-communicable diseases.* The Lancet, 2016. **388**(10051): p. 1311-1324.
12. WHO. *Who guidelines on physical activity and sedentary behaviour*. 2020 [cited 2020 November 27]; Available from: https://www.who.int/publications/i/item/9789240015128.
13. Lu, C., et al., *Factors of physical activity among Chinese children and adolescents: a systematic review.* International Journal of Behavioral Nutrition and Physical Activity, 2017. **14**(1): p. 36.
14. Guthold, R., et al., *Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants.* Lancet Glob Health, 2018. **6**(10): p. e1077-e1086.

15. Tremblay, M.S., et al., *Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome.* Int J Behav Nutr Phys Act, 2017. **14**(1): p. 75.
16. Hallal, P.C., et al., *Global physical activity levels: surveillance progress, pitfalls, and prospects.* The lancet, 2012. **380**(9838): p. 247-257.
17. Butcher, K., et al., *Correlates of physical activity guideline compliance for adolescents in 100 US cities.* Journal of Adolescent Health, 2008. **42**(4): p. 360-368.
18. Colley, R.C., et al., *Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey.* Health reports, 2011. **22**(1): p. 15.
19. Wang, C., P. Chen, and J. Zhuang, *A national survey of physical activity and sedentary behavior of Chinese city children and youth using accelerometers.* Research Quarterly for Exercise and Sport, 2013. **84**(sup2): p. S12-S28.
20. Trost, S.G., et al., *Age and gender differences in objectively measured physical activity in youth.* Medicine and science in sports and exercise, 2002. **34**(2): p. 350-355.
21. Riddoch, C.J., et al., *Physical activity levels and patterns of 9-and 15-yr-old European children.* Medicine & Science in Sports & Exercise, 2004. **36**(1): p. 86-92.
22. Sagatun, Å., et al., *Three-year follow-up of physical activity in Norwegian youth from two ethnic groups: associations with socio-demographic factors.* BMC Public Health, 2008. **8**(1): p. 419.
23. Nelson, M.C., et al., *Longitudinal and secular trends in physical activity and sedentary behavior during adolescence.* Pediatrics, 2006. **118**(6): p. e1627-e1634.
24. Anderssen, N., B. Wold, and T. Torsheim, *Tracking of physical activity in adolescence.* Research Quarterly for Exercise and Sport, 2005. **76**(2): p. 119-129.
25. Miljanovic Damjanovic, V., et al., *Identifying Predictors of Changes in Physical Activity Level in Adolescence: A Prospective Analysis in Bosnia and Herzegovina.* Int J Environ Res Public Health, 2019. **16**(14).
26. Hallal, P.C., et al., *Adolescent physical activity and health.* Sports medicine, 2006. **36**(12): p. 1019-1030.
27. Malina, R.M., *Physical activity and fitness: pathways from childhood to adulthood.* American Journal of Human Biology: The Official Journal of the Human Biology Association, 2001. **13**(2): p. 162-172.
28. Park, H. and N. Kim, *Predicting factors of physical activity in adolescents: A systematic review.* Asian Nursing Research, 2008. **2**(2): p. 113-128.

29. Sterdt, E., S. Liersch, and U. Walter, *Correlates of physical activity of children and adolescents: A systematic review of reviews.* Health Education Journal, 2014. **73**(1): p. 72-89.
30. Salmon, J., et al., *Promoting physical activity participation among children and adolescents.* Epidemiologic reviews, 2007. **29**(1): p. 144-159.
31. Baranowski, T., C. Anderson, and C. Carmack, *Mediating variable framework in physical activity interventions: How are we doing? How might we do better?* American journal of preventive medicine, 1998. **15**(4): p. 266-297.
32. Sekulic, D., J. Rodek, and T. Sattler, *Factors associated with physical activity levels in late adolescence: a prospective study.* Medycyna Pracy, 2020. **71**(6).
33. Sallis, J.F., J.J. Prochaska, and W.C. Taylor, *A review of correlates of physical activity of children and adolescents.* Med Sci Sports Exerc, 2000. **32**(5): p. 963-75.
34. McCaul, K., J. Baker, and J.K. Yardley, *Predicting substance use from physical activity intensity in adolescents.* Pediatric Exercise Science, 2004. **16**(3): p. 277-289.
35. Veliz, P., et al., *Competitive sports participation in high school and subsequent substance use in young adulthood: Assessing differences based on level of contact.* International review for the sociology of sport, 2017. **52**(2): p. 240-259.
36. Lesjak, V. and O. Stanojević-Jerković, *Physical Activity, Sedentary Behavior and Substance use Among Adolescents in Slovenian Urban Area/Telesna Aktivnost, Oblike Sedečega Vedenja In Uživanje Psihoaktivnih Snovi Med Mladostniki V Slovenskem Urbanem Okolju.* Slovenian Journal of Public Health, 2015. **54**(3): p. 168-174.
37. Lisha, N.E. and S. Sussman, *Relationship of high school and college sports participation with alcohol, tobacco, and illicit drug use: A review.* Addictive behaviors, 2010. **35**(5): p. 399-407.
38. Donatiello, E., et al., *Physical activity, adiposity and urbanization level in children: results for the Italian cohort of the IDEFICS study.* Public Health, 2013. **127**(8): p. 761-765.
39. Regis, M.F., et al., *Urban versus rural lifestyle in adolescents: associations between environment, physical activity levels and sedentary behavior.* Einstein (São Paulo), 2016. **14**(4): p. 461-467.
40. Sallis, J.F., et al., *Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study.* The Lancet, 2016. **387**(10034): p. 2207-2217.

41. Sygit, K.M., et al., *Physical activity as an important element in organizing and managing the lifestyle of populations in urban and rural environments.* Annals of agricultural and environmental medicine: AAEM, 2019. **26**(1): p. 8-12.
42. Drenowatz, C., F. Hinterkorner, and K. Greier, *Physical Fitness in Upper Austrian Children Living in Urban and Rural Areas: A Cross-Sectional Analysis with More Than 18,000 Children.* Int J Environ Res Public Health, 2020. **17**(3).
43. Bathrellou, E., et al., *Physical activity patterns and sedentary behaviors of children from urban and rural areas of Cyprus.* Central European journal of public health, 2007. **15**(2): p. 66-70.
44. Machado-Rodrigues, A.M., et al., *Correlates of aerobic fitness in urban and rural Portuguese adolescents.* Annals of human biology, 2011. **38**(4): p. 479-484.
45. Chillón, P., et al., *Physical fitness in rural and urban children and adolescents from Spain.* Journal of Science and Medicine in Sport, 2011. **14**(5): p. 417-423.
46. Kopcakova, J., et al., *Are school factors and urbanization supportive for being physically active and engaging in less screen-based activities?* International journal of public health, 2018. **63**(3): p. 359-366.
47. Machado-Rodrigues, A.M., et al., *Cardiorespiratory fitness, weight status and objectively measured sedentary behaviour and physical activity in rural and urban Portuguese adolescents.* Journal of Child Health Care, 2012. **16**(2): p. 166-177.
48. Loucaides, C.A., S.M. Chedzoy, and N. Bennett, *Differences in physical activity levels between urban and rural school children in Cyprus.* Health education research, 2004. **19**(2): p. 138-147.
49. Bucksch, J., et al., *Associations between perceived social and physical environmental variables and physical activity and screen time among adolescents in four European countries.* International journal of public health, 2019. **64**(1): p. 83-94.
50. Sjolie, A.N. and F. Thuen, *School journeys and leisure activities in rural and urban adolescents in Norway.* Health promotion international, 2002. **17**(1): p. 21-30.
51. Dowda, M., et al., *Family support for physical activity in girls from 8th to 12th grade in South Carolina.* Preventive medicine, 2007. **44**(2): p. 153-159.
52. Gustafson, S.L. and R.E. Rhodes, *Parental correlates of physical activity in children and early adolescents.* Sports medicine, 2006. **36**(1): p. 79-97.
53. Beets, M.W., B.J. Cardinal, and B.L. Alderman, *Parental social support and the physical activity-related behaviors of youth: a review.* Health Education & Behavior, 2010. **37**(5): p. 621-644.

54. Brustad, R.J., *Who will go out and play? Parental and psychological influences on children's attraction to physical activity.* Pediatric exercise science, 1993. **5**(3): p. 210-223.
55. Kohl, H.W., 3rd and K.E. Hobbs, *Development of physical activity behaviors among children and adolescents.* Pediatrics, 1998. **101**(3 Pt 2): p. 549-54.
56. Goldscheider, F., A. Thornton, and L. Young-DeMarco, *A portrait of the nest-leaving process in early adulthood.* Demography, 1993. **30**(4): p. 683-99.
57. General, U.S.P.H.S.O.o.t.S., et al., *The Surgeon General's call to action to prevent and decrease overweight and obesity*. 2001: US Government Printing Office.
58. Welk, G.J., K. Wood, and G. Morss, *Parental influences on physical activity in children: An exploration of potential mechanisms.* Pediatric exercise science, 2003. **15**(1): p. 19-33.
59. Hohepa, M., et al., *Social support for youth physical activity: Importance of siblings, parents, friends and school support across a segmented school day.* Int J Behav Nutr Phys Act, 2007. **4**: p. 54.
60. Li, K., et al., *Motivation and planning as mediators of the relation between social support and physical activity among U.S. adolescents: a nationally representative study.* Int J Behav Nutr Phys Act, 2014. **11**(1): p. 42.
61. Verloigne, M., et al., *Exploring associations between parental and peer variables, personal variables and physical activity among adolescents: a mediation analysis.* BMC public health, 2014. **14**(1): p. 966.
62. Heitzler, C.D., et al., *Evaluating a model of youth physical activity.* American journal of health behavior, 2010. **34**(5): p. 593-606.
63. Moore, L.L., et al., *Influence of parents' physical activity levels on activity levels of young children.* The Journal of pediatrics, 1991. **118**(2): p. 215-219.
64. Trost, S.G. and P.D. Loprinzi, *Parental influences on physical activity behavior in children and adolescents: a brief review.* American Journal of Lifestyle Medicine, 2011. **5**(2): p. 171-181.
65. Mellin, A.E., et al., *Unhealthy behaviors and psychosocial difficulties among overweight adolescents: the potential impact of familial factors.* Journal of adolescent health, 2002. **31**(2): p. 145-153.
66. Simonen, R.L., et al., *Familial aggregation of physical activity levels in the Quebec Family Study.* Medicine and science in sports and exercise, 2002. **34**(7): p. 1137-1142.

67. Moral-García, J.E., et al., *Relationship of Parental Support on Healthy Habits, School Motivations and Academic Performance in Adolescents.* International journal of environmental research and public health, 2020. **17**(3): p. 882.
68. Trost, S.G., et al., *Evaluating a model of parental influence on youth physical activity.* Am J Prev Med, 2003. **25**(4): p. 277-82.
69. Jaeschke, L., et al., *Socio-cultural determinants of physical activity across the life course: a 'Determinants of Diet and Physical Activity' (DEDIPAC) umbrella systematic literature review.* Int J Behav Nutr Phys Act, 2017. **14**(1): p. 173.
70. Lau, R.R., M.J. Quadrel, and K.A. Hartman, *Development and change of young adults' preventive health beliefs and behavior: influence from parents and peers.* J Health Soc Behav, 1990. **31**(3): p. 240-59.
71. Sallis, J.F., et al., *Correlates of physical activity in a national sample of girls and boys in grades 4 through 12.* Health Psychol, 1999. **18**(4): p. 410-5.
72. Sadowsky, D.A., A.G. Gilliam, and J. Cornfield, *The statistical association between smoking and carcinoma of the lung.* J Natl Cancer Inst, 1953. **13**(5): p. 1237-58.
73. Doll, R. and A.B. Hill, *Smoking and carcinoma of the lung; preliminary report.* Br Med J, 1950. **2**(4682): p. 739-48.
74. Vink, J.M. and D.I. Boomsma, *Interplay between heritability of smoking and environmental conditions? A comparison of two birth cohorts.* Bmc Public Health, 2011. **11**: p. 316.
75. ESPAD, *ESPAD Group (2020), ESPAD Report 2019: Results from the European School Survey Project on Alcohol and Other Drugs, EMCDDA Joint Publications, Publications Office of the European Union, Luxembourg.*
76. Sekulic, D., et al., *Sport and scholastic factors in relation to smoking and smoking initiation in older adolescents: a prospective cohort study in Bosnia and Herzegovina.* BMJ Open, 2017. **7**(3): p. e014066.
77. Sekulic, D., et al., *Substance abuse prevalence and its relation to scholastic achievement and sport factors: An analysis among adolescents of the Herzegovina-Neretva Canton in Bosnia and Herzegovina.* BMC public health, 2012. **12**(1): p. 274.
78. Idrizovic, K., et al., *Cigarette Smoking among 17-18 Year Old Adolescents - Prevalence and Association with Sociodemographic, Familial, Sport, and Scholastic. Factors.* Med Pr, 2015. **66**(2): p. 153-63.

79. Zenic, N., et al., *Prospective Analysis of the Influence of Sport and Educational Factors on the Prevalence and Initiation of Smoking in Older Adolescents from Croatia.* Int J Environ Res Public Health, 2017. **14**(4).
80. Dunn, M.S., *Association between physical activity and substance use behaviors among high school students participating in the 2009 Youth Risk Behavior Survey.* Psychological reports, 2014. **114**(3): p. 675-685.
81. Blair, S.N., D.R. Jacobs Jr, and K.E. Powell, *Relationships between exercise or physical activity and other health behaviors.* Public health reports, 1985. **100**(2): p. 172.
82. Pate, R.R., et al., *Associations between physical activity and other health behaviors in a representative sample of US adolescents.* American journal of public health, 1996. **86**(11): p. 1577-1581.
83. Peltzer, K., *Leisure Time Physical Activity and Sedentary Behavior and Substance Use Among In-School Adolescents in Eight African Countries.* International Journal of Behavioral Medicine, 2010. **17**(4): p. 271-278.
84. Moore, M.J. and E. Chudley, *Sport and physical activity participation and substance use among adolescents.* Journal of Adolescent Health, 2005. **36**(6): p. 486-493.
85. Tahiraj, E., et al., *Prevalence and Factors Associated with Substance Use and Misuse among Kosovar Adolescents; Cross Sectional Study of Scholastic, Familial-, and Sports-Related Factors of Influence.* Int J Environ Res Public Health, 2016. **13**(5).
86. Holmen, T.L., et al., *Physical exercise, sports, and lung function in smoking versus nonsmoking adolescents.* Eur Respir J, 2002. **19**(1): p. 8-15.
87. Turner, J.C. and P.J. Oakes, *The significance of the social identity concept for social psychology with reference to individualism, interactionism and social influence.* British Journal of Social Psychology, 1986. **25**(3): p. 237-252.
88. Zenic, N., et al., *Does participation in sports influence the prevalence of and initiation into multiple substance misuse in adolescence? A two-year prospective analysis.* Children, 2020. **7**(9): p. 109.
89. Bedford, J., et al., *COVID-19: towards controlling of a pandemic.* Lancet, 2020. **395**(10229): p. 1015-1018.
90. Lai, C.-C., et al., *Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and corona virus disease-2019 (COVID-19): the epidemic and the challenges.* International journal of antimicrobial agents, 2020: p. 105924.
91. WHO, *World Health Organization coronavirus disease 2019 (COVID-19) situation report*. 2020.

92. Rundle, A.G., et al., *COVID-19-Related School Closings and Risk of Weight Gain Among Children.* Obesity (Silver Spring), 2020. **28**(6): p. 1008-1009.
93. Hall, G., et al., *A tale of two pandemics: How will COVID-19 and global trends in physical inactivity and sedentary behavior affect one another?* Prog Cardiovasc Dis, 2020.
94. FITBIT, B., *FITBIT News: The Impact of Coronavirus on Global Activity [Internet]*. 2020.
95. Moore, S.A., et al., *Impact of the COVID-19 virus outbreak on movement and play behaviours of Canadian children and youth: a national survey.* International Journal of Behavioral Nutrition and Physical Activity, 2020. **17**(1): p. 1-11.
96. Bates, L.C., et al., *COVID-19 Impact on behaviors across the 24-hour day in children and adolescents: physical activity, sedentary behavior, and sleep.* Children, 2020. **7**(9): p. 138.
97. López-Bueno, R., et al., *Health-related behaviors among school-aged children and adolescents during the Spanish Covid-19 confinement.* Frontiers in pediatrics, 2020. **8**.
98. Gilic, B., et al., *Contextualizing Parental/Familial Influence on Physical Activity in Adolescents before and during COVID-19 Pandemic: A Prospective Analysis.* Children, 2020. **7**(9): p. 125.
99. Gilic, B., et al., *Evidencing the influence of pre-pandemic sports participation and substance misuse on physical activity during the COVID-19 lockdown: a prospective analysis among older adolescents.* International Journal of Occupational Medicine and Environmental Health, 2021.
100. Sekulic, D., et al., *Prospective analysis of levels and correlates of physical activity during COVID-19 pandemic and imposed rules of social distancing; gender specific study among adolescents from Southern Croatia.* Sustainability, 2020. **12**(10): p. 4072.
101. Howley, E.T., *Type of activity: resistance, aerobic and leisure versus occupational physical activity.* Medicine & Science in Sports & Exercise, 2001. **33**(6): p. S364-S369.
102. Zimmermann-Sloutskis, D., et al., *Physical activity levels and determinants of change in young adults: a longitudinal panel study.* International Journal of Behavioral Nutrition and Physical Activity, 2010. **7**(1): p. 2.
103. Cavill, N., S. Kahlmeier, and F. Racioppi, *Physical activity and health in Europe: evidence for action*. 2006: WHO Regional Office Europe.

104. Micucci, D., M. Mobilio, and P. Napoletano, *Unimib shar: A dataset for human activity recognition using acceleration data from smartphones.* Applied Sciences, 2017. **7**(10): p. 1101.
105. Strong, W.B., et al., *Evidence based physical activity for school-age youth.* The Journal of pediatrics, 2005. **146**(6): p. 732-737.
106. Guthold, R., et al., *Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1.6 million participants.* Lancet Child Adolesc Health, 2020. **4**(1): p. 23-35.
107. WHO, *World Health Organization Global recommendations on physical activity for health.* Geneva, Switzerland: WHO, 2010.
108. Dumith, S.C., et al., *Physical activity change during adolescence: a systematic review and a pooled analysis.* International journal of epidemiology, 2011. **40**(3): p. 685-698.
109. Štefan, L., et al., *Tracking of physical activity, sport participation, and sedentary behaviors over four years of high school.* Sustainability, 2018. **10**(9): p. 3104.
110. Telama, R., et al., *Tracking of physical activity from early childhood through youth into adulthood.* Medicine & Science in Sports & Exercise, 2014. **46**(5): p. 955-962.
111. Van der Horst, K., et al., *A brief review on correlates of physical activity and sedentariness in youth.* Medicine & Science in Sports & Exercise, 2007. **39**(8): p. 1241-1250.
112. Springer, A.E., D.M. Hoelscher, and S.H. Kelder, *Prevalence of physical activity and sedentary behaviors in US high school students by metropolitan status and geographic region.* Journal of physical activity and health, 2006. **3**(4): p. 365-380.
113. Sandercock, G., C. Angus, and J. Barton, *Physical activity levels of children living in different built environments.* Preventive Medicine, 2010. **50**(4): p. 193-198.
114. Yan, Z. and H.R. Spaulding, *Extracellular superoxide dismutase, a molecular transducer of health benefits of exercise.* Redox Biology, 2020: p. 101508.
115. Pojskic, H. and B. Eslami, *Relationship Between Obesity, Physical Activity, and Cardiorespiratory Fitness Levels in Children and Adolescents in Bosnia and Herzegovina: An Analysis of Gender Differences.* Front Physiol, 2018. **9**: p. 1734.
116. Benítez-Porres, J., et al., *Cut-off values for classifying active children and adolescents using the Physical Activity Questionnaire: PAQ-C and PAQ-A.* Nutricion hospitalaria, 2016. **33**(5): p. 1036-1044.

117. Mraković, M., et al., *Developmental characteristics of motor and functional abilities in primary and secondary school pupils.* Kineziologija: međunarodni znanstveni časopis iz područja kineziologije i sporta, 1996. **28**(2): p. 57.
118. Leger, L.A., et al., *The multistage 20 metre shuttle run test for aerobic fitness.* Journal of sports sciences, 1988. **6**(2): p. 93-101.
119. Grgić, I., et al., *Quality of life in rural areas of Croatia: To stay or to leave?* African Journal of Agricultural Research, 2010. **5**(8): p. 653-660.
120. Bergman Markovic, B., et al., *Continental-Mediterranean and rural-urban differences in cardiovascular risk factors in Croatian population.* Croat Med J, 2011. **52**(4): p. 566-75.
121. Ujevic, T., et al., *Differences between health-related physical fitness profiles of Croatian children in urban and rural areas.* Coll Antropol, 2013. **37**(1): p. 75-80.
122. Machado-Rodrigues, A.M., et al., *Urban-rural contrasts in fitness, physical activity, and sedentary behaviour in adolescents.* Health Promot Int, 2014. **29**(1): p. 118-29.
123. Martin, S.L., et al., *Urban, rural, and regional variations in physical activity.* J Rural Health, 2005. **21**(3): p. 239-44.
124. Zubak, Z., et al., *Are Sports-Related Factors Correlated to the Prevalence and Initiation of Illicit Drug Misuse in Adolescence? Prospective Study in Older Adolescents.* Biomed Res Int, 2018. **2018**: p. 1236284.
125. Lago-Peñas, C., et al., *Relationship between performance characteristics and the selection process in youth soccer players.* Journal of Human Kinetics, 2014. **40**(1): p. 189-199.
126. Moss, S.L., et al., *Anthropometric and physical performance characteristics of top-elite, elite and non-elite youth female team handball players.* Journal of sports sciences, 2015. **33**(17): p. 1780-1789.
127. Malina, R.M., C. Bouchard, and O. Bar-Or, *Growth, maturation, and physical activity*. 2004: Human kinetics.
128. Drenowatz, C., et al., *Association between Club Sports Participation and Physical Fitness across 6-to 14-Year-Old Austrian Youth.* International journal of environmental research and public health, 2019. **16**(18): p. 3392.
129. Government, *https://vlada.gov.hr/coronavirus-protection-measures/28950*. 2020.
130. CIPH, *https://www.hzjz.hr/sluzba-promicanje-zdravlja/zivjeti-zdravo-kod-kuce-preporucene-dnevne-razine-tjelesne-aktivnosti-za-sve-dobne-skupine*. 2020.

131. Bartfay, E., et al., *Is There an Association between Physical Activity and Sleep in Community-Dwelling Persons with Dementia: An Exploratory Study Using Self-Reported Measures?* Healthcare (Basel), 2019. **7**(1).
132. Andersen, P., et al., *Physical Activity on Prescription with Counsellor Support: A 4-Year Registry-Based Study in Routine Health Care in Sweden.* Healthcare (Basel), 2018. **6**(2).
133. Boreham, C. and C. Riddoch, *The physical activity, fitness and health of children.* Journal of sports sciences, 2001. **19**(12): p. 915-929.
134. Activity, P., *Health: A Report of the Surgeon General. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention.* National Center for Chronic Disease Prevention and Health Promotion, 1996. **28**.
135. Organization, W.H., *Global strategy on diet, physical activity and health.* 2004.
136. Biddle, S. and N. Cavill, *Physical activity and children. Review 1: Descriptive epidemiology.* National Institute for Health and Clinical Excellence und Public Health Collaborating Centre [CC] for Physical Activity. http://www. children-onthemove. ch/dateien/dokumentation/NICE_PromotingPhysicalActivityChildrenReview1Epidemiology. pdf. Accessed on, 2010. **30**.
137. Sallis, J.F. and N. Owen, *Physical activity and behavioral medicine*. Vol. 3. 1998: SAGE publications.
138. Moral-García, J.E., et al., *The influence of physical activity, diet, weight status and substance abuse on students' self-perceived health.* International Journal of Environmental Research and Public Health, 2020. **17**(4): p. 1387.
139. Arriaza Jones, D., et al., *Moderate leisure-time physical activity: who is meeting the public health recommendations? A national cross-sectional study.* Archives of family medicine, 1998. **7**(3): p. 285.
140. Patrick, K., et al., *Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence.* Archives of pediatrics & adolescent medicine, 2004. **158**(4): p. 385-390.
141. Lubans, D.R., C. Foster, and S.J. Biddle, *A review of mediators of behavior in interventions to promote physical activity among children and adolescents.* Preventive medicine, 2008. **47**(5): p. 463-470.
142. Sallis, J., *Physical activity interventions with individuals.* Physical Activity Behavioral Medicine, 1999: p. 142-144.

143. Biddle, S.J. and N. Mutrie, *Psychology of physical activity: Determinants, well-being and interventions*. 2007: Routledge.
144. Ferreira, I., et al., *Environmental correlates of physical activity in youth–a review and update.* Obesity reviews, 2007. **8**(2): p. 129-154.
145. Sirard, J.R. and R.R. Pate, *Physical activity assessment in children and adolescents.* Sports medicine, 2001. **31**(6): p. 439-454.
146. Kilanowski, C.K., A.R. Consalvi, and L.H. Epstein, *Validation of an electronic pedometer for measurement of physical activity in children.* Pediatric Exercise Science, 1999. **11**(1): p. 63-68.
147. KLESGES, R.C., et al., *A validation of two motion sensors in the prediction of child and adult physical activity levels.* American journal of epidemiology, 1985. **122**(3): p. 400-410.
148. Emons, H., et al., *Comparison of heart rate monitoring combined with indirect calorimetry and the doubly labelled water (2 H 2 18 O) method for the measurement of energy expenditure in children.* European journal of applied physiology and occupational physiology, 1992. **65**(2): p. 99-103.
149. Sallis, J.F., et al., *Validation of interviewer-and self-administered physical activity checklists for fifth grade students.* Medicine and science in sports and exercise, 1996. **28**(7): p. 840-851.
150. Baranowski, T., et al., *Reliability and validity of self report of aerobic activity: Family Health Project.* Research Quarterly for Exercise and Sport, 1984. **55**(4): p. 309-317.
151. Sallis, J.F., et al., *The Caltrac accelerometer as a physical activity monitor for school-age children.* Medicine and Science in Sports and Exercise, 1990. **22**(5): p. 698.
152. Wallace, J.P., T.L. McKenzie, and P.R. Nader, *Observed vs. recalled exercise behavior: a validation of a seven day exercise recall for boys 11 to 13 years old.* Research Quarterly for Exercise and sport, 1985. **56**(2): p. 161-165.
153. Halverson Jr, C.F. and M.F. Waldrop, *The relations of mechanically recorded activity level to varieties of preschool play behavior.* Child Development, 1973: p. 678-681.
154. Manios, Y., A. Kafatos, and G. Markakis, *Physical activity of 6-year-old children: Validation of two proxy reports.* Pediatric Exercise Science, 1998. **10**(2): p. 176-188.
155. Bouchard, C., et al., *A method to assess energy expenditure in children and adults.* The American journal of clinical nutrition, 1983. **37**(3): p. 461-467.

156. Zenic, N., et al., *Examination of the community-specific prevalence of and factors associated with substance use and misuse among Rural and Urban adolescents: a cross-sectional analysis in Bosnia and Herzegovina.* BMJ Open, 2015. **5**(11): p. e009446.
157. Zenic, N., et al., *Gender-Specific Analyses of the Prevalence and Factors Associated with Substance Use and Misuse among Bosniak Adolescents.* Int J Environ Res Public Health, 2015. **12**(6): p. 6626-40.
158. Killip, S., Z. Mahfoud, and K. Pearce, *What is an intracluster correlation coefficient? Crucial concepts for primary care researchers.* Ann Fam Med, 2004. **2**(3): p. 204-8.
159. Sallis, J.F., *Epidemiology of physical activity and fitness in children and adolescents.* Critical reviews in food science and nutrition, 1993. **33**(4-5): p. 403-408.
160. Vilhjalmsson, R. and G. Kristjansdottir, *Gender differences in physical activity in older children and adolescents: the central role of organized sport.* Social science & medicine, 2003. **56**(2): p. 363-374.
161. Sallis, J.F., et al., *Aggregation of physical activity habits in Mexican-American and Anglo families.* Journal of behavioral medicine, 1988. **11**(1): p. 31-41.
162. Vilhjalmsson, R. and T. Thorlindsson, *The integrative and physiological effects of sport participation: A study of adolescents.* Sociological Quarterly, 1992. **33**(4): p. 637-647.
163. Ennis, C.D., *Students' Experiences in Sport-Based Physical Education: More Than] Apologies are Necessary.* Quest, 1996. **48**(4): p. 453-456.
164. Finkenberg, M., *Sex and ethnicity as factors for participation in physical activity.* International Journal of Physical Education, 1991. **28**(2): p. 23-26.
165. Lantz, C.D. and P.J. Schroeder, *Endorsement of Masculine and Feminine Gender Roles: Differences Between Participation In and.* Journal of sport behavior, 1999. **22**(4).
166. Lenskyj, H., *Power and play: Gender and sexuality issues in sport and physical activity.* International Review for the Sociology of Sport, 1990. **25**(3): p. 235-245.
167. Stewart, C. and J. Taylor, *Why female athletes quit: Implications for coach education.* The Physical Educator, 2000. **57**(4).
168. Harding, S.K., et al., *Longitudinal changes in sedentary time and physical activity during adolescence.* International Journal of Behavioral Nutrition and Physical Activity, 2015. **12**(1): p. 44.
169. Farooq, M.A., et al., *Timing of the decline in physical activity in childhood and adolescence: Gateshead Millennium Cohort Study.* British journal of sports medicine, 2018. **52**(15): p. 1002-1006.

170. Corder, K., et al., *Change in objectively measured physical activity during the transition to adolescence.* British journal of sports medicine, 2015. **49**(11): p. 730-736.
171. Telford, R.M., et al., *Why are girls less physically active than boys? Findings from the LOOK longitudinal study.* PloS one, 2016. **11**(3): p. e0150041.
172. Sallis, J.F., et al., *Correlates of vigorous physical activity for children in grades 1 through 12: comparing parent-reported and objectively measured physical activity.* Pediatric Exercise Science, 2002. **14**(1): p. 30-44.
173. Madsen, K.A., C.E. McCulloch, and P.B. Crawford, *Parent modeling: perceptions of parents' physical activity predict girls' activity throughout adolescence.* The Journal of pediatrics, 2009. **154**(2): p. 278-283. e2.
174. Hanson, M.D. and E. Chen, *Socioeconomic status and health behaviors in adolescence: a review of the literature.* Journal of behavioral medicine, 2007. **30**(3): p. 263.
175. Bjelica, D., et al., *An Examination of the Ethnicity-Specific Prevalence of and Factors Associated with Substance Use and Misuse: Cross-Sectional Analysis of Croatian and Bosniak Adolescents in Bosnia and Herzegovina.* Int J Environ Res Public Health, 2016. **13**(10).
176. Cross, C.J., R.J. Taylor, and L.M. Chatters, *Ethnic and Gender Differences in Family Social Support among Black Adolescents.* Healthcare (Basel), 2018. **6**(1).
177. Ornelas, I.J., K.M. Perreira, and G.X. Ayala, *Parental influences on adolescent physical activity: a longitudinal study.* International journal of behavioral nutrition and physical activity, 2007. **4**(1): p. 3.
178. Spera, C., *A review of the relationship among parenting practices, parenting styles, and adolescent school achievement.* Educational psychology review, 2005. **17**(2): p. 125-146.
179. Schmitz, K.H., et al., *Psychosocial correlates of physical activity and sedentary leisure habits in young adolescents: the Teens Eating for Energy and Nutrition at School study.* Preventive medicine, 2002. **34**(2): p. 266-278.
180. Andersen, M.R., et al., *Antismoking parenting practices are associated with reduced rates of adolescent smoking.* Archives of Pediatrics & Adolescent Medicine, 2004. **158**(4): p. 348-352.
181. Garcia, F., et al., *A third emerging stage for the current digital society? Optimal parenting styles in Spain, the United States, Germany, and Brazil.* International Journal of Environmental Research and Public Health, 2019. **16**(13): p. 2333.
182. Huck, S.W., *Reading Statistics and Research*. 2000: Longman.

183. Maric, D., et al., *Parental and Familial Factors Influencing Physical Activity Levels in Early Adolescence: A Prospective Study.* Healthcare (Basel), 2020. **8**(4).
184. Štefan, L., et al., *One-year changes in physical activity and sedentary behavior among adolescents: The Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS).* International Journal of Adolescent Medicine and Health, 2018. **1**(ahead-of-print).
185. Alotaibi, T., et al., *The Relationship between Technology Use and Physical Activity among Typically-Developing Children.* Healthcare (Basel), 2020. **8**(4).
186. Faigenbaum, A.D., T.R. Rebullido, and I. Chulvi-Medrano, *Youth Physical Activity Is All About the "F-Words".* Strength & Conditioning Journal, 2020. **42**(6): p. 2-6.
187. Patnode, C.D., et al., *The relative influence of demographic, individual, social, and environmental factors on physical activity among boys and girls.* Int J Behav Nutr Phys Act, 2010. **7**: p. 79.
188. Mattoo, K., et al., *Influence of Parental Physical Activity and Screen Time on the BMI of Adult Offspring in a Saudi Population.* Healthcare (Basel), 2020. **8**(2).
189. Sasayama, K. and M. Adachi, *Tracking of objective physical activity and physical fitness in Japanese children.* BMC Res Notes, 2019. **12**(1): p. 252.
190. Wyszyńska, J., et al., *Adaptation and validation of the Physical Activity Questionnaire for Adolescents (PAQ-A) among Polish adolescents: cross-sectional study.* BMJ Open, 2019. **9**(11): p. e030567.
191. Zubak, Z., et al., *A Prospective Study on the Influence of Scholastic Factors on the Prevalence and Initiation of Illicit Drug Misuse in Adolescence.* Int J Environ Res Public Health, 2018. **15**(5).
192. Eime, R.M., et al., *Socioecological factors potentially associated with participation in physical activity and sport: A longitudinal study of adolescent girls.* Journal of science and medicine in sport, 2015. **18**(6): p. 684-690.
193. Wheeler, S., *The significance of family culture for sports participation.* International review for the sociology of sport, 2012. **47**(2): p. 235-252.
194. Sajber, D., et al., *Alcohol Drinking Among Kosovar Adolescents: An Examination of Gender-Specific Sociodemographic, Sport, and Familial Factors Associated With Harmful Drinking.* Subst Use Misuse, 2016. **51**(4): p. 533-9.
195. Eime, R.M., et al., *Changes in sport and physical activity participation for adolescent females: a longitudinal study.* BMC Public Health, 2016. **16**(1): p. 533.

196. Raudsepp, L., *The relationship between socio-economic status, parental support and adolescent physical activity.* Acta Paediatr, 2006. **95**(1): p. 93-8.
197. Casey, M.M., et al., *Using a socioecological approach to examine participation in sport and physical activity among rural adolescent girls.* Qualitative health research, 2009. **19**(7): p. 881-893.
198. Park, E., H.R. Park, and E.S. Choi, *Barriers to and Facilitators of Physical Activity among Korean Female Adults with Knee Osteoarthritis and Comorbidity: A Qualitative Study.* Healthcare (Basel), 2020. **8**(3).
199. Greendorfer, S.L. and J.H. Lewko, *Role of family members in sport socialization of children.* Res Q, 1978. **49**(2): p. 146-52.
200. Rossow, I. and J. Rise, *Concordance of parental and adolescent health behaviors.* Soc Sci Med, 1994. **38**(9): p. 1299-305.
201. Martin, L., et al., *The social environment in sport: selected topics.* International Review of Sport and Exercise Psychology, 2014. **7**(1): p. 87-105.
202. Larson, R. and M.H. Richards, *Daily companionship in late childhood and early adolescence: changing developmental contexts.* Child Dev, 1991. **62**(2): p. 284-300.
203. Larson, R.W., et al., *Changes in adolescents' daily interactions with their families from ages 10 to 18: Disengagement and transformation.* Developmental psychology, 1996. **32**(4): p. 744.
204. Blakemore, S.-J. and K.L. Mills, *Is adolescence a sensitive period for sociocultural processing?* Annual review of psychology, 2014. **65**: p. 187-207.
205. Bauman, A. and P. Phongsavan, *Epidemiology of substance use in adolescence: prevalence, trends and policy implications.* Drug and alcohol dependence, 1999. **55**(3): p. 187-207.
206. Wing, E.K., M. Belanger, and J. Brunet, *Linking Parental Influences and Youth Participation in Physical Activity In- and Out-of-school: The Mediating Role of Self-efficacy and Enjoyment.* Am J Health Behav, 2016. **40**(1): p. 31-7.
207. Sanchez Castillo, S., et al., *Levels of Physical Activity in Spanish Asthmatics: A Cross-Sectional Study.* Medicina (Kaunas), 2020. **56**(12).
208. Tamme, R., et al., *Physical Activity in Puberty is Associated with Total Body and Femoral Neck Bone Mineral Characteristics in Males at 18 Years of Age.* Medicina (Kaunas), 2019. **55**(5).

209. Barranco-Ruiz, Y., et al., *Active Commuting to University and its Association with Sociodemographic Factors and Physical Activity Levels in Chilean Students.* Medicina (Kaunas), 2019. **55**(5).
210. Trang, N.H.H.D., et al., *Longitudinal physical activity changes in adolescents: HO Chi Minh City youth cohort.* Medicine & Science in Sports & Exercise, 2012. **44**(8): p. 1481-1489.
211. Lopez-Sanchez, G.F., et al., *Levels of Physical Activity in Lithuanian Adolescents.* Medicina (Kaunas), 2018. **54**(5).
212. Corder, K., et al., *Change in physical activity from adolescence to early adulthood: a systematic review and meta-analysis of longitudinal cohort studies.* British journal of sports medicine, 2019. **53**(8): p. 496-503.
213. Wickel, E.E., J.C. Eisenmann, and G.J. Welk, *Maturity-related variation in moderate-to-vigorous physical activity among 9–14 year olds.* Journal of Physical Activity and Health, 2009. **6**(5): p. 597-605.
214. Boyes, R., et al., *Gender-specific associations between involvement in team sport culture and canadian adolescents' substance-use behavior.* SSM-population health, 2017. **3**: p. 663-673.
215. Holmen, T.L., et al., *Gender differences in the impact of adolescent smoking on lung function and respiratory symptoms. the Nord-Trondelag Health Study, Norway, 1995-1997.* Respir Med, 2002. **96**(10): p. 796-804.
216. Dixon, M.A., S.M. Warner, and J.E. Bruening, *More than just letting them play: Parental influence on women's lifetime sport involvement.* Sociology of Sport Journal, 2008. **25**(4): p. 538-559.
217. Hardin, M. and J.D. Greer, *The influence of gender-role socialization, media use and sports participation on perceptions of gender-appropriate sports.* Journal of Sport Behavior, 2009. **32**(2): p. 207.
218. Zenic, N., et al., *Levels and changes of physical activity in adolescents during the COVID-19 pandemic: contextualizing urban vs. rural living environment.* Applied Sciences, 2020. **10**(11): p. 3997.
219. Maric, D., et al., *Analysis of the Relationship between Tobacco Smoking and Physical Activity in Adolescence: A Gender Specific Study.* Medicina, 2021. **57**(3): p. 214.
220. Sekulic, D., et al. *Familial and Parental Predictors of Physical Activity in Late Adolescence: Prospective Analysis over a Two-Year Period*. in *Healthcare*. 2021. Multidisciplinary Digital Publishing Institute.

Overview of the PhD period of Miss Dora Marić

In the following text, Miss Marić work during three years of the joint international program in "Health Promotion and Cognitive Sciences" will be briefly presented. Through this period, Miss Marić had the privilege to participate in conferences, seminars, webinars, attend lectures from national and international professors, attend Ph.D./summer schools, and collaborate on different research projects. All of which led to significant improvement of her skill set and knowledge and an even bigger strive for personal growth in the sense of education and scientific exploration.

During her Ph.D. experience Miss Marić published 17 papers, and explored different research areas, with a main focus on two research fields:

(i) Physical activity - Factors Influencing Physical Activity Levels in Adolescence

(ii) Doping - Doping behavior in various sports; analysis of sport, sociodemographic and social-cognitive factors of influence on doping susceptibility in high-level athletes.

Publications and conference proceedings are presented in the Appendix section.

International mobility:

1. Six months - University of Split, Croatia, Faculty of Kinesiology– 1.4. 2018 - 30.9. 2018

Throughout this period, Miss Marić was guided by her mentor Prof. Damir Sekulić. Her work was mostly oriented towards doping research. She adopted the methodology for questionnaires validation and learned how to apply the backtranslation method. Moreover, she learned how to use a new statistical software - SPSS, and she adopted new statistical methods - logistical regression and multinomial logistical regression.

2. Six months - University of Ljubljana, Slovenia, Faculty of Sport – 1.10. 2019 – 1.4. 2020

During this period, Miss Marić was led by prof. Dorica Šajber, with whom she collaborated on two doping-related research, one entitled: "Toward prevention of doping in youth sport: cross-sectional analysis of correlates of doping tendency in swimming" and second entitled: "Factors associated with potential doping behavior in Olympic-sailing: a gender-specific analysis".

Conferences

1. *X Congresso Nazionale SISMES Messina, October 5. – 7. 2018*
   Poster presentation entitled: "Analysis of sociodemographic and sports-related factors as correlates of potential doping behavior in high-level junior swimmers"
2. *11th International Symposium University of Tuzla Faculty of Physical Education and Sport, November 30. 2018*
   Full paper published in Croatian/Bosnian language, entitled: "Dietary supplementation use among Olympic team-sport athletes"
3. *9 th International Conference on "Sports Science and Health" Banja Luka, March 15. 2019*
   Oral presentation of full paper published in Croatian/Bosnian language, entitled: "Factors associated with potential doping behavior in basketball; differential analysis between juniors and seniors"
4. *XI Congresso Nazionale SISMES Bologna, September 27. – 29. 2019*
   Abstract submitted, entitled: "Doping factors in team sports; parallel analysis among athletes and coaches"
5. *From Active Childhood to Healthy Aging 5th International Scientific Conference Novi Sad, April 11. -13. 2019*
   Poster presentation, entitled: "Doping factors and correlates of potential doping behavior in team sport coaches; gender-specific analysis"
6. *12 th INTERNATIONAL CONFERENCE ON KINANTHROPOLOGY „Sport and Quality of Life "Brno, November 7. – 9. 2019*
   Full paper published, entitled: "Doping knowledge and doping attitudes in competitive bodybuilding"
7. *17th Annual Scientific Conference of Montenegrin Sports Academy "Sport, Physical Activity and Health: Contemporary Perspectives", April 2. – 5. 2020*
   Abstract submitted, entitled: "Internal and external training load of young team handball player's during the competition"

8. *10th International e-Conference on "Sports Science and Health" Banja Luka, June 24.-26. 2020*

   Two full papers published in Croatian/Bosnian language, entitled: (i) "Construction and preliminary validation of reactive and non-reactive agility tests for primary school children", (ii) "Factors related to participation in fitness programs among students of the University of Split"
9. *4th International Conference of Sport Science – AESA, February, 4. 2021*

   Two abstract submitted, entitled: (i) "Reliability of the newly developed tests of handball specific change of direction speed and reactive agility", (ii) "Doping Knowledge and correlates of potential doping behavior in kinesiology students"

Other activities

1. *Collaboration - Multicentric study between the University of Palermo and the University of Split*

   Research subject was influence of mouth guard on body stability and masseter and temporal muscles activity in elite taekwondo athletes.

   While testing athletes, Miss Marić learned how to use, Moover® sensor to evaluate of articular and cervical range of motions (ROMs), and Teethan® non-invasive Bluetooth electromyography.
2. *EMUNI Summer school 2018 HALS – "Healthy and Active Lifestyle" -7 days (15th – 21st July 2019), Piran, Slovenia*

   In seven days, Miss Marić attended 25 hours of lectures and 50 hours of lab and field work (workshops). During that time, she learned how to assess physical activity using accelerometer sensor, how to process the obtained data and how to use tensiomyograph. Additionally, Miss Marić learned about bed rest study, muscle adaptation in everyday activities and mechanisms of cardiovascular decline in aging, benefits of physical activity and exercise in elderly and children, and development of sports injury model for effective prevention, diagnostic, and rehabilitation.
3. *PhD school within the conference - From Active Childhood to Healthy Aging 5th International Scientific Conference Novi Sad, April 11 -13 2019*

   Miss Maric learned more about European projects and partnerships between European Universities.

4. *Field and Lab testing of football and handball players'*

   Testing took place as part of the project funded by the Croatian Science Foundation (IP-2018-01-8330), during which preplanned and nonplaned agility, sprint speed, reactive strength index, and static and dynamic balance were assessed and tested. As a result, Miss Maric learned how to handle and use Optojump system, Powertimer 300, Biodex balance system, and a new measuring instrument for preplanned and nonplaned agility testing constructed on the Faculty of Kinesiology in Split.

5. *The construction of a test intended for middle school children reactive agility testing*

   Together with colleagues from the Faculty of Kinesiology in Split, Miss Marić constructed the test designed for middle school children reactive agility testing. Afterward the data was collected on the sample of middle school kids with the purpose of validation of a new reactive agility test, and one paper was published in Croatian language, entitled: "Construction and preliminary validation of reactive and non-reactive agility tests for primary school children"

6. *The construction of sport-specific taekwondo tests for reaction time and agility testing*

   Together with colleagues from the Faculty of Kinesiology in Split, Miss Marić constructed three sport-specific taekwondo tests. However, due to technical difficulties, data have not yet been collected, but testing is planned in the near future.

7. *Sport, science & practice project*

   In collaboration with one of her colleagues Miss Marić designed, wrote, and submitted a project. After the finances got approved, Miss Marić dealt with the organization and management of the project, which included organizing free lectures and seminars for additional education of Kinesiology, Physiotherapy and Nutrition students and other students interested in presented topics.

Appendix - Abstracts of accepted and published papers

1. Sekulic, D., Zenic, N., Versic, S., Maric, D., Gabrilo, G., & Jelicic, M. (2017). The prevalence and covariates of potential doping behavior in kickboxing; analysis among high-level athletes. *Journal of human kinetics*, *59*(1), 67-77. doi: 10.1515/hukin-2017-0148

The official reports on doping behavior in kickboxing are alarming, but there have been no empirical studies that examined this problem directly. The aim of this study was to investigate the prevalence, gender differences and covariates of potential-doping-behavior, in kickboxing athletes. A total of 130 high-level kickboxing athletes (92 males, 21.37 ± 4.83 years of age, 8.39 ± 5.73 years of training experience; 38 women, 20.31 ± 2.94 years of age; 9.84 ± 4.74 years of training experience) completed questionnaires to study covariates and potential-doping behavior. The covariates were: sport factors (i.e. experience, success), doping-related factors (i.e. opinion about penalties for doping users, number of doping testing, potential-doping-behavior, etc.), sociodemographic variables, task- and ego-motivation, knowledge on sports nutrition, and knowledge on doping. Gender-based differences were established by independent t-tests, and the Mann-Whitney test. Multinomial logistic regression analyses were performed to define the relationships between covariates and a tendency toward potential-doping behavior (positive tendency – neutral – negative tendency). The potential-doping behavior was higher in those athletes who perceived kickboxing as doping contaminated sport. The more experienced kickboxers were associated with positive intention toward potential-doping behavior. Positive intention toward potential-doping behavior was lower in those who had better knowledge on sports nutrition. The task- and ego- motivation were not associated to potential-doping behavior. Because of the high potential-doping-behavior (less than 50% of athletes showed a negative tendency toward doping), and similar prevalence of potential-doping behavior between genders, this study highlights the necessity of a systematic anti-doping campaign in kickboxing. Future studies should investigate motivational variables as being potentially related to doping behavior in younger kickboxers.

2. Devcic, S., Bednarik, J., Maric, D., Versic, S., Sekulic, D., Kutlesa, Z., & Liposek, S. (2018). Identification of factors associated with potential doping behavior in sports: a cross-sectional analysis in high-level competitive swimmers. *International journal of environmental research and public health*, *15*(8), 1720. doi:10.3390/ijerph15081720

Background: Doping behavior, including the misuse of performance-enhancing drugs, is currently a serious problem in sports, and the efficacy of preventive efforts directly depends on information regarding the associations among different precipitating factors (PF) and doping behavior. This study aimed to establish the PF of potential doping behavior (PDB) in competitive swimmers. Methods: The study included 301 swimmers from Slovenia (153 females, 16.4 ± 2.4 years), tested during the 2017 National Championship. Variables were collected by previously validated questionnaires, which included questions on sociodemographics, sports-related factors, consumption of dietary supplements, knowledge of doping, factors of hesitation, and doping-related factors (i.e., number of doping tests, opinion about the presence of doping in sport). The PDB (positive, neutral, or negative intention toward doping) was observed as a criterion, while other variables were included as predictors in multinomial regression analyses (with "negative" as reference value), which additionally controlled for gender and age category (cadet-, junior-, and senior-level) as confounders. Results: The results confirmed higher susceptibility to doping in males (positive: odds ratio (OR): 2.77, 95% confidence interval (CI): 1.27–6.04), those swimmers who reported higher alcohol consumption (neutral: OR: 2.18, 95%CI: 1.06–4.16, positive: OR: 2.14, 95%CI: 1.05–4.37), and those regularly used dietary supplements (positive: OR: 3.62, 95%CI: 1.25–10.52). Competitive achievement in Olympic- (neutral: OR: 0.57, 95%CI: 0.41–0.81, positive: OR: 0.59, 95%CI: 0.39–0.88), and non-Olympic disciplines (positive: OR: 0.54, 95%CI: 0.35–0.83) was protective against PDB. Swimmers who were more concerned about the negative social consequences of doping behavior (i.e., condemnation by family and friends) were less likely to declare a positive intention toward the PDB (family condemnation: OR: 0.69, 95%CI: 0.56–0.86, friends' condemnation: OR: 0.65, 95%CI: 0.52–0.80). Conclusions: The results of the study provide more precise insight into the specific factors associated with PDB in swimming. The established precipitating factors should be incorporated into targeted anti-doping campaigns in this sport.

3. Sekulic, D., Tahiraj, E., Maric, D., Olujic, D., Bianco, A., & Zaletel, P. (2019). What drives athletes toward dietary supplement use: objective knowledge or self-perceived competence? Cross-sectional analysis of professional team-sport players from Southeastern Europe during the competitive season. *Journal of the International Society of Sports Nutrition, 16*(1), 25. doi:10.1186/s12970-019-0292-9

Background: Issues related to knowledge of nutrition and dietary supplementation (DS) are understudied in professional athletes. This study aimed to examine the possible association between knowledge of nutrition and DS (KN&DS) and dietary supplement use (DSU) among professional athletes involved in team sports. Methods: The sample comprised professional team-sport athletes (N = 912, age: 22.11 ± 3.37 years, 356 females) involved in four Olympic sports: basketball (N = 228), soccer (N = 324), volleyball (N = 154), and handball (N = 206). The participants were tested by previously validated questionnaires to examine their self-perceived competence on nutrition and DS (S/KN&DS), their objectively evaluated (tested) KN&DS (O/KN&DS), sociodemographic and sport-specific variables (predictors), and DSU (criterion). Associations between the predictors and the criterion (No-DSU - Irregular-DSU - Regular-DSU) were determined by multinomial regression analysis for the total sample and separately for the studied sports. Results: DSU was found to be less prevalent in older and more successful players. The O/KN&DS and S/KN&DS were positively correlated with DSU, but S/KN&DS was a stronger predictor of DSU than O/KN&DS. Sport-specific associations between predictors and criterion were identified, with stronger correlations in sports with a higher prevalence of DSU. Conclusions: Due to the low correlations between O/KN&DS and S/KN&DS in the studied players, this study highlights the necessity for more frequent monitoring of biomarkers of nutritional status and its usage by coaches and practitioners to provide quantitative instruction.

4. Maric, D., Versic, S., & Va silj, S. (2019). Doping knowledge and doping attitudes in competitive bodybuilding, *12 th International Conference on Kinanthropology „Sport and Quality of Life "Brno*

Purpose: Bodybuilding becomes more visible and acceptable within mainstream society thanks to social media, which is promoting, and developing grooving interest in bodies, fitness and active lifestyle. However, this is concerning knowing that according to the latest world anti-

doping agency report bodybuilding is one of two sports with the highest number of Anti-Doping Rule Violations (ADRVs) committed by athletes. This study aimed to evaluate doping attitudes and correlates of doping attitudes in top level body builders. Methods: Study included 26 competitive bodybuilders form Croatia. Variables were collected by a previously validated Questionnaire of Substance Use (QSU). Statistical procedures included means and standard deviations (for parametric variables), frequencies and percentages (for ordinal and nominal variables). Spearman's correlations were calculated to determine associations between studied variables. Results: The most positive attitudes are found towards injectable anabolic steroids (mean ± standard deviation; 4.00 ± 1.52), followed by fat burners (3.73 ± 1.46), growth hormone (3.69 ± 1.64), and estrogen blockers (3.60 ± 1.22), oral anabolic steroids (3.58 ± 1.27). Significant correlation was identified between: (i) result achieved in bodybuilding (RBB) and alcohol consumption, ($R= -0.57$ $p < 0.05$) (ii) RBB and subjective knowledge on nutrition ($R=0.66$, $p < 0.05$), (iii) RBB and subjective knowledge on doping ($R=0.72$, $p < 0.05$). Conclusion: The lack of correlation between self-perceived competence and objectively evaluated knowledge on nutrition is alarming due to the possible "anchoring effect", accordingly even though objective knowledge is not correlated with attitudes towards doping substances, it is important to properly educate athletes who are in the misconception of their true knowledge.

5. Sajber, D., Maric, D., Rodek, J., Sekulic, D., & Liposek, S. (2019). Toward prevention of doping in youth sport: cross-sectional analysis of correlates of doping tendency in swimming. *International journal of environmental research and public health*, *16*(23), 4851. doi:10.3390/ijerph16234851

Doping is recognized as one of the most important problems in sports, but a limited number of studies have investigated doping problems in youth athletes. This study aimed to evaluate doping tendency (potential doping behavior (PDB)) and correlates of PDB in youth age swimmers. The participants were 241 competitive swimmers (131 females; 15.3 ± 1.1 years of age, all under 18 years old). Variables included predictors and PDB (criterion). Predictors consisted of sociodemographic factors (gender and age), sport-related variables (i.e., experience in swimming and sport achievement), variables explaining coaching strategy and training methodology, consumption of dietary supplements (DS), knowledge about doping, and knowledge about sports nutrition and DS (KSN). In addition to the descriptive statistics and

differences between genders, a multinomial regression using PDB as the criterion (negative-, neutral-, or positive-PDB, with a negative-PDB as the reference value) was calculated to define associations between predictors and criterion. With only 71% of swimmers who declared negative-PDB results indicated an alarming figure. Boys with better KSN were more negatively oriented toward positive-PDB (OR: 0.77, 95%CI: 0.60–0.95). In girls, lower competitive achievement was evidenced as a risk factor for neutral-PDB (OR: 0.39, 95%CI: 0.24–0.63). Also, higher neutral-PDB (OR: 0.88, 95%CI: 0.81–0.96) and positive-PDB (OR: 0.90, 95%CI: 0.83–0.99) were identified in girls who began with intensive training in younger age. Because of the alarming figures of PDB, there is an evident need for the development of systematic antidoping educational programs in youth swimming. In doing so, focus should be placed on girls who began intensive training at an earlier age and those who did not achieve high competitive results.

6. Versic, S., Uljevic, O., Maric, D., Sekulic, D., & Sajber, D. (2019). Factors associated with potential doping behavior in Olympic-sailing: a gender-specific analysis. *Medicina dello Sport*, *72*(4), 513-523. doi:10.23736/S0025-7826.19.03511-7

BACKGROUND: Olympic-sailing is not contaminated with doping, and special efforts are needed to keep this sport free of doping. The aim of this study was to evaluate factors associated with potential doping behavior (PDB) in professional Olympic sailors. METHODS: The sample of participants were professional Olympic Laser class athletes (N.=80, 39 females; all >18 years). Data were collected through previously validated questionnaires, utilizing sociodemographic-variables, sport-related-factors, and various factors of hesitation against doping (predictors), and PDB (criterion). To calculate the associations between predictors and the criterion, gender-stratified logistic regression models were calculated. RESULTS: Negative social consequences of doping were identified as the important factors of hesitation against PDB in men, while health-related problems were identified as being highly important factors of hesitation in women. Sailing conditions present particular health challenges specific to women; therefore, women tend to be much more responsive to health concerns in general. CONCLUSIONS: The results of this study provided evidence about necessity of gender-specific approach in antidoping preventive campaigns. Further studies in other sports and with younger athletes are warranted.

7. Maric, D., Gilic, B., & Foretic, N. Monitoring the Internal and External Loads of Young Team Handball Players during Competition. *Sport Mont*, *19*(1), Ahead-Of. DOI: 10.26773/smj.210204

The aim of study was to examine the internal- and external-training-load (ETL and ITL, respectively) during the match of young handball players. Field testing included heart-rate-monitoring (Memory belt, Suunto) as a marker of ITL and accelerometry (motion-biosensor, Actical Respironcis, Philips) as a marker of ETL. Time motion analysis data was obtained through recording player's game activities and later analysed with a software package (Matlab). T-test and Pearson-product-moment correlation coefficient was used to examine the differences and the relationship between variables collected in the study. T-test analysis did not show significant differences between the total distance covered (2216.42-2135.42 meters), steps conducted (1829.25-1829.83 steps), steps per minute (91.46-91.49 steps/min), energy expenditure (92.24-90.87 METS), time spent in higher intensity zones calculated by motion biosensor (13.08-12.75 minutes), training-load calculated by Edwards TRIMP method (91.54-88.56 scores) in the first- and in the second-half of the match. Physical activity variables show no significant correlations with the data assessed by heart rate monitors. Similar results in monitored training-load variables in first and second half is connected with game intensity that was consistent during whole match. Lack of correlations between ITL and ETL variables points that accelerometry is not suitable for assessment of metabolic training-load in intermittent activities such as handball. ITL measures used in this study are more suitable for controlling load during training and competition while used ETL parameters are more appropriate for better understanding players activity in period when players don't train - other activities that can influence players fatigue and training and competition performance.

8. Šime V., Marić D., & Sekulić D. (2021). Doping Knowledge and correlates of potential doping behavior in kinesiology students, Asian Exercise and Sport Science Journal, Accepted

Introduction: Consumption of banned performance-enhancing substances and prohibited techniques, presents one of the most essential problems in modern sport. Previous researches indicated alarmingly poor knowledge on doping issues in athletes. The aim of this study was to

evaluate the level of knowledge on this topic on students of Kinesiology, future coaches, and sport practitioners. Methods: Study included 130 kinesiology students (19.45±1.31 years) from the University in Split both female and male (53 female). Students were tested during the second semester of 2019/2020 academic year. Variables were collected through questions about socio-demographics, and doping-related factors. Descriptive statistics were calculated for age, sports experience, knowledge of doping, and subjective knowledge of doping. The Pearson correlation was used to assess the relationship between variables collected in the study. Results: Descriptive statistics is indicating low doping knowledge with an average score of 1.98±1.79: while 63% of students declared negative doping attitudes. Correlation analysis identified a statistically significant correlation between KD and potential doping behavior (PDB) (-0.32). Conclusion: Considering the fact that students of Kinesiology are future sports coaches, very low level of their doping knowledge and negative associations between KD and PDB, indicate a clear need for systematic education on doping among them.

9. Pokrajčić V., Maric, D., Foretic, N, & Uljevic O. (2021). Reliability of the newly developed tests of handball specific change of direction speed and reactive agility, Asian Exercise and Sport Science Journal, Accepted

Agility is an important factor of success in handball. There is a lack of reliable specific tests for the evaluation of different agility components in handball. In this study, we evaluated the reliability of the two newly developed tests of agility for handball. The sample consisted of 6 senior male amateur handball players (age: 19,83 years) who were tested on anthropometrics (body height: 185,5 cm, body mass: 84 kg), newly developed tests of handball specific reactive agility (HS-RAGL), and change of direction speed (HS-CODSL). The relative reliability is evaluated by calculation of Intra-Class-Correlation coefficients (ICC), while the absolute reliability was evaluated by calculation of the coefficient of variation (CV). Further, systematic bias was checked by analysis of variance for repeated measurements (ANOVA). The associations between studied variables were evidenced by Pearson's correlation. The reliability statistic for HS-CODSL L and HS-RAGL L are shown in table 1. CA ranges from 0.92 to 0.95, IIR is 0.88, and CV ranges from 7.27% to 8.24%, while in HS-CODSL and HS-RAGL CA ranges from 0.91 to 0.93, IIR ranges from 0.78 to 0.80, and CV ranges from 7.98% to 8.75%. Correlation analysis of the HS-CODSL test performance on the left and right side (three trials), identified a statistically significant correlation between; (i) HS-CODSL D1 and HS-CODSL L2

(R=0.97, p<0.05) (ii) HS-CODSL D1 and HS-CODSL D2 (R=0.84, p<0.05), (iii) HS-CODSL D1 and HS-CODSL L3 (R= 0.94, p<0.05), (iv) HS-CODSL D1 and HS-CODSL D3 (R=0.85, p<0.05), (v) HS-CODSL L2 and HS-CODSL L3 (R= 0.98, p<0.05), (vi) HS-CODSL L2 and HS-CODSL D3 (R=0.83, p<0.05). While the correlation analysis of the HS-RAGL test performance on the left and right side (three trials), identified a statistically significant correlation between almost all test performances, and the most significant correlation coefficient was found between; (i) HS-RAGL L1 and HS-RAGL D1 (R=0.97, p<0.05) (ii) HS-RAGL L1 and HS-RAGL D2 (R=0.96, p<0.05), (iii) HS-RAGL D1 and HS-RAGL L2 (R= 0.95, p<0.05). Results showed appropriate reliability of the newly developed tests of handball specific change of direction speed and reactive agility. Therefore, here proposed H-CODS and H-RAG can be used as reliable measures of agility components in handball. Further studies should evaluate the discriminative validity of the here proposed tests (i.e. identification of position-specific or performance-related differences), as well as reliability in different handball categories than those studied herein.

Papers published in Croatian/Bosnian language

1. Tahiraj, E., Maric, D., & Sekulic, D. (2018). Dietary supplementation uses among Olympic team-sport athletes. *11th International Symposium University of Tuzla Faculty of Physical Education and Sport*

2. Maric, D., Versic, S., & Rodek, J. (2019). Factors associated with potential doping behavior in basketball; differential analysis between juniors and seniors. *9th International Conference on "Sports Science and Health" Banja Luka*

3. Telenta, M., Maric, D., & Miodrag, S. (2020). Construction and preliminary validation of reactive and non-reactive agility tests for primary school children. *10th International e-Conference on "Sports Science and Health"* Banja *Luka*, June 24.-26. 2020

4. Zenic, N., Maric, D, & Klisovic, M. (2020) Factors related to participation in fitness programs among students of the University of Split. *10th International e-Conference on "Sports Science and Health"* Banja *Luka*, June 24.-26. 2020

Conference proceedings – abstracts

1. Maric, D., Bianco, A., & Sekulic, D., Analysis of sociodemographic and sports-related factors as correlates of potential doping behaviour in high-level junior swimmers, *X Congresso Nazionale SISMES Messina*, October 5 – 7 2018
2. Maric, D., Versic S., & Bianco, A. Doping factors and correlates of potential doping behaviour in team sport coaches; gender-specific analysis, *From Active Childhood to Healthy Aging 5th International Scientific Conference Novi Sad*, April 11 -13 2019
3. Maric, D., Tahiraj, E., & Versic S., Doping factors in team sports; parallel analysis among athletes and coaches, *XI Congresso Nazionale SISMES Bologna*, September 27 - 29 2019
4. Maric, D., Gilic, B., & Foretic, N., Internal and external training load of young team handball player's during the competition, *17th Annual Scientific Conference of Montenegrin Sports Academy "Sport, Physical Activity and Health: Contemporary Perspectives"*, April 2. – 5. 2020
5. Pokrajčić V., Maric, D., Foretic, N, & Uljevic, O., Reliability of the newly developed tests of handball specific change of direction speed and reactive agility, *4th International Conference of Sport Science – AESA 2021*
6. Marić D., Šime V., & Sekulić D., Doping Knowledge and correlates of potential doping behavior in kinesiology students, *4th International Conference of Sport Science – AESA 2021*