

Levels and factors of influence on physical activity among adolescents during the COVID-19 pandemic

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Doctoral thesis / Disertacija

2022

Degree Grantor / Ustanova koja je dodijelila akademski / stručni stupanj: **University of Zagreb, Faculty of Kinesiology / Sveučilište u Zagrebu, Kineziološki fakultet**

Permanent link / Trajna poveznica: <https://um.nsk.hr/um:nbn:hr:117:888332>

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University of Zagreb

FACULTY OF KINESIOLOGY

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**LEVELS AND FACTORS OF INFLUENCE
ON PHYSICAL ACTIVITY AMONG
ADOLESCENTS DURING THE COVID-19
PANDEMIC**

DOCTORAL THESIS

Zagreb, 2022



Sveučilište u Zagrebu

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TJELESNU AKTIVNOST KOD
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DOKTORSKI RAD

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Supervisor:
Full Professor Damir Sekulić, PhD

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Mentor:
prof.dr.sc. Damir Sekulić

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SUPERVISOR INFORMATION

Damir Sekulić was born in 1970 in Split (Croatia). He is a full professor at the University of Split, Faculty of Kinesiology. Since 2019, he serves as a Dean of the Faculty of Kinesiology, University of Split. He qualified as a professor of Physical Education at the Faculty of Physical Education, University of Zagreb (Croatia) in 1996 and earned his PhD in Kinesiology at the same institution in 2001. His main scientific interests relate to the sport-specific measuring protocols and tests, substance use and misuse in sport and exercise, and objective measurement of physical activity. Up to date, he published 145 scientific papers in journals indexed in the Web of Science. For the last two years, he has been actively involved in identifying factors influencing the physical activity and fitness status of adolescents. During the COVID-19 pandemic, he published 8 original scientific papers related to the physical activity and fitness status of adolescents. According to the Google scholar, his work received 4398 citations up to date (accessed 07.03.2022). During his career, professor Sekulić was involved in numerous scientific projects relating to the field of physical activity and health prevention. He was an invited speaker on several international scientific meetings and an active participant in more than 20 national and international scientific meetings. He was lecturing at numerous foreign institutions (Sport Science master level program, Reykjavik University, Reykjavik, Iceland, Sport science master level program, Mid Sweden University, Östersund, Sweden, Doctoral study, School of Medicine, University of Mostar, Bosnia and Herzegovina, Doctoral study, Faculty of Sport and Physical Education, University of Novi Sad, Serbia, Master level study, Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia, Bachelor and Master level study, Faculty of Natural Sciences, Mathematics and Education; University of Mostar, Bosnia and Herzegovina). So far, he has mentored eleven doctoral students in the country and abroad. In 2017, professor Sekulić received National Award for Science of the Republic of Croatia.

ACKNOWLEDGMENTS

Firstly, I would like to thank my supervisor, Damir Sekulić who taught me most of the things I know about scientific research, kinesiology, and general life values. He is not an ordinary mentor who just leads and monitors his candidates during doctoral studies. He is willing to devote hours and hours of his time to actually teach and transfer knowledge to his students/candidates. Also, he taught me how to think and how to consider things from many different aspects.

I would like to thank all of my colleagues from the “Project office” who supported me and still support me on my academic and scientific journey. I would like to thank professor Nataša Zenić Sekulić who taught me how to be simple and honest with students and people in general. Especially, I would like to thank all coauthors of the published studies. Thanks to my colleagues from my doctoral studies who helped me and supported me during the last three years. Thanks to Marija Ivanković who taught me (or at least tried) how to relax during my stay in Zagreb and who was/is a friend. Special thanks go to my colleague and friend, Mirela Šunda, who is on the same wavelength as me when it comes to discipline, working habits, and numerous life perspectives.

I wish to thank my family. My parents Ivan and Sanda supported me in every aspect of my life, my brother Josip for being the „life virtuous“, and my brother Frane who helped me with technical issues and motivation while writing this thesis. And finally, I would like to thank my husband Krešo Škugor, who supports me and endures my “occasional” outburst.

List of abbreviations:

95% CI – 95 percent confident interval

MET – Metabolic equivalent

MWZ – Mann-Whitney test

OR – odds ratio

PA – physical activity

PAL – physical activity levels

PAQ-A – Physical Activity Questionnaire for Adolescents

SUM – substance use and misuse

WHO – World Health Organization

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ABSTRACT

The main aim of this doctoral thesis is (i) to determine the changes in physical activity levels (PAL) because of the pandemic and measures of social distancing and (ii) to determine the factors that are associated with PAL and changes in PAL among adolescents due to social distancing measures. Precisely, Study 1 aimed to determine the associations between gender and fitness status; Study 2 aimed to determine the association of living environment; Study 3 aimed to determine the association of familial factors; and Study 4 aimed to determine the associations between substance use and misuse and sports participation with PAL and PAL changes among adolescents due to social distancing measures. Studies were carried out on adolescents from Croatia (Study 1 and Study 2) and Bosnia and Herzegovina (Study 3 and Study 4), all attending high school. All studies followed a similar testing procedure that consisted of two testing points: baseline, conducted before lockdown (during February and early March 2020), and follow-up, conducted during the COVID-19 lockdown (during April 2020). Study 1 included 388 adolescents aged 16.4 ± 1.9 years from southern Croatia. During the baseline testing, participants were assessed on PAL (assessed with PAQ-A), gender (female/male), anthropometrics (body height, mass, body mass index), and physical fitness tests (long jump, bent-arm hold test, sit and reach test, 400 meters running, beep test, and the maximal number of abdominal sit-ups in 60 seconds). Follow-up testing included only PAL assessment. Results of Study 1 evidenced a significant PAL decline for the total sample (t -test = 3.46, $p < 0.001$), primarily influenced by PAL decrease in boys (t -test=5.15, $p < 0.001$). The fitness status was consistently positively correlated with PAL at both testing waves among boys and girls, and the most evident association was noted between anaerobic and aerobic endurance capacities and PAL. Differences in changes in PAL between genders were most likely related to the fact that boys' PAL is mostly related to sports participation. Associations between fitness status and PAL indicate the importance of physical literacy in maintaining PAL in challenging circumstances such as the COVID-19 pandemic. Study 2 included 823 adolescents aged 16.5 ± 2.1 years from Split, Croatia. During the baseline testing, participants were assessed on PAL (using PAQ-A), gender, anthropometrics, physical fitness tests, and living environment (urban/rural). Follow-up testing included only PAL assessment. The results of Study 2 showed a considerable influence of the living environment on the PAL decrease, with a larger decrease in urban adolescents ($F=2.98$, $p < 0.001$). Logistic regression showed a higher likelihood for normal PAL at baseline in adolescents with better fitness status, with no strong confounding

effect of the urban/rural environment. Dynamic strength (OR:1.44, 95% CI:1.22–1.68), aerobic endurance (OR:1.64, 95% CI:1.10–2.24), and anaerobic endurance (OR:0.79, 95% CI:0.60–0.980) were positively correlated with normal PAL at follow-up. The differences between rural and urban adolescents regarding the established changes in PAL are explained by the characteristics of the living communities (i.e., lack of sports clubs and activities in rural areas) and the level of restrictive measures in the studied region and country. Study 3 included 688 adolescents (15–18 years of age) from Bosnia and Herzegovina. The baseline testing included assessment of PAL (using PAQ-A), sociodemographic-, parental-, and familial factors, while follow-up included only PAL assessment. In Study 3, a significant decline in PAL was recorded between two testing points (t-test: 11.88, $p < 0.001$). Father's education was positively correlated (baseline: OR (95%CI): 6.63 (4.58–9.96), follow-up: 3.33 (1.19–7.01)), and familial conflict was inversely correlated (baseline: 0.72 (0.57–0.90), follow-up: 0.77 (0.60–0.99)) with PAL before and during the pandemic. Study 3 evidenced that family cohesion and higher parental educational level reduce the incidence of PAL decline during the pandemic. Therefore, this study highlights the importance of the parent-child relationship and parental support in promoting PA during regular life and challenging situations like the COVID-19 pandemic. Study 4 included 661 students aged 15–18 years attending high school from Bosnia and Herzegovina. Baseline testing consisted of PAL assessment (by PAQ-A), sports factors, and substance use and misuse factors. Follow-up testing during the COVID-19 lockdown included only the PAL assessment. Baseline sports factors, including individual-sports participation, team-sports participation, sports experience, and sports achievements, were higher in adolescents with a sufficient PAL at follow-up (MWZ: 6.65, 7.95, 7.48, and 6.78, respectively, $p < 0.01$). Smoking cigarettes negatively affected PAL at follow-up (MWZ: 1.56, $p = 0.04$). Drinking alcohol was positively correlated with PAL at baseline (MWZ: 1.56, $p = 0.04$), while it did not affect follow-up PAL. The results of Study 4 confirmed the value of sports participation in attaining PAL during the COVID-19 lockdown. The influence of substance use and misuse on PAL before and during the pandemic points to adolescents' social and cultural aspects of substance use and misuse behaviors.

Key words: youth, physical exercise, physical education, crisis outbreak, public health, Coronavirus, living environment, physical fitness, sports, family cohesion, parental education, substance use

SAŽETAK

Cilj Glavni cilj ovog doktorskog rada je (i) utvrditi promjene razine tjelesne aktivnosti (TA) kao rezultat pandemije i nametnutih mjera socijalnog distanciranja i (ii) utvrditi čimbenike koji su povezani s TA i promjenama TA kod adolescenata uslijed mjera socijalnog distanciranja. Točnije, Studija 1 imala je za cilj utvrditi povezanost spola i fitness statusa; Studija 2 imala je za cilj utvrditi povezanost životne sredine; Studija 3 imala je za cilj utvrditi povezanost obiteljskih čimbenika; i studija 4 imala je za cilj utvrditi povezanost upotrebe psihoaktivnih supstanci te sudjelovanja u sportu s TA i promjena u TA kod adolescenata uslijed mjera socijalnog distanciranja. Istraživanja su provedena na adolescentima iz Hrvatske (Studija 1 i Studija 2) i Bosne i Hercegovine (Studija 3 i Studija 4), koji pohađaju srednju školu. Sve studije slijedile su sličan postupak testiranja koji se sastojao od dva vremena testiranja: inicijalnog, provedenog prije pandemije (tijekom veljače i početkom ožujka 2020) i finalnog, provedenog tijekom pandemije bolesti COVID-19 (tijekom travnja 2020).

Metode Studija 1 Istraživanjem je obuhvaćeno 388 adolescenata u dobi od $16,4 \pm 1,9$ godina iz Splita, Hrvatske. Inicijalno testiranje je uključivalo procjenu TA (procijenjeno PAQ-A upitnikom), spol (žensko/muško), antropometriju (tjelesna visina, masa, indeks tjelesne mase) i testove tjelesnog fitnessa (skok u dalj, test izdržaj u visu, test sjed raznožno, trčanje na 400 metara, beep test i maksimalni broj trbušnjaka u 60 sekundi). Finalno testiranje uključivalo je samo procjenu TA.

Rezultati Studija 1 Za ukupan uzorak zabilježen je značajan pad TA ($t\text{-test}=3,46$, $p<0,001$), prvenstveno zbog smanjenja TA kod dječaka ($t\text{-test}=5,15$, $p<0,001$). Fitness status bio je sustavno pozitivno povezan s TA u obje točke testiranja kod dječaka i djevojčica, a najočitija povezanost zabilježena je između anaerobnih i aerobnih kapaciteta i TA.

Zaključak Studija 1 Razlike u promjenama TA između dječaka i djevojčica najvjerojatnije su povezane s činjenicom da je TA kod dječaka uglavnom povezana s bavljenjem sportom. Povezanosti između fitness statusa i TA ukazuju na važnost tjelesne pismenosti u održavanju TA u izazovnim okolnostima kao što je pandemija bolesti COVID-19.

Metode Studija 2 Istraživanje je obuhvatilo 823 adolescenta u dobi od $16,5 \pm 2,1$ godina iz Splita, Hrvatske. Tijekom osnovnog testiranja sudionicima se procijenila TA pomoću PAQ-A upitnika, izmjerila se antropometrija, testovi tjelesnog fitnessa i životnog okruženja (urbano/ruralno). Naknadno testiranje uključivalo je procjenu TA.

Rezultati Studija 2 Rezultati su pokazali značajan utjecaj životne sredine na smanjenje TA, uz veće smanjenje kod urbanih adolescenata ($F=2,98$, $p<0,001$). Logistička regresija pokazala je veću vjerojatnost za normalnu razinu TA prije pandemije u adolescenata koji su imali bolji fitness status, bez utjecaja urbanog/ruralnog okruženja. Jakost (OR:1,44, 95% CI:1,22–1,68), aerobna izdržljivost (OR:1,64, 95% CI:1,10–2,24) i anaerobna izdržljivost (OR:0,79, 95% CI:0,60–0,980) bile su pozitivno povezane s normalnim razinama TA za vrijeme pandemije.

Zaključak Studija 2 Razlike između ruralnih i urbanih adolescenata u utvrđenim promjenama u TA objašnjavaju se karakteristikama životnih sredina (tj. nedostatak sportskih klubova i aktivnosti u ruralnim područjima), te razinom restriktivnih mjera u proučavanoj regiji i državi.

Metode Studija 3 Ovo istraživanje obuhvatilo je 688 adolescenata (15-18 godina) iz Bosne i Hercegovine. Inicijalno testiranje uključivalo je procjenu TA (koristeći PAQ-A), sociodemografske, roditeljske i obiteljske čimbenike, dok je finalno testiranje uključivalo samo procjenu TA.

Rezultati Studija 3 Zabilježen je značajan pad razina TA između dvije točke testiranja (t-test: 11,88, $p < 0,001$). Očevo obrazovanje bilo je u pozitivnoj korelaciji (inicijalna vrijednost: OR (95% CI): 6,63 (4,58–9,96), finalna vrijednost: 3,33 (1,19–7,01)), a obiteljski sukob bio je u obrnutoj korelaciji (inicijalna vrijednost: 0,72 (0,57–0,90), finalna vrijednost: 0,77 (0,60–0,99)) s TA prije i tijekom pandemije.

Zaključak Studija 3 Ova studija je dokazala da obiteljska kohezija i viša razina obrazovanja roditelja smanjuju pad TA tijekom pandemije. Stoga ova studija naglašava važnost odnosa između roditelja i djeteta u promicanju PA tijekom uobičajenog života, kao i tijekom kriza i izazovnih situacija poput pandemije COVID-19.

Metode Studija 4 Istraživanjem je obuhvaćen 661 učenik u dobi od 15 do 18 godina koji je pohađao srednju školu iz Bosne i Hercegovine. Inicijalno testiranje sastojalo se od procjene TA, sportskih čimbenika i faktora uporabe i zlouporabe supstanci. Finalno testiranje tijekom pandemije bolesti COVID-19 uključivalo je procjenu TA.

Rezultati Studija 4 Osnovni sportski čimbenici, uključujući individualno sudjelovanje u sportu, sudjelovanje u timskim sportovima, sportsko iskustvo i sportska postignuća, bili su viši u adolescenata koji su imali dovoljne razine TA za vrijeme pandemije (MWZ: 6,65, 7,95, 7,48, odnosno 6,78, $p < 0,01$). Pušenje cigareta negativno je utjecalo na TA u finalnom mjerenju

(MWZ: 1,56, $p = 0,04$). Konzumacija alkohola bila je u pozitivnoj korelaciji s TA prije pandemije (MWZ: 1,56, $p = 0,04$), dok nije imala utjecaja na TA za vrijeme pandemije.

Zaključak Studija 4 Rezultati studije potvrdili su važnost sudjelovanja u sportu u postizanju dovoljne TA tijekom pandemije bolesti COVID-19. Utjecaj uporabe i zlouporabe supstanci na TA prije i tijekom pandemije ukazuje na društvene i kulturne aspekte upotrebe supstanci kod adolescenata.

Ključne riječi: mladi, tjelesno vježbanje, tjelesni odgoj, zdravstvena krize, javno zdravstvo, koronavirus, životna sredina, tjelesni fitness, sport, obiteljska kohezija, odgoj roditelja, upotreba supstanci

THESIS OUTLINE

This thesis consists of four chapters. Chapter one covered the research context, general introduction, and research aims and questions. Chapter two describes the definitions of PA in adolescents, correlates of PA in normal life circumstances, and the potential impact of the COVID-19 pandemic on PA. Chapter three presents four published articles that are included in this thesis. Study 1 investigated PAL changes during the COVID-19 lockdown, emphasizing differences according to gender and fitness status, while Study 2 investigated PAL changes according to differences in the living environment. Study 3 aimed to determine the changes in PAL regarding familial and parental factors. Finally, Study 4 investigated PAL changes regarding sports participation and substance use and misuse. Chapter four includes the general conclusions of all presented studies. Also, strengths, limitations, practical implications, and perspectives for further research are presented.

INTRODUCTION

Context

Physical activity (PA) has numerous health benefits for the human body and reduces the risk for more than 25 chronic diseases (Warburton & Bredin, 2017). Sufficient PAL in adolescents provides benefits to bone health, cardiovascular health, muscle mass, mental health, and self-esteem (Warburton & Bredin, 2017). However, insufficient physical activity level (PAL) is one of the primary problems of public health and modern life in general. Indeed, insufficient PAL is one of the main risk factors for chronic noncommunicable diseases and is in the 4th place of all death causes (after hypertension, smoking, and diabetes) (Hallal et al., 2006). The most worrying fact is that PAL drops in adolescence, and only 19% of adolescents are sufficiently physically active (Dumith et al., 2011; Guthold et al., 2020). This is the problem as this is the life period where future lifestyle habits are attained, influencing health status in older ages (Dumith et al., 2011).

Increasing PAL in adolescents has been in the focus of research in the public health scope for the last few decades; thus, numerous correlates and determinants of PA have been identified. Namely, demographic, environmental, biological, and psychological factors are identified to have the greatest influence on PA (Bauman et al., 2012). Precisely, age, gender, socioeconomic status, peer and parental influence, and previous PA experience are the most investigated factors (Craggs et al., 2011). Briefly, it has repeatedly been reported that boys are more active than girls; PAL declines with increased age; children with higher socioeconomic status and with better-educated parents have higher PAL; urban adolescents have higher PAL than rural ones (Bauman et al., 2012; Craggs et al., 2011).

The declaration of the COVID-19 pandemic at the beginning of 2020 led to substantial global lifestyle changes (Cucinotta & Vanelli, 2020). Governments implemented measures of social distancing and home-confinement. Therefore, it was logical to assume that measures of social distancing and decreased movement opportunities will lead to even more reduced PAL during the COVID-19 pandemic. Several studies warned about the negative consequences of the pandemic on PA and alarmed about what happens to the body when it becomes less and less active (Jakobsson et al., 2020; Pinho et al., 2020). Precisely, muscle atrophy, altered metabolic parameters such as insulin sensitivity, cardiovascular system, immune system, and psychological deterioration occur after just a short period of reduced PA (Narici et al., 2021).

Early scientific reports regarding COVID-19 revealed that older individuals and ones with comorbidities had increased odds of severe complications and mortality outcomes following COVID-19 infection (Emami et al., 2020). Specifically, people that required COVID-19 hospitalization most frequently had diabetes, hypertension, and cardiovascular disease (Chen et al., 2020). Thus, it indirectly indicates that obesity, altered immune system, and low fitness are one of the primary risks for severe COVID-19 illness. On the other side, regular PA protects against cellular stress, and improves coagulation and cardiovascular functions (Narasimhan & Rajasekaran, 2016). What is more, regular PA increases the strength and endurance of respiratory muscles, positively effects the immune system, and improves immune response to viral incidence (Jakobsson et al., 2020; McKenzie, 2012). All of the above-mentioned positive effects or regular PA can lower the incidence of viral infections, including the COVID-19 infection. Also, PA can alter comorbidities that are related to severe COVID-19 illness. Thus, identifying correlates and determinants of PA during the COVID-19 pandemic is crucial for stopping the further reduction of PAL and lowering the incidence of severe COVID-19 illness.

Research aims and questions

Adolescents are a very vulnerable group as they are sensitive to changes in a social context. Also, this life period is characterized by a large decline in PAL. Thus, in the context of the COVID-19 pandemic, adolescents are expected to decline their PAL even more.

The main aims of this research are (i) to determine the changes in PAL as a result of pandemic and imposed measures of social distancing and (ii) to determine the factors that are associated with levels and changes of PA among adolescents, with the emphasis on sociodemographic factors, fitness status, sports participation, and substance use and misuse.

Questions:

1. Will PAL of adolescents decline during the COVID-19 pandemic?
2. Are there any gender differences in PAL before and during the COVID-19 pandemic?
3. Does the living environment influence PAL before and during the COVID-19 pandemic?
4. Does sports participation and fitness status influence PAL before and during the COVID-19 pandemic?
5. Does substance use and misuse influence PAL before and during the COVID-19 pandemic?
6. Do parental/familial factors influence PAL before and during the COVID-19 pandemic?

List of research studies

To answer the scientific questions of this thesis, four studies were published:

Sekulić, D., Blažević, M., **Gilić, B.**, Kvesić, I., Zenić, N. (2020). 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*, 12(10), 4072. doi.org/10.3390/su12104072

Zenić, N., Taiar, R., **Gilić, B.**, Blažević, M., Marić, D., Pojskić, H., Sekulić, 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

Gilić, B., Ostojić, L., Čorluka, M., Volarić, T., Sekulić, D. (2020). Contextualizing Parental/Familial Influence on Physical Activity in Adolescents before and during COVID-19 Pandemic: A Prospective Analysis. *Children*, 7(9): 125. doi.org/10.3390/children7090125

Gilić, B., Zenić, N., Separović, V., Jurčev Savičević, A., Sekulić, D. (2021). Evidencing the influence of prepandemic 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*, 34(2):151-163. <https://doi.org/10.13075/ijomeh.1896.01733>

LITERATURE REVIEW

Physical activity in adolescence

Physical activity is defined as "any bodily movement produced by skeletal muscles that result in energy expenditure" (Caspersen et al., 1985). The energy expenditure of PA is mainly expressed through metabolic equivalents (MET), which is equal to 1 kcal.kg⁻¹.h⁻¹. PA has many domains, including leisure-time, occupational, household, and transportation PA (Howley, 2001). Leisure-time PA is thought to be contributing the most to overall PA, as it represents sports activities, resistance-training activities, and endurance exercise programs (Howley, 2001). Moreover, PA occurs in several intensities, including light, moderate and vigorous intensity. Those intensity categories primarily represent the amount of energy expenditure; light PA represents 1.9-3.3 METs/h and occurs while standing or strolling, moderate PA represents 3.4-4.7 METs/h and occurs during a brisk walk, slow-pace cycling, and vigorous PA represents >4.8 METs/h and occurs while running or exercising (Bouchard et al., 1994).

There are numerous important positive health effects of PA. Specifically, regular moderate to vigorous PA has the following health benefits in adolescence: optimizes muscular strength, maintains a healthy weight, attains peak bone mass, improves cardiovascular and neuromuscular health, benefits mental health and academic achievement, and improves general wellbeing (Kumar et al., 2015). Most importantly, regular PA reduces the risk of many noncommunicable chronic diseases (cardiovascular diseases, diabetes mellitus, cancers) (Hallal et al., 2006). Specifically, active children have fewer cardiovascular risk factors, lower incidence of coronary heart disease, and lower blood pressure than less active children (Lotan et al., 2005). Thus, knowing that the onset of chronic diseases happens in early childhood and adolescence, positive PA habits must be formed as soon as possible (Lotan et al., 2005).

To achieve the health benefits of PA, World Health Organization (WHO) proposed international PA guidelines. According to the WHO guidelines, children and adolescents (5-17 years old) should accumulate at least 60 minutes a day of moderate- to vigorous-intensity PA during the week and vigorous-intensity aerobic PA and resistance exercise on at least three days a week (World Health Organization, 2020). However, research has shown that a substantial number of adolescents do not reach the proposed PA guidelines. A large international study that included 1.6 million adolescents aged 11-17 years from 146 countries showed that 81% of adolescents (77.6% boys and 84.7% girls) have insufficient PA (Guthold et al., 2020). Similar

trends of insufficient PAL have been recorded in Croatia, and Bosnia and Herzegovina. Precisely, in 2016, 70.1% of boys and 83.9% of Croatian girls had insufficient PA (Guthold et al., 2020). It is important to emphasize that PA habits are formed in earlier stages of life (i.e., childhood and adolescence) and are tracking into adulthood (Telama, 2009). Thus, it is crucial to investigate the factors that influence PA in youth in order to promote a physically active lifestyle for life.

Numerous studies have tried identifying the factors influencing PA among children and adolescents. The most significant correlates and determinants of PA are gender (girls are less active), age (PA declines with age), living environment (adolescents living in a rural environment are less active), sports participation, and fitness status (fitter adolescents and those involved in sports are more active), social support (adolescents with social support are more active) (Sallis et al., 2000; Van Der Horst et al., 2007). The following section will display the determinants and correlates of adolescent PA in more detail.

Sociodemographic factors

Sociodemographic factors mainly include gender, age, environmental factors, and socioeconomic status.

Gender

It has repeatedly been reported that boys have higher PAL than girls (Telford et al., 2016; Trost et al., 2002; Vilhjalmsón & Kristjansdóttir, 2003). Specifically, boys are more involved in vigorous PA than girls, and this gender difference was recorded to be substantial (45%) (Trost et al., 2002). The explanation for boys being more active than girls mostly lies in the nature of the boys' activities; boys practice sports, resistance, and endurance exercise training more than girls (Telford et al., 2016; Vilhjalmsón & Kristjansdóttir, 2003). Knowing that sports participation makes the largest proportion of leisure-time PA in adolescents, it is logical that boys display higher levels of PA than girls.

The reasons for boys participating more in sports are numerous. Sports are commonly more accessible to boys; boys have more accessible training facilities and equipment, more convenient training hours, more competition opportunities, and better opportunities for sports success (Vilhjalmsón & Kristjansdóttir, 2003). Also, boys are more likely to be supported in the financial and material sense (prizes, scholarships), contributing to their greater sports involvement. What is more, boys value sports accomplishments more than girls and commonly identify themselves through sports. Also, boys have more physically active friends, which is among the strongest correlates of PA (peer, social support) (Vilhjalmsón & Thorlindsson, 1998).

The gender difference in accumulating PA could also be found in the nature of the sports boys and girls participate in. Specifically, boys mostly participate in high-intensity, competitive, and team sports such as soccer, handball, basketball, and weightlifting. On the other hand, girls participate in individual, non-competitive, and low- to medium-intensity sports such as dance, gymnastics, swimming, and roller skating (Vilhjalmsón & Kristjansdóttir, 2003). Also, girls have fewer options for choosing the sport, as the sport is mainly oriented toward males (Sherman & Hume, 2002). Furthermore, apart from lower participation in sports activities outside of school, girls have less support from family and peers (Kågesten et al., 2016). Moreover, girls are more prone to have negative exercise, sports, and physical education experiences, which lower their willingness to further participate in PA (Telford et al., 2016).

Age

The decline of PAL is associated with increased age. Precisely, older adolescents have lower PAL than younger children and adolescents (Dumith et al., 2011; Tanaka et al., 2018). It was recorded that the most significant decline in PA occurs during middle adolescence, precisely during the transition to high school (Trost et al., 2002). Specifically, PAL reaches its peak at the age of 13 and declines annually by 7% (Dumith et al., 2011). The study on adolescents from Bosnia and Herzegovina recorded that 14 years old children had significantly lower PAL than 10-year-old children (18% difference) (Pojskic & Eslami, 2018). Further, a study on Croatian students showed a substantial decline in PAL from the 1st to the 2nd grade of high school (Štefan et al., 2018), and similar was reported for high school students aged 16-18 years in Bosna and Herzegovina (Miljanovic Damjanovic et al., 2019).

The decline of PAL with advancing age can be a result of changes in the social environment (increased socializing with friends), less impact of parents on children's PA habits, and changes in life situations (school, employment) (Dumith et al., 2011). The differences in PAL between younger and older adolescents could also be explained by dropping out of sports. Briefly, ages 14-15 years represent the largest sports dropout incidence. This can be attributed to students spending more time studying, doing school duties, and focusing on academic achievement and employment (Eime et al., 2019). Thus, as sports participation contributes to the total PAL the most, a decrease in sport participation with increased age influences PAL decline.

Collectively, changes (decline) in PAL with increased age can be a consequence of changes in life priorities and obligations, increased school obligations, increased focus on academic achievement, decline in active transport, and drop out of sports.

Living environment

Numerous studies highlight the great impact of the environment on lifestyle and PA. Specifically, adolescents who live only a few kilometers away from a larger city have a different lifestyle than their peers who live in the city (Sallis et al., 2016). Consequently, studies reported differences in PAL between adolescents in urban and rural environments. Even though not conclusive, most studies in various countries reported that urban adolescents reach higher PAL than rural adolescents (Sandercock et al., 2010). Specifically, boys in Portugal who live in an urban environment reported higher PAL than rural adolescents (Machado-Rodrigues et al., 2012). Also, a study conducted in the USA recorded that individuals living in urban environments reach higher PAL than rural ones (Martin et al., 2005). Supportively, studies

conducted on Croatian adolescents also reported urban adolescents having higher PAL than their rural peers (Bergman Marković et al., 2011).

The most likely reason for urban adolescents having higher PAL is that they have greater accessibility to sports facilities and programs, recreational infrastructure (playgrounds, sports courts), and transport infrastructure (pathways for bicycles and sidewalks) (Davison & Lawson, 2006). Conversely, rural adolescents do not have adequate infrastructure and opportunities for organized activities. Also, rural adolescents are often limited in terms of connections and transport to the city, which makes it even more difficult for them to participate in the desired sports activities.

It must be emphasized that life in rural environments has changed substantially in the last few decades. Precisely, labor markets, agriculture, crafts, and rural affairs have been neglected and reduced due to urbanization, modernization, and technological advancements. People are less and less involved in agricultural activities because there has been a large import of agricultural products and a reduction in the need for domestic production (O'Dubhchair et al., 2001). Therefore, people in rural areas do not participate in physical work but spend more and more time in sedentary activities. Likewise, both children and adolescents living out of town have lost the habit of helping with work, running, and playing outside with peers, and these activities have replaced sedentary activities like playing video and computer games, and online communication with peers. In line with reduced PA and fitness, children in rural areas have been reported to have higher levels of obesity and overweight and a higher risk of cardiovascular disease than children living in urban areas in the USA (Liu et al., 2008).

It was evidenced that rural youth spend more time in outdoor play, but this is mostly related to younger children aged less than 13 years, while children that are older than 13 years tend to accumulate vigorous PA mainly from organized sports activities (Springer et al., 2009). Thus, as rural adolescents have fewer options and opportunities to participate in organized activities, they have lower PAL. Moreover, following the logic that PA habits track into adulthood, the finding that rural adults have lower PAL than those living in urban areas has concerning implications for rural adolescents (Reis et al., 2004).

Familial/parental factors

Adolescents are in the life period where they form their identity and are influenced by other people, especially parents and other family members. Thus, studies repeatedly analyzed the influence of parents and family on children's PA habits. Namely, parental education, socioeconomic status, parental PA habits, and family cohesion are some of the most influential factors on PA in children and adolescents (Gustafson & Rhodes, 2006).

Parental educational level

Studies reported inconsistent findings regarding the parental educational level and adolescents' PA. Some studies revealed a positive association between higher educational levels and PAL, while some did not record a significant association (Jaeschke et al., 2017; Sekulic et al., 2020). The association between parental educational level and adolescent's PA can be explained in several ways.

First, parents with better education will most likely possess knowledge of the health benefits of PA (Ruedl et al., 2021). Thus, it is reasonable to assume that better-educated parents will encourage their children to be physically active. However, there are possible differences in the influence of maternal and paternal educational levels. Briefly, mothers are more responsible for educating children, including health-related education and knowledge of the importance of PA (Fredricks & Eccles, 2004), and it can be assumed that the mother's influence has a long-lasting effect. Indeed, studies on adolescents from Croatia and Bosnia and Herzegovina recorded that the mother's educational level positively influenced changes in PAL during adolescence (Maric et al., 2020; Sekulic et al., 2020). Mothers most likely influence the children's awareness of the benefits of PA on health, which results in better health-related behavior of adolescents. Indeed, a study on Nigerian children reported that mothers who had higher educational levels had greater knowledge of PA that they could teach their children (Hammed et al., 2021).

On the other side, fathers probably have a more pronounced influence on younger children, as they primarily influence the PA of their children by being active with them (Lee et al., 2010). What is more, fathers have a greater influence on their children's sports participation, which is stronger at a younger age (i.e., sports dropout occurs later). This has recently been supported in the study on adolescents from Bosnia and Herzegovina, as fathers' education was more noticeable in younger adolescents (Sekulic et al., 2021). Namely, according to the social perception, fathers (men) are more competent in sports and PA than women and act as role models for their children (Shropshire & Carroll, 1997).

Furthermore, higher education most likely influences better employment status and higher socioeconomic status. This most likely leads to better possibilities for purchasing sports and recreational equipment, paying club memberships, and driving to training and competitions (Shropshire & Carroll, 1997). Indeed, high costs of sports participation have been reported as one of the main reasons for non-participation in sports and PA (Beets et al., 2010). Low-income families have fewer opportunities to provide children with financial support for participating in the sport they choose, limiting their sports involvement and PA in general (Beets et al., 2010). Indeed, it has been reported that children with better-educated fathers had greater odds of participating in sports than children of less-educated fathers (Yang et al., 1996).

Parental social support

Social support represents the interaction between parent and child in the context of participating in, discussing, and providing opportunities related to PA (Beets et al., 2010). Social support has two main types: tangible and non-tangible social support.

Tangible social support refers to parental behaviors that directly facilitate the involvement in PA. Tangible support includes (i) providing transportation to sports practices, competitions, play with friends; (ii) purchase of equipment and payment of club fees; (iii) parental direct involvement in PA with child; (iv) watching and supervising activity (Beets et al., 2010). The most effective form of tangible social support is supposed to be active parental involvement in PA (Gustafson & Rhodes, 2006). Parental involvement is more overt support and can include coaching or playing with children.

Indeed, children who had both parents active were six times more likely to be sufficiently physically active compared to children who did not have active parents (Moore et al., 1991). Similarly, a study on adolescents from Portugal noted that boys and girls reached higher PAL if both parents were physically active, and this was more gender-pronounced (Rodrigues et al., 2018). Specifically, boys with active fathers had greater odds of being involved in organized sport, while girls with mothers who were practicing organized PA were more likely to be involved in sports more times per week (Rodrigues et al., 2018). Higher PAL of children with more active parents can be explained by the theory that parents are role models. Namely, parents act as role models to their children; that is, children observe, imitate, and copy the behaviors they observe from their parents (Zecevic et al., 2010).

Even though direct parental involvement in PA positively affects children's PA, parents do not have to be entirely directly involved to have that influence. Namely, only being present while

their children are practicing sports or exercising leads to increased PAL in children (Heitzler et al., 2006). This mainly relates to parents watching and supervising sports activities, which directly encourages children to be more active.

On the other side, intangible social support refers to verbal encouragement and information about the benefits of PA. Motivation or encouragement for being physically active is a precursor for involving in activity and is related to the intensity and amount of the activity. Precisely, providing encouragement develops feelings of greater self-competence, attraction to activity, and motivation to be active, which leads to greater participation in PA (Beets et al., 2010). Further, providing information about the importance of PA and how to be active leads to greater involvement in PA (Beets et al., 2010). This was supported by a study that recorded that those children who had greater knowledge and understanding of PA had higher PAL and better fitness status (Longmuir et al., 2018).

Family cohesion

Family cohesion reflects family members' social and emotional bonds (Zloković, 2012). It includes familial support, affection, and mutual assistance of family members. Family cohesion has been associated with positive health-related behaviors such as healthy eating behavior in adolescents (Franko et al., 2008). Also, family cohesion was associated with moderate- to vigorous PA in Mexican adolescents (Bigman et al., 2015). Specifically, adolescents who reported high family cohesion had 32% greater odds of being sufficiently physically active than adolescents from families with lower cohesion (Bigman et al., 2015).

Families with better cohesion are more likely to create a positive environment, support, and encouragement for being physically active (Trost & Loprinzi, 2011). Thus, it is expected that the opposing phenomenon – family conflict will have adverse effects on PA in adolescents. This has recently been proven in older adolescents from Bosnia and Herzegovina. Precisely, familial conflict negatively influenced the PA of adolescents aged 16-18 years, probably because older adolescents are prone to rebellious behavior (Sekulic et al., 2021). Collectively, family cohesion should be attained and maintained in order to create a fruitful ground for increasing the PAL of adolescents.

Sports participation and fitness status

Sports participation is one of the most significant contributors to overall PA in children and adolescents. Indeed, it has been directly recorded that adolescents involved in sports activities have higher total PAL compared with non-sports participants (Eime et al., 2015). Nowadays, children and adolescents are not active during unstructured play, non-organized activities, and active transportation, which is why sports have the most prevalent influence on PA. However, sports participation reaches its peak at ages 10-13, and later sports dropout rates substantially increase (Eime et al., 2019). Dropout most likely happens as sports are mainly oriented towards competitive success, meaning that individuals with insufficient physical capacities and motor skills will be disadvantaged in participating in sports (Westerbeek & Eime, 2021). Thus, children and adolescents with lower competency, self-efficacy, and enjoyment will most likely quit sports. Indeed, in the territory of Southeastern Europe, the phenomenon of sports dropout is also very prevalent. Specifically, a study on Croatian adolescents reported that adolescents decreased PAL during the two years, which is mainly related to sports dropout (Sekulic et al., 2020). This most likely occurs as a consequence of non-adequate knowledge about positive outcomes of sports, including the health and social benefits of sports participation.

Apart from sport being the primary source of current PA, adolescents who are involved in sports most likely gained knowledge of benefits of regular PA. Indeed, previous sports experience was positively associated with physical literacy levels in the Danish adult population (Elsborg et al., 2021). Accordingly, it has been proven that adolescents from six European countries involved in sports achieve higher PAL and probably possess better physical literacy skills (Kokko et al., 2019). Physical literacy is defined as the "disposition to capitalize on our human embodied capability, wherein the individual has: the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for maintaining purposeful physical pursuits/activities throughout the life course" (Whitehead, 2010). By this logic, adolescents involved in sports will more likely have the knowledge, skills, and motivation to participate in PA, which will also probably track into adulthood. Indeed, in a review of correlates of PA, previous PA and sports participation have been related to current PA, which supports the theory of tracking of PA over time (Sallis et al., 2000).

Similarly, adolescents with better fitness status achieve higher PAL. This can mainly be related to the previously explained relation of sports participation, as practicing sports is the main medium for achieving good physical fitness (Telford et al., 2016). Therefore, adolescents participating in sports activities have better physical fitness, allowing them to reach higher PAL

overall (Telford et al., 2016). Moreover, fitter adolescents having higher PAL could be explained by another phenomenon. Precisely, more physically fit adolescents will have more confidence and self-esteem and will participate in more physical activities, including sports, recreational activities, and non-organized PA (Westerbeek & Eime, 2021). Adolescents who feel competent to do any type of PA have greater odds of higher PAL. Supportively, physical fitness in Canadian children was related to physical literacy, meaning that fitter adolescents possess better physical literacy skills (Lang et al., 2018). This means that adolescents with better fitness status also possess physical competence, confidence, motivation, and knowledge and understanding of the importance of PA, which leads to lifetime good PA practices (Lang et al., 2018).

Substance use and misuse

Substance use and misuse also affect PA among adolescents. Precisely, it has been reported that cigarette smoking and drug consumption are negative, while drinking alcohol is positively associated with PA (Dinger et al., 2014). These findings have been explained by the theory that drinking alcohol is socially accepted among the active population (mostly in forms of post-activity gatherings), while smoking and drug use are not socially accepted among that population (Lisha & Sussman, 2010).

Alcohol consumption

Alcohol has been associated with PAL in adolescents. However, it is interesting that numerous studies noted a positive relationship, meaning that adolescents who drink are more physically active (Kwan et al., 2014; Piazza-Gardner & Barry, 2012). Before explaining such phenomena, the problem of alcohol drinking will be explained from the cultural aspect. Namely, many European adolescents are involved in harmful alcohol drinking, and the prevalence of alcohol drinking is also very high in countries in Southeastern Europe (Hibell et al., 2012). Indeed, Bosnia and Herzegovina is among the European countries with the highest incidence of alcohol drinking, with 41% of boys and 27% of girls reporting harmful alcohol drinking (Hibell et al., 2012). Further, 29% of Croatian adolescents and 39% of adolescents from Kosovo are harmful alcohol drinkers (Devcic et al., 2018; Tahiraj et al., 2016). A high incidence of drinking alcohol is probably a consequence of the culture, as alcohol drinking is socially accepted behavior.

The common finding that drinking alcohol is positively associated with PA can be explained by the following theory (Lisha & Sussman, 2010). First, sports are the main source of PA among adolescents. Further, it is well known that alcohol is a socially desirable behavior in the sports culture. Thus, as sports are characterized by social and team nature, and knowing that drinking alcohol is socially desirable behavior, the findings that more active individuals drink more is somewhat logical. Indeed, drinking alcohol is very prevalent in the sports culture. Commercials for alcoholic beverages following sports competitions, celebrations, and other sports events are very common (Lisha & Sussman, 2010), encouraging individuals to drink alcohol. Further, the main factor of high alcohol drinking in the active population is social gatherings after sports activities in bars or clubs, which include alcohol drinking (Piazza-Gardner & Barry, 2012). Specifically, drinking alcohol is a social activity and is socially desirable among athletes and the active population. Thus, in the context of sports, drinking alcohol is proclaimed and individuals are encouraged to drink alcohol which consequently led to findings that more active

individuals drink alcohol more than their non-active peers (Piazza-Gardner & Barry, 2012). This has also recently been supported by a study on Bosnia and Herzegovina adolescents, that is, adolescents with higher alcohol consumption had higher PAL (Zenic et al., 2021).

Further, adolescents are in a very sensitive period of life where they form their identities and are more prone to fall under the influence of their peers or social groups. Specifically, adolescents try to make stronger social bonds with people around them, making them more susceptible to adopting other people's behaviors (Turner & Oakes, 1986). Adolescents involved in sports form a close bond within a sports team, and they develop their identity through that group of peers (Connell et al., 2010). Also, adolescents are more prone to experimenting and trying new things, and alcohol is one of the most accessible substances to them. Thus, adolescents regularly start drinking alcohol very early, which reflects to their group of peers, and in the context of sports, teammates, and members of sports clubs (Connell et al., 2010; Wichstrøm & Wichstrøm, 2009).

Tobacco consumption

The second most prevalent substance is tobacco, i.e., smoking cigarettes. In Southeastern Europe, there is a large prevalence of adolescent smokers (37%), with Croatia and Bosnia and Herzegovina having among the higher rates of smokers in Europe (ESPAD, 2020). However, contrary to alcohol drinking, smoking cigarettes is not prevalent among athletes and the physically active population. In a study on US college students, smoking cigarettes had a negative correlation with achieving PA guidelines (Walker et al., 2015). More specifically, adolescents who consumed more than 20 cigarettes daily had the lowest likelihood of achieving sufficient PAL (Walker et al., 2015). Supportively, a review article noted an inverse relationship between cigarette use and sports participation (Lisha & Sussman, 2010). Accordingly, a recent study on Bosnia and Herzegovina adolescents showed that girls who smoke have a lower PAL (Maric et al., 2021).

The first explanation of such findings could be found in the fact that smoking cigarettes is not socially acceptable, favorable, and not part of the perceived norms in the group of physically active people (Lisha & Sussman, 2010). Further, smoking is related to youth who participate in deviant and health-risk behaviors and are generally less physically active (Dinger et al., 2014). Moreover, athletes are aware of the short- and long-term negative consequences of smoking (Wang et al., 2014). Precisely, smoking negatively affects lungs and heart functions, reducing cardiorespiratory fitness and physical capacity for exercise and sports (Pederson et al., 1992).

What is more, the adverse effects of smoking, such as breathing difficulties and lower alertness, often manifest very soon and immediately lower sports and exercise performance (Pederson et al., 1992). Indeed, after just a few years of smoking, physical fitness (muscular and cardiorespiratory) declined in adolescents from Croatia (Misigoj-Durakovic et al., 2012). Highly developed muscular and cardiorespiratory fitness are prerequisites in many sports, and even a small change in fitness level can contribute to success or failure in sports (Telford, Telford, Cochrane, et al., 2016). Thus, as athletes and active individuals are most likely aware of the negative consequences of smoking tobacco, they will not jeopardize their competitive success or exercise performance (Wichstrøm & Wichstrøm, 2009).

Illicit drugs consumption

Contrary to alcohol and tobacco use, Croatia and Bosnia and Herzegovina have the lowest rates of illicit drugs (i.e., marijuana, hashish, cocaine, heroin, LSD) consumption in Europe, with a prevalence of 7% (Bjelica et al., 2016). Studies generally reported that illicit drugs use is inversely related to participating in sports and any form of PA (Kwan et al., 2014; Lisha & Sussman, 2010). Like tobacco use, drugs are not perceived as socially acceptable and desirable behavior among active populations (Kwan et al., 2014). Also, drugs have almost immediate negative effects on sports and exercise performance. Precisely, drug use leads to detriments of physical capacities, including reduced blood capacity for carrying oxygen, increased heart rate, and reduced cognitive functioning (Thomas et al., 2014). Also, drug use decreases concentration, coordination, and reaction, alters time orientation and leads to confusion and cardiorespiratory arrest (Thomas et al., 2010). Thus, as adolescents are probably aware of the negative consequences of drug consumption, they will probably avoid taking that risk that will negatively affect their health and physical performance.

However, it was reported that athletes sometimes consume marijuana, but this trend is primarily apparent in younger adolescents and decreases with age (Lisha & Sussman, 2010). Indeed, younger adolescents are more prone to try new things and be popular and socially accepted (Sussman et al., 2007). Thus, as marijuana is widespread and considered as a drug with the least negative effects, adolescents report trying it (Kwan et al., 2014). However, marijuana consumption is not prevalent among older athletes as they are aware of its negative health effects (Wichstrøm & Wichstrøm, 2009). This has been supported in the study on Croatian adolescents, with recording a negative relationship between marijuana consumption and sports participation (Obradovic Salcin et al., 2019).

COVID-19 pandemic

The WHO declared the SARS-CoV-2 virus outbreak (COVID-19) a global pandemic on March 11, 2020 (Cucinotta & Vanelli, 2020). The COVID-19 outbreak started in China (Wuhan) in December 2019 and rapidly spread across the globe. The main symptoms of the illness are breathing difficulties, fever, cough, and pneumonia (Tomasi, 2020). The main reason for concern is that virus spreads very fast and rapidly caused many deaths all around the globe. The virus is primarily transmitted from human to human, via respiratory droplets from sneezes and coughs within a range of 2 meters (Tomasi, 2020). Also, it can be spread through indirect contact via contaminated surfaces. The virus incubation lasts from 2 to 14 days, which means that the infected person does not know about the illness immediately, which raises the chances of further virus transmission (Team, 2020).

Many countries introduced several strategies to slow down the spread of the virus. The most common strategies included tracing cases and contacts, self-isolation or quarantine, and promoting public health measures, including handwashing and social distancing (Bedford et al., 2020). Social distancing measures included banning large social gatherings closing schools, sports clubs and events (Bedford et al., 2020). In Croatia and Bosnia and Herzegovina, the strictest government measures, so-called lockdown/quarantine, lasted from mid-March until the end of April 2020, including closing schools, sports clubs, churches, theaters, bars, restaurants, and other places of social gatherings. The government had a stay-at-home policy, meaning that people were allowed to go outside just for grocery supplies and emergency situations. This led to reduced movement opportunities and, probably, even more reduced PAL. Several opinion and commentary papers were published at the beginning of the first and strictest lockdown (in March-May 2020), warning about the negative consequences of lockdown on already low PAL (Jakobsson et al., 2020; Pinho et al., 2020).

First, a commentary paper warned that COVID-19 is not a pandemic but a syndemic between the array of noncommunicable diseases and COVID-19 illness (Horton, 2020). Knowing that physical inactivity is among the most influential factors leading to numerous non-communicable diseases, the syndemic of physical inactivity and COVID-19 is considered a major potential problem. Indeed, social distancing measures led to reduced movement opportunities and adopting of sedentary behaviors and inactivity. The human body responds to reduced activity very fast. Bed rest studies noted that muscle atrophy occurs after just 2-3 days of inactivity (Narici et al., 2021). Further, step reduction has a detrimental impact on aerobic capacity, with maximal oxidative capacity (VO_{2max}) being reduced by 7% within two weeks

of reduced activity. Also, increased inactivity periods lead to increased cardiometabolic risks even in healthy populations (Narici et al., 2021). What is alarming, only two weeks of inactivity and reduced step count induced insulin resistance, reduced muscle mass, and increased central adiposity in healthy adolescents (Thyfault & Krogh-Madsen, 2011).

Moreover, just one week of reduced activity negatively impacts mood and depression (Edwards & Loprinzi, 2016). Further, being quarantined and socially isolated imposes a substantial psychosocial impact on children as it drastically changes their lifestyle, including mental and physical activities (Ghosh et al., 2020). Also, closing schools, apart from limiting its educational and pedagogical aspects, leads to limited interaction with friends and overall socialization. Schools provide a normalization setting and promote the importance of hygiene, physical activity, exercise, and healthy habits (Ghosh et al., 2020).

At the beginning of the pandemic, several opinion and commentary papers warned about the potential negative consequences of COVID-19 lockdown on already low PAL (Dwyer et al., 2020). Long self-isolation (more than two weeks) places a significant challenge for remaining active and could impair the overall quality of life. Increased stress and depression during previous outbreaks resulted from social distancing (Hawryluck et al., 2004). Thus, the importance of maintaining adequate PAL during the pandemic is emphasized, and several papers offered strategies and suggestions for home-based exercise (Dwyer et al., 2020; Jakobsson et al., 2020).

Concerning the inevitable negative impact of the COVID-19 pandemic on PAL in adolescents, it is crucial to address the most influential factors that impact PA during the pandemic. Identifying these factors could aid public-health authorities, physical education teachers, fitness professionals, and parents' insight into what they should aim to correct to attain and maintain the PAL of adolescents during the pandemic and similar crises.

ORIGINAL STUDIES

Study 1: 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

Sekulić, D., Blažević, M., **Gilić, B.**, Kvesić, I., Zenić, N. (2020). 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*, 12(10), 4072. doi.org/10.3390/su12104072



Sustainability

Sustainability, 12(10), 4072.

doi.org/10.3390/su12104072

Manuscript submitted for publication: 23 April 2020

Manuscript accepted for publication: 14 May 2020

Journal impact factor: 2.592

Indexed/Abstracted in: Current Contents Connect (CCC); Web of Science Core Collection (WoSCC); Science Citation Index Expanded (SCI-EXP); Social Science Citation Index (SSCI); SCI-EXP, SSCI i/ili A&HCI; Scopus

ISSN/eISSN 2071-1050

Article

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

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Received: 23 April 2020; Accepted: 14 May 2020; Published: 15 May 2020



Abstract: Background: Due to the COVID-19 pandemic, global authorities have imposed rules of social distancing that directly influence overall physical activity in populations. The aim of this study was to evaluate the trends of changes in physical-activity levels (PALs) in adolescents and factors that may be associated with PALs among the studied boys and girls. Methods: Participants in this prospective study comprised 388 adolescents (126 females; mean age: 16.4 ± 1.9 years) from southern Croatia who were tested at a baseline (before the imposed rules of social distancing) and at a follow-up measurement (three weeks after the initiation). Baseline testing included anthropometric variables, variables of fitness status (done at the beginning of the school year), and PALs. At the follow-up, participants were tested on PALs. PALs were evaluated over an online platform using the Physical Activity Questionnaire for Adolescents. Results: A significant decrease of PALs was evidenced for the total sample (t -test = 3.46, $p < 0.001$), which was primarily influenced by a significant decrease of PALs in boys (t -test = 5.15, $p < 0.001$). The fitness status (jumping capacity, abdominal strength, aerobic endurance, and anaerobic endurance) was systematically positively correlated with PALs at the baseline and follow-up among boys and girls, with the most evident association between aerobic and anaerobic endurance capacities and PALs. Correlations between anthropometric and fitness variables with changes in physical activity (e.g., the difference between baseline and follow-up PALs) were negligible. Conclusions: Differences in PAL changes between genders were probably related to the fact that PALs among boys were mostly related to participation in organized sports. Correlations between baseline fitness status and PALs indicated the importance of overall physical literacy in preserving PALs in challenging circumstances, such as the COVID-19 pandemic observed here.

Keywords: physical activity; pandemic; COVID-19; puberty; fitness; physical literacy

1. Introduction

Physical activity provides numerous benefits, including those directly related to the prevention of cardiovascular diseases, Type II diabetes, colonic cancer, and obesity [1-3]. Therefore, reaching the appropriate physical activity levels is important public-health concern, while some forms of physical activity are proven to be beneficial for persons with severe health conditions [1,4-6]. Knowing the problems related to the lack of regular physical work (due to technological advancements), and reduced active transportation (mostly because of a busy every-day schedule and distances that cannot practically be covered by active transportation), reaching an appropriate level of physical activity is an important global topic [7-9]. The negative influence of reduced physical activity is generally expected in late adulthood. However, knowing that practically all human behaviors related to health are developed and formed in childhood and adolescence, these periods of life are of the utmost importance for the promotion of physical activity [10,11]. Not surprisingly, studies frequently have investigated the level of physical activity and factors that influence physical-activity levels in various age groups, including adolescents [12-15]. Indeed, the period of adolescence is particularly interesting, since there is a growing body of evidence showing that every-day physical activity rapidly decreases in this period of life [15]. Contextual factors that result in such trends are numerous, and include sociocultural, school-related, sport-related, and familial factors [16,17]. However, irrespective of the specific causes for changes in physical-activity levels, the importance of physical activity remains an important issue in global public-health efforts.

The problem of the decrease of physical-activity levels (PAL) in adolescents from Croatia and surrounding countries was not systematically studied until recently. However, negative trends in motor competences and a decrease in physical fitness were evidenced for quite some time, while recent studies confirmed global negative trends of an alarming decrease in PAL [15,18]. Specifically, Stefan et al. studied adolescents from the Croatian capital of Zagreb and evidenced a significant decrease of PAL in both boys and girls between the first and second grades of high school (approximately from 15 to 17 years of age) [18]. In brief, total energy expenditure was reduced by 13 kcal/kg/day on average, with a significant decline of moderate and vigorous physical activity [18]. Supportively, recent study confirmed a significant decrease of PAL in Bosnian and Herzegovinian adolescents between 16 and 18 years [15], which is in line with findings from another Croatian study done with urban adolescents [19].

The current coronavirus disease (COVID-19) is causing global health concerns. With almost 2.5 million confirmed cases, and more than 130.000 deaths (as of April 16th 2020), COVID-19

has an impact on majority of world population, and there is practically no region that is not directly or indirectly impacted by this threat [20]. Although most people infected with the COVID-19 virus experience a mild to moderate respiratory illness and recover without any special treatment, some people (i.e., older individuals, and those with underlying medical problems such as cardiovascular disease, diabetes, chronic respiratory disease, and cancer) are more likely to develop a serious illness. The COVID-19 virus spreads primarily through droplets of saliva or discharge from the nose, and therefore measures of so-called social distancing are considered as an important epidemiological preventive tool. Following the suggestions from World Health Organization, in most countries with confirmed COVID-19 cases authorities introduced some form of social distancing for their citizens in order to prevent spread of the virus through social contacts [21].

While COVID-19 causes detrimental health consequences by itself, it is also clear that social distancing negatively influences the PAL of all age groups. Indeed, Chen et al., in early February 2020, just after the outbreak of the disease, precisely identified an almost certain increase of sedentarism due to the on-going virus and consequent stay-at-home politics [22]. Naturally, in the following period, several papers highlighted the problem of physical activity in such a situation, the necessity of physical activity and its importance for overall health and well-being, and suggested models of physical exercises performed at home during the COVID-19 pandemic [23-25]. However, there is an evident lack of studies that directly examine changes in PAL during the COVID-19 pandemic. To the best of our knowledge, no study has so far reported changes in PAL among adolescents, and factors that may be associated to changes in PAL induced by the COVID-19 pandemic in this age group.

This prospective study aimed to evaluate the level of changes in PAL among adolescents from southern Croatia, specifically for boys and girls. We also explored factors that may be associated to PAL, and changes in PAL for studied adolescents. We hypothesized that the PAL of adolescents will be significantly reduced as a consequence of COVID-19 pandemic and the imposed social-distancing measures

2. Materials and Methods

2.1. Participants and Design

Participants in this prospective study were adolescents from a Croatian coastal region—specifically, from Split-Dalmatia County. During the course of the study, all participants were attending high school in this region, and the majority of them were residentially located in urban regions. At the study’s baseline, they were 16.4 ± 1.9 years of age (from 15 to 18 years). All participants were healthy, meaning that they regularly participated in physical education classes 2 times a week, while some of them were involved in extracurricular sporting activities. Specifically, 35% of the studied participants reported involvement in organized sport activities at the study’s baseline (i.e., when the fitness variables were collected at the beginning of the school year—please see later for the study’s design), and the majority of that 35% reported involvement in competitive sports (e.g., football/soccer, handball, and martial arts). This study was originally initiated as part of another investigation (“The influence of sport and physical activity on substance use and misuse in adolescents from Croatia and Bosnia and Herzegovina; a prospective study”). Therefore, all participants were previously informed about the study aims, risks, and benefits, and parental consent was obtained before the study’s baseline (please see later in the text for the study’s design). The original study was approved by the Ethical Board of the University of Split, Faculty of Kinesiology (EBO: 2181-205-05-02-05-20-004).

The current study included two measurements, baseline (done before the imposed measures of social distancing), and follow-up (done during the period of social distancing). Baseline-tests included anthropometrics, fitness status, and baseline PALs (PAL-BL—please see below for details on variables). For the purpose of this study, it is important to note that in this period, the COVID-19 pandemic was not directly translated into changes in the school schedule and duties in the territory of Croatia. There were also no travel bans or limitations with regard to sporting and social activities in the country’s territory, although people with a confirmed COVID-19 infection were placed in self-isolation, quarantined (detained), and/or hospitalized. The follow-up measurement included the testing of PALs (PAL-FU). In this period, numerous measures related to control over the COVID-19 pandemic had already been implemented. Schools and universities were closed in March 2020, while as of 20 March, the government of Croatia implemented other extensive social-distancing measures, including banning 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 measures of social distancing. At the time of the follow-up testing, local authorities were also entitled to close open playgrounds and parks, which was the case in the region from where the

sample was drawn (Split-Dalmatia County). Meanwhile, there was no strict prohibition of different forms of individual training (e.g., running, cycling). The study's design and the characteristics of the periods of time when the study was done are presented in Figure 1.

2.2. Variables and Measurements

The variables in this study included basic sociodemographic characteristics (age and gender—both collected by regular school evidence and diaries), anthropometrics (body height and mass and the calculated body mass index, $BMI = \text{mass (kg)}/\text{height}^2 \text{ (m)}$), variables of physical fitness, and PALs.

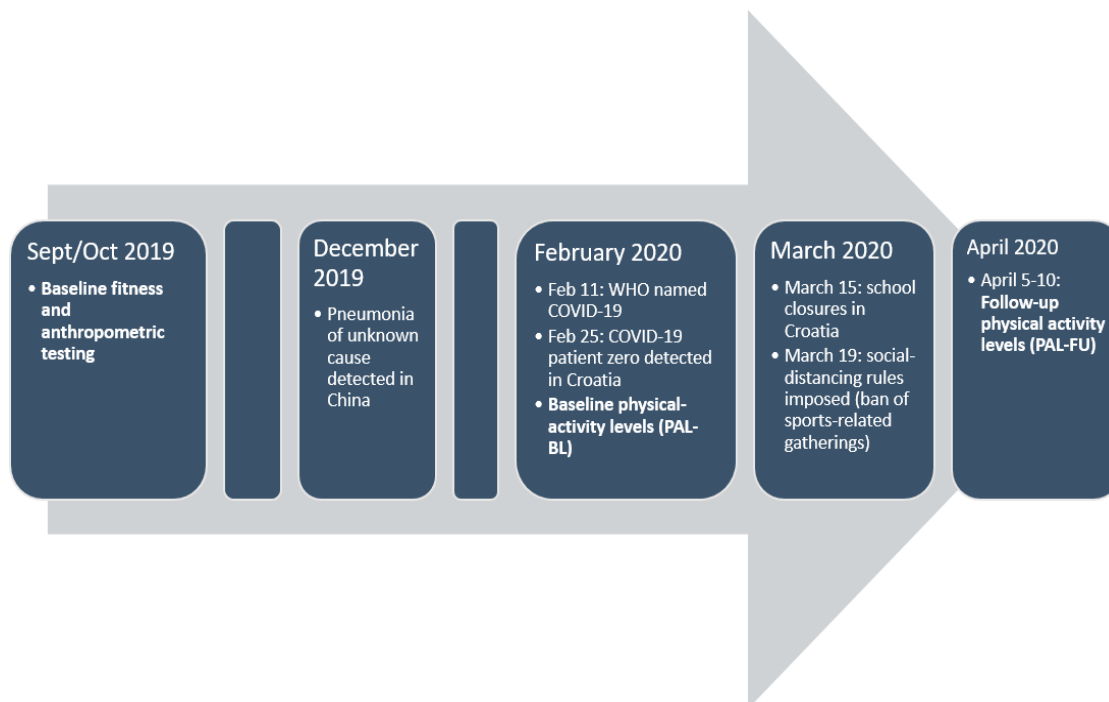


Figure 1. Study design, time frames, and indicators related to the COVID-19 pandemic for the study period.

PAL-BL and PAL-FU were measured by the Physical Activity Questionnaire for Adolescents (PAQ-A), and data were collected through the Internet-based SurveyMonkey platform (SurveyMonkey Inc., San Mateo, CA). The PAQ-A has already been confirmed to be a valid test for the evaluation of PALs in similar samples of participants from Croatia and the surrounding countries, with reliability indicated by a Cronbach's Alpha value of 0.763 [13,23,24]. This questionnaire consists of nine items asking participants to report a seven-day recall. The theoretical score ranged from 0 (minimal) to 5 (maximal physical-activity level). The first 8 items were scored on a 5-point scale and included questions on different types of physical activity (i.e., activity during sports, physical education, active transportation, and free

play); the ninth item did not contribute to the overall score and it was only used for the selection of participants whose results should not be observed as reliable and valid (e.g., evidencing participants who suffered a sort of injury/illness, and whose physical activity was therefore reduced). For the purpose of the study, three scores obtained by PAQ-A were evidenced: (i) PAL-BL; (ii) PAL-FU; and (iii) the delta score ($PAL\Delta$), calculated as the difference between PAL-BL and PAL-FU as previously suggested [13], providing evidence of the magnitude of change in physical activity that occurred as a consequence of the imposed rules of social distancing because of the COVID-19 pandemic.

Physical fitness was evidenced by variables mostly included in the mandatory fitness panel in the Croatian educational system. Therefore, in this study we evaluated broad jumps (broad-jump), the maximal number of sit-ups performed in 60 s (sit-ups), a static hold in hanging with bent arms (bent-arm-hang), a sit-and-reach test (sit-and-reach), a 400 meter run (run-400m), and a multilevel endurance fitness test (multilevel-test). All tests were measured by experienced evaluators—physical education teachers.

The broad-jump was used as a measure of jumping (power) capacity. This test was performed in the gym, from a standing position using standardized equipment (Elan, Begunje, Slovenia). Regular instructions were given to the participants that allowed them to begin the jump with bent knees and to swing their arms to assist in the jump. The test was performed three times within approximately 20 s, and the best result (in cm) was used as the final achievement.

Sit-ups were measured in the gym in order to evaluate the strength of the abdominal region. The test was done with palms locked behind the head and knees bent under 90 degrees. The participants' feet were fixed during the test execution (partner sitting on the feet and holding the examiner's lower legs with two hands), and one testing trial was done with a number of completed repetitions in a 1 min period.

The bent-arm-hang was used as a test of static upper-body strength. The test was performed in the gymnasium over one trial. Participants were helped to perform one pull-up on a standard horizontal bar. When the arms were maximally bent (chin over the bar), a participant had to hold this position for as long as possible. The test result was expressed in seconds.

Sit-and-reach was performed in the gymnasium as a test of flexibility. The test was done using a standard measuring box. Participants sat on the floor with legs stretched out straight ahead. Shoes were removed. The soles of the feet were placed flat against the box, with both knees locked and pressed flat to the floor. With the palms facing downwards and the hands on top of

each other or side by side, participants reached forward along the measuring line placed on the box as far as possible and held that position for 1–3 s while the distance was recorded. The test was done over three trials, and the best result (in cm) was recorded.

Run-400m consisted of running a distance of 400 m at a concrete handball playground of standard dimensions (40 × 20 meters; 3 full circles + 40 m). The test was performed as a measure of anaerobic capacity, and the results were recorded in seconds.

The multilevel-test of aerobic endurance included running continuously between two points that were 20 m apart [25]. Runs of 20 m distance were synchronized with a prerecorded sound signal that beeped at the set intervals. At the beginning of the test, two consecutive beeps were separated by 9 s, and as the test proceeded, the interval between beeps decreased (with an approximately 10% increase in tempo per minute). Consequently, participants had to increase their running speed over the course. The test was finalized when participants were not able to keep in sync with the sound signal. Specifically, one missed lap was allowed, but the tester recorded the time (in minutes and seconds) of the second missed lap as the final result for each participant.

2.3. Statistical Analyses

The parametric nature of the variables was checked with the Kolmogorov-Smirnov test for distribution normality, and all variables were confirmed to be normally distributed. Therefore, means and standard deviations were reported for all variables but gender.

To demonstrate the differences between PAL-BL and PAL-FU, and the possible effect of gender on those differences, repeated measure factorial analysis of variance (ANOVA; gender × measurement) with *t*-test post hoc analyses was calculated. To evaluate the effect sizes, the partial eta squared values (η^2) were also reported (small effect size (ES): >0.02; medium ES: >0.13; and large ES: >0.26).

In order to evidence the association between the anthropometric and fitness variables and PALs, univariate and multivariate correlation analyses were applied. First, correlations between the variables were evaluated by Pearson's correlation coefficients. Next, multivariate associations were evaluated by multiple regressions. Prior to the multiple-regression calculation, predictors were checked for multicollinearity, and due to a high-variance inflation factor, the BMI was not included in the multiple regressions. The analyses were calculated for the total sample and stratified for gender.

For all statistical analyses, a *p*-value of 95% was applied, and the statistical package Statistica ver.13.5 (Tibco Inc., Palo Alto, CA) was used for all calculations.

3. Results

Descriptive statistics for the anthropometric and fitness variables with differences between genders are presented in Supplementary Table S1. In brief, boys were taller, heavier, and achieved significantly better results in most of the fitness variables than girls. Girls performed better than boys in the flexibility test (sit-and-reach). No significant differences between genders were found in BMI and run-400m.

Significant ANOVA effects for PALs were evidenced for the main effects “measurement” (F-test = 4.29, *p* < 0.05; small effect size), “gender” (F-test = 9.47, *p* < 0.001; small effect size), and for interaction (F-test = 12.01, *p* < 0.001; small effect size) (Table 1).

Table 1. Repeated measurement factorial analysis of variance results (F-test, *p* – level of significance, η^2 – effect size)

Variables	Main effects						Interaction		
	Gender			Measurement			Gender x Measurement		
PAL	F-test	<i>p</i>	η^2	F-test	<i>p</i>	η^2	F-test	<i>p</i>	η^2
	9.47	0.001	0.05	4.29	0.04	0.03	12.01	0.001	0.07

Post-hoc analysis evidenced a significant decrease of PALs over the course of the study for the total sample of participants (2.99 ± 0.70 and 2.67 ± 0.60 for PAL-BL and PAL-FU, respectively; *t*-test = 3.46, *p* < 0.001). When differences were separately calculated for gender, the decrease of PALs was significant for boys (3.10 ± 0.78 and 2.79 ± 0.82 for PAL-BL and PAL-FU, respectively; *t*-test = 5.15, *p* < 0.001), but no significant differences were found for girls (2.71 ± 0.66 and 2.59 ± 0.90 , respectively; *t*-test = 0.61, *p* > 0.05). Boys and girls significantly differed in PAL-BL (*t*-test = 4.30, *p* < 0.01) and PAL-FU (*t*-test = 2.11, *p* < 0.05), with higher PALs among boys (Figure 2). Of all the components of the PAQ-A, the most evident decrease was found for sub-scores related to physical education classes (from an average result of 3.1 evidenced at the baseline, to 1.0 (minimum PALs) at the follow-up).

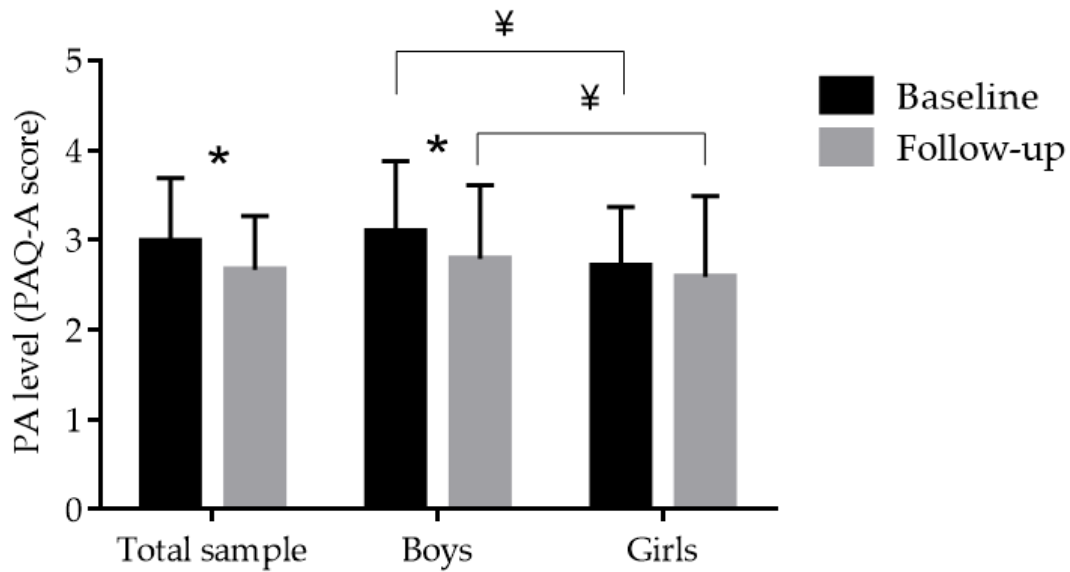


Figure 2. Physical activity levels for total sample, and gender stratified, with indicated significant differences among groups (¥) and between groups (*).

Correlations between the anthropometric and fitness variables with physical-activity values for the total sample, and stratified for gender, are presented in Tables 2–4. When observed for the total sample, PAL-BL was correlated with body height, body mass, BMI, the broad jump, sit-ups, the bent-arm-hang, and the multilevel-test. When gender stratified, the PAL-BL was correlated with sit-ups, the bent-arm-hand, and the multilevel-test among boys. Among girls, significant correlates of PAL-BL were the broad-jump, sit-and-reach, bent-arm-hang, and run-400m (Table 2).

Table 2. Pearson’s product moment correlations between anthropometric and fitness variables, and physical activity for the total sample and separately for boys and girls at the baseline.

Variables	Total (n = 401) Pearson’s R	Boys (n = 271) Pearson’s R	Girls (n = 130) Pearson’s R
Physical activity at baseline			
Body height	0.23 ***	0.01	0.08
Body mass	0.21 ***	0.04	0.07
Body mass index	0.11 *	0.05	0.02
Broad-jump	0.29 ***	0.05	0.24 **
Sit-ups	0.27 ***	0.12 *	0.17
Sit-and-reach	0.03	−0.09	0.25 **
Bent-arm-hang	0.32 ***	0.17 **	0.23**
Run-400m (-)	0.04	0.07	−0.22 *
Multilevel-test	0.36 ***	0.28 ***	0.19*

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, (-) indicates opposite metrics of run-400m, with better achievement evidenced as a lower numerical value

Table 3. Pearson’s product moment correlations between anthropometric and fitness variables, and physical activity at the follow-up for the total sample and separately for boys and girls.

Variables	Total (n = 401) Pearson’s R	Boys (n = 271) Pearson’s R	Girls (n = 130) Pearson’s R
Physical activity at follow-up			
Body height	0.06	0.08	-0.01
Body mass	0.03	0.04	-0.06
Body mass index	-0.02	-0.01	-0.07
Broad-jump	0.11 *	0.03	0.22 *
Sit-ups	0.15 *	0.11	0.16
Sit-and-reach	0.07	-0.04	0.18 *
Bent-arm-hang	0.13 *	0.07	0.17
Run-400m (-)	0.07	-0.12 *	-0.22 *
Multilevel-test	0.12 *	0.13 *	0.13

Note: * $p < 0.05$, (-) indicates opposite metrics of run-400m, with better achievement evidenced as lower numerical value.

Table 4. Pearson’s product moment correlations between anthropometric and fitness variables, and physical activity difference between the baseline and follow-up for the total sample and separately for boys and girls.

Variables	Total (n = 401) Pearson’s R	Boys (n = 271) Pearson’s R	Girls (n = 130) Pearson’s R
Physical activity difference between baseline and follow-up			
Body height	0.17 ***	-0.10	0.09
Body mass	0.18 ***	0.00	0.13
Body mass index	0.13 **	0.06	0.10
Broad-jump	0.17 ***	0.02	-0.02
Sit-ups	0.10 *	0.00	-0.02
Sit-and-reach	-0.05	-0.05	0.03
Bent-arm-hang	0.18***	0.10	0.03
Run-400m (-)	-0.04	-0.08	0.04
Multilevel-test	0.23 ***	0.15 *	0.04

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, (-) indicates opposite metrics of run-400m, with better achievement evidenced as a lower numerical value.

The broad-jump, sit-ups, bent-arm-hang, and multilevel-test were correlated with PAL-FU for the total sample. The run-400m and multilevel-test were positively correlated with PAL-FU in boys, while the broad-jump and run-400m were correlated to PAL-FU among girls (Table 3).

The changes in PALs (e.g., the decrease of PALs between the baseline and follow-up) were associated with the anthropometric and fitness variables, but only in the total sample. The multilevel-test was correlated to $PAL\Delta$ among boys, but no significant correlations between the anthropometric/fitness variables measured at the baseline and $PAL\Delta$ were evidenced in girls (Table 4).

When calculated for the total sample of participants, the bent-arm-hang and multilevel-tests were significant predictors of PAL-BL (11% of the explained variance), sit-ups were partially significantly associated with PAL-FU (2% of the explained variance), while the multilevel-test was the single significant predictor of PAL Δ (6% of the explained variance). Among boys, PAL-BL was determined by body mass and the multilevel-test (16% explained variance), with better PAL-BL for boys who were heavier and had better aerobic endurance. Further, aerobic endurance as evidenced by the multilevel-test was a significant predictor of PAL-FU in boys (6% of the explained variance). The achievement at sit-and-reach and the bent-arm-hang were partial predictors of PAL-BL in girls (9% of the explained variance). No significant multivariate associations were established between the studied predictors and PAL Δ when participants were stratified for gender (Table 5).

Table 5. Forward stepwise multiple regression results between anthropometric and fitness predictors and physical-activity levels criteria for the total sample and stratified for gender and community.

Criteria/Predictors	Total (n = 401)	Boys (n = 271)	Girls (n = 130)
	Beta	Beta	Beta
Physical activity at baseline			
Body height	-0.19	-0.25	
Body mass	0.22	0.38 **	0.15
Sit-and-reach		-0.16	0.18 *
Bent-arm-hang	0.19 *	0.19	0.22*
Run-400m (-)		0.12	
Multilevel-test	0.25 **	0.39 **	
Multiple R	0.38 **	0.43 *	0.31 *
Physical activity at follow-up			
Broad-jump			0.11
Sit-ups	0.15 *	0.10	
Sit-and-reach			0.12
Run-400m (-)		-0.14	-0.17
Multilevel-test		0.30 *	
Multiple R	0.14 *	0.25*	0.29 *
Differences in physical activity between baseline and follow-up			
Body height	0.10		
Body mass			0.13
Multilevel-test	0.18 *	0.15	
Multiple R	0.25 **	0.14	0.12

Note: * $p < 0.05$, ** $p < 0.01$, (-) indicates opposite metrics of run-400m, with better achievement evidenced as a lower numerical value.

4. Discussion

Although the results of the study allow a broad discussion on a problem, we next focus on the most important findings related to the study aims. First, a significant decrease of PALs was evidenced for boys. As a result, our initial study hypotheses may be partially accepted. Second, analyses evidenced a positive correlation between fitness status and physical-activity levels before and after the imposed

rules of social distancing. Specifically, strength and aerobic endurance were evidenced as the most important correlations of PALs in boys. Meanwhile, the physical-activity levels of girls were correlated with all measured fitness variables. Finally, correlations between anthropometric and fitness variables with PAL changes were generally negligible.

4.1. Changes in Physical-Activity Levels and Baseline Correlates of Physical-Activity Levels

There is global concern about PAL reduction as a result of the COVID-19 pandemic [19,20]. Therefore, our study aimed to evaluate changes in PALs among adolescents from southern Croatia that occurred as a result of social distancing imposed due to the COVID-19 pandemic. In general, the results confirmed that adolescents reduced their PALs, but the evidenced changes were gender specific. While the PALs of boys significantly decreased from the baseline to the follow-up measurement, changes were not significant for girls. Although these results may seem controversial, they can be explained by two specific reasons: (i) baseline differences in physical activity and (ii) the nature of the physical activity in the studied groups.

PAL-BL for boys was significantly greater than that in girls. This is supported by previous studies that examined similar topics in Croatia and the surrounding countries [13,16] as well as by studies from other regions where authors regularly evidenced higher PALs for boys than in girls of the same age [26]. Because of such differences, the measures of social distancing resulted in a more evident decrease of PALs in boys than in girls. Second, boys and girls also differ in the “nature” of their physical activity. In brief, investigations done in our region have regularly confirmed that boys are more often involved in competitive sports than girls [27–29]. When follow-up measurements were taken, sporting activities in sports clubs and facilities had been banned. Logically, overall physical activity among boys decreased to a greater extent than among girls.

Anthropometrics were not significantly associated with PALs in boys or in girls. On the other hand, the fitness status was significantly associated with PAL-BL both in boys and girls, with a better fitness status among adolescents with higher PAL-BL. These results may be observed as expected as studies have regularly confirmed such an association among various age groups, including adolescents [30,31]. Irrespective of some differences in associations between genders, we cannot currently specify if fitness status is the factor of influence on the baseline PALs, or if causality should be interpreted in the opposite direction (i.e., higher PALs may positively influence the fitness status). Naturally, it is possible that those adolescents who were more physically active consequently developed their fitness capacities to a greater extent than their less active peers. On the other hand, it is also understandable that adolescents with better developed fitness capacities would feel comfortable in physically demanding activities and would, therefore, report higher PAL-BL. Indeed, both specified causal directions are possible. However, for the purpose of this study, the interpretation of baseline causality is not of the utmost importance, and therefore more attention needs to be paid to the prospective analysis of the influence of the baseline fitness status on PAL-FU.

4.2. Correlates of Activity Levels in the Period of Imposed Rules of Social Distancing

The fact that baseline fitness status determined the PAL-FU both in boys and girls is one of the most important findings of this study. It probably points to the fact that boys and girls of better (initial) fitness status tended to have higher PALs, even in the period of when situations and imposed rules logically prevented them from being physically active in their usual manner (e.g., participation in organized sports and physical-education classes). In explaining these findings, some specifics of the epidemiology of physical activity, as well as factors known to be associated with physical activity, may be helpful [32]. Specifically, studies have already evaluated factors that positively and/or negatively influence PALs. Among the most important ones that could be particularly interesting to both (i) the studied adolescents here and (ii) the specifics of the study period (i.e., the COVID-19 pandemic) are: self-efficacy, an intention to exercise, enjoyment of exercise, perceived health or fitness, self-motivation, social support, the expectation of benefits from exercise, and the perceived benefits [33].

Although we did not collect the data explicitly in this study, it is generally known and therefore expected that adolescents who had a better fitness status at the study's baseline actually had most of the previously specified characteristics (e.g., better self-efficacy, a higher intention to exercise) simply because a better fitness status must be observed as a consequence of systematic work (i.e., physical training). Therefore, involvement in physically demanding activities (that

result in a better fitness status) positively influenced even (i) self-efficacy (as fitter adolescents are more likely to believe in their own ability), (ii) enjoyment in exercise (fitter adolescents already experienced the “positive” hormonal responses to exercise), and (iii) personal awareness of the clear benefits of physical exercising (fitter adolescents are familiar with exercise, they are aware that exercising is effective, and they expect further benefits) [34–36]. Therefore, it is more expected that adolescents who have such characteristics probably participate in a certain type of physical exercise even when settings do not support being active (e.g., in the period of social-distancing).

Further, other previously specified factors may also result in better PALs among adolescents who had better physical fitness at the baseline. For example, it is well documented that parental and peer support is a significant determinant of PALs in adolescence [37–39]. Consequently, it could be expected that adolescents with a better fitness status were properly socially supported in order to be physically active (i.e., experienced parental and peer support), which resulted in higher PAL-BA and a better fitness status. With regard to peer support, it must be stated that, although the environment changed due to the COVID-19 pandemic, social contacts were preserved, at least throughout social networks such as Facebook, Zoom, Skype, and Twitter. In the period when the follow-up measurement was done, parental influence may also have even been increased simply because adolescents were likely to spend more time at home together with their parents. Therefore, we may hypothesize that those adolescents who had experienced social support for an active lifestyle before were likely to experience social support for being physically active after social-distancing rules were employed.

The majority of the previously discussed factors that determined the influence of the baseline fitness level on follow-up PALs can be conceptualized through the term of physical literacy [40]. Specifically, physical literacy can be described as the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engagement in physical activities for life. In an excellent overview of this concept, Mandigo et al. among others indicated that “physical literacy is crucial to the acquisitions by every child, young person, and adult of essential life skills that enable them to address challenges they can face in life” [41]. From our perspective, the previous citation summarizes different aspects of physical literacy that collectively resulted in the relationship between the fitness status and PALs in the current challenging times. Most specifically, adolescents with a higher level of physical literacy were able to apply and use their overall theoretical and practical knowledge even in a situation when regular physical activity was compromised. The adolescents who had better physical literacy

were probably (i) well aware about the necessity and importance of physical activity, (ii) properly motivated to be physically active, and (iii) sufficiently skilled to choose and apply certain types of physical activity, even when circumstances drastically changed.

4.3. Limitations and Strengths

The most important limitation of the study comes from the fact that PALs were not objectively measured but self-reported by participants; therefore, self-reporting bias may appear. However, this limitation does not influence our findings to a great extent as similar bias can be expected for the baseline and follow-up measurement. The fitness level was exclusively observed by field testing procedures that are known to be less reliable than laboratory-based tests. Apart from the BMI, no other indices of body composition were included. Finally, our study included only few sociodemographic variables, which almost certainly limited the possibility of a comprehensive discussion.

This is one of the rare prospective studies that have examined changes in PALs occurring as a consequence of social distancing due to the COVID-19 pandemic, which is probably the most important strength of the investigation. To the best of our knowledge, this is one of the first investigations where correlations of PAL changes were studied and reported for a relatively large sample of participants (adolescents). Knowing the overall importance of PALs in these challenging times, our study, although not the final word on the issue, contributes to knowledge in the field and will induce further investigations.

5. Conclusions

The study evidenced a significant decrease in PALs among adolescents from southern Croatia during the COVID-19 pandemic, but changes in PALs were mostly influenced by a decrease of PALs in boys. This is probably influenced by the fact that the PALs of boys is generally determined by participation in formal sport and organized recreational activities (competitive sport in sports clubs and/or recreation in fitness centers and gyms), while the imposed rules of social distancing reduced their possibility to participate in such activities.

The baseline fitness status significantly influenced PALs at the baseline and follow-up, and the baseline fitness status was consistently related to higher PALs in the period when regular physical activities were limited due to the COVID-19 pandemic. These results could be observed as plausible for other situations where the standard physical-activity patterns of

adolescents would be compromised and/or significantly changed (e.g., school recess, changes of place of residence, different types of personal isolation because of health-related issues, and weather conditions).

From our perspective, physical literacy is the baseline paradigm and milestone that should be conceptualized in public-health efforts targeted toward reaching an appropriate PAL in adolescence but also in the overall population.

We did not find evidence of an association between the studied fitness and anthropometric factors with changes in PALs induced by the COVID-19 pandemic. Therefore, further studies should explore other factors that could possibly influence PAL changes. In doing so special attention should be placed on the living environment.

Supplementary Materials: The supplementary materials are available online at <http://www.mdpi.com/2071-1050/12/10/4072/s1>.

Author Contributions: Data curation, D.S. and M.B.; formal analysis, M.B. and I.K.; investigation, B.G. and N.Z.; methodology, D.S. and B.G.; resources, M.B.; supervision, N.Z.; validation, I.K.; writing—original draft, D.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors are particularly grateful to all participants for their voluntary participation. Additionally, special thanks goes to the school authorities in Split-Dalmatia County who approved the study.

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

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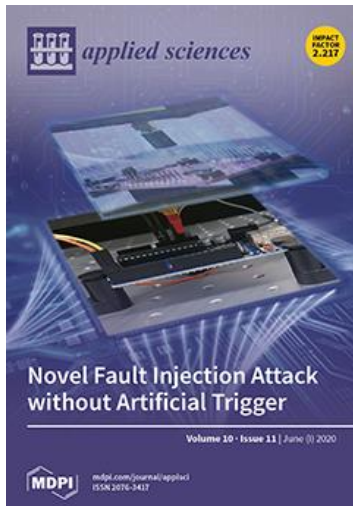
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Study 2: Levels and Changes of Physical Activity in Adolescents during the COVID-19 Pandemic: Contextualizing Urban vs. Rural Living Environment

Zenić, N., Taiar, R., **Gilić, B.**, Blažević, M., Marić, D., Pojskić, H., Sekulić, 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



Applied Sciences-Basel

Appl Sci, 10(11) , 3997.

doi:10.3390/app10113997

Manuscript submitted for publication: 5 May 2020

Manuscript accepted for publication: 5 June 2020

Journal impact factor: 2.679

Indexed/Abstracted in: Current Contents Connect (CCC); Web of Science Core Collection (WoSCC); Science Citation Index Expanded (SCI-EXP); SCI-EXP, SSCI i/ili A&HCI; Scopus

ISSN/eISSN:2076-3417

Article

Levels and Changes of Physical Activity in Adolescents during the COVID-19 Pandemic: Contextualizing Urban vs. Rural Living Environment

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Received: 5 May 2020; Accepted: 5 June 2020; Published: 9 June 2020



Featured Application: The study findings can be applied in the development of modalities and strategies aimed at the preservation of physical activity levels during crises similar to the COVID-19 pandemic.

Abstract: The COVID-19 pandemic and the social distancing implemented shortly after influence physical activity levels (PALs). The purpose of this investigation was to evaluate the changes in PAL and factors associated with PALs among Croatian adolescents while considering the impact of community (urban vs. rural living environment). The sample included 823 adolescents (mean age: 16.5 ± 2.1 years) who were tested on baseline (from October 2019 to March 2020; before COVID-19 pandemic in Croatia) and follow-up (in April 2020; during the COVID-19 pandemic and imposed rules of social distancing). Baseline testing included anthropometrics, physical fitness status, and evaluation of PALs, while follow-up included only PALs (evaluated by a standardized questionnaire through an internet application). The results showed a significant influence of the living environment on the decrease of PAL, with a larger decrease in urban adolescents. Logistic regression showed a higher likelihood for normal PALs at baseline in adolescents who had better fitness status, with no strong confounding effect of the urban/rural environment. The fitness status of urban adolescents predicted their PALs at follow-up. The differences between urban and rural adolescents with regard to the established changes in PALs and relationships between the predictors and PALs are explained by the characteristics of the living communities (lack of organized sports in rural areas), and the level of social distancing in the studied period and region/country.

Keywords: exercise; predictors; puberty; SARS-CoV-2; lockdown

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 [1]. Tracking the physical activity levels (PALs) is one of the main research interests in public health [2-4], as having sufficient PALs is associated with higher health-related quality of life [5]. Despite the conclusive evidence of the importance of physical activity at all ages, the problem is particularly important in youth, since the PALs in youth over the past few decades have significantly declined [6]. 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 physical activity [6,7]. It is approximated that PALs in adolescents decline with age by a mean of -7% a year [8, 9]. Therefore, there is a global consensus of the importance of tracking the changes in the trends of PALs and related influential factors [10].

Numerous factors influence the PALs, with the emphasis on biological, psychological, social, and environmental factors [11]. Over the last decade, interest has risen in the investigation of the factors that directly or indirectly influence PALs in children and youth [12,13]. However, studies confirmed the importance of living environment on lifestyle and consequently its influence on PAL [14,15]. 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 [16]. This is indirectly confirmed in studies conducted with Italian, Polish, Austrian, Cyprus, Portuguese, Spanish, and Slovak children and adolescents [14,17-22]. Children and adolescents living in urban vs. rural communities regularly differ not only in PAL (with higher PALs in urban adolescents) but also in fitness status and anthropometric/body built indices [15,21,23,24].

Although PALs are generally known to be influenced by certain personal (individual) characteristics (i.e., motivation, self-esteem, and conative facets), considering the established differences in PALs between rural and urban communities, it is expected that some specific factors associated with a community also determine the PAL among adolescents [22]. Indeed, 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 [15,25]. Logically, 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) [19,26].

COVID-19, which was recognized in December 2019, 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 [27,28]. 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) [29]. Therefore, a significant reduction in PAL was expected [30]. The claims about decline of the PALs as a result of COVID-19 pandemic 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 PALs (as measured by the average number of steps per day) was 7%–38% when compared to the same period for 2019 [31]. Additionally, during the COVID-19 pandemic schools are closed and physical education classes are inaccessible. Therefore, the decrease in PALs would be particularly evident in children and adolescents [32].

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. In the recent investigation Sekulic et al confirmed higher decrease of the PALs in males than in females, which was explained by low levels of PALs in girls before COVID-19 pandemic, and highlighted the necessity for further studies which will take into account possible influence of various environmental factors on changes in PALs [33]. However, to the best of our knowledge no study examined the changes in PALs 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 PALs as a result of the COVID-19 pandemic, will be lower in adolescents living in rural communities than those living in urban communities.

2. Materials and Methods

2.1. Participants and Study Design

The participants in this prospective study were 823 adolescents from a Croatian coastal region. 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: 2181-205-05-02-05-20-004).

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.

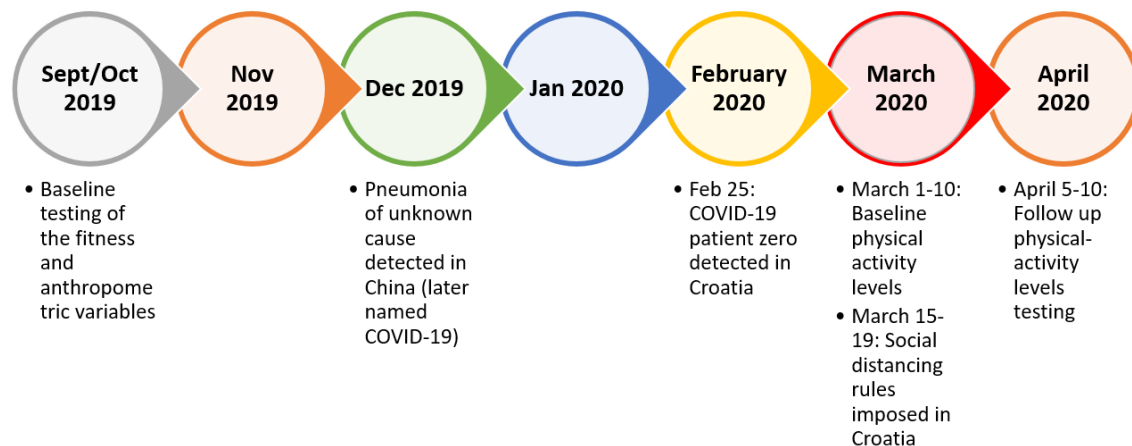


Figure 1. Study design and most important time frames.

Throughout baseline testing, participants were tested on anthropometrics, fitness status (during late October and early September 2019), and baseline PALs (early March 2020). During the PAL-baseline 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-follow-up) was conducted in April 2020 and included only online testing of the 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.

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) [34-36].

The PAQA was used for measuring PALs at baseline and follow-up. 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 ($PA\Delta$), 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 [35,36].

Measures of physical fitness were measured only during the baseline testing, and included six tests: (i) standing broad-jump test (broad-jump), (ii) hanging on the bar with bent arms (bent-arm-hang), (iii) sit-and-reach (sit-and-reach), (iv) multilevel fitness test (multilevel-test), (v) 400 meters run (run-400m), and (vi) sit-ups for 60-seconds (sit-ups). Tests are regularly used in the Croatian educational system and were measured by experienced physical education teachers [37,38].

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 [38]. 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.

2.3. 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.

3. Results

ANOVA results were significant for both main effects (“Environment” and “Measurement”), and for their 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).

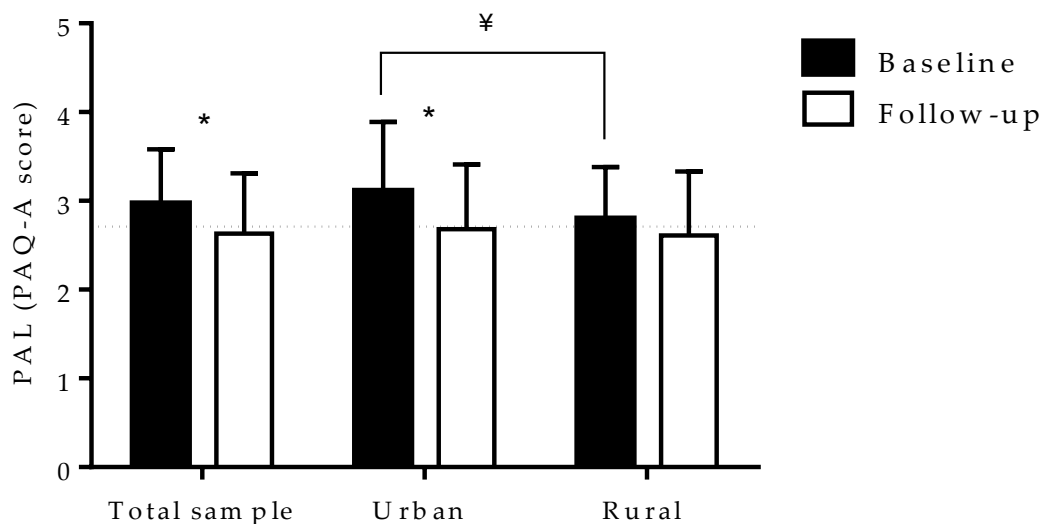


Figure 2. Descriptive statistics for physical activity levels at baseline (before COVID-19 pandemic), and at follow-up (during COVID-19 pandemic) with significant t-test differences (¥ indicates significant ($p < 0.05$) differences between groups, * indicates significant ($p < 0.05$) differences within groups); dotted line presents normal PAL

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 testing waves. 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 3).

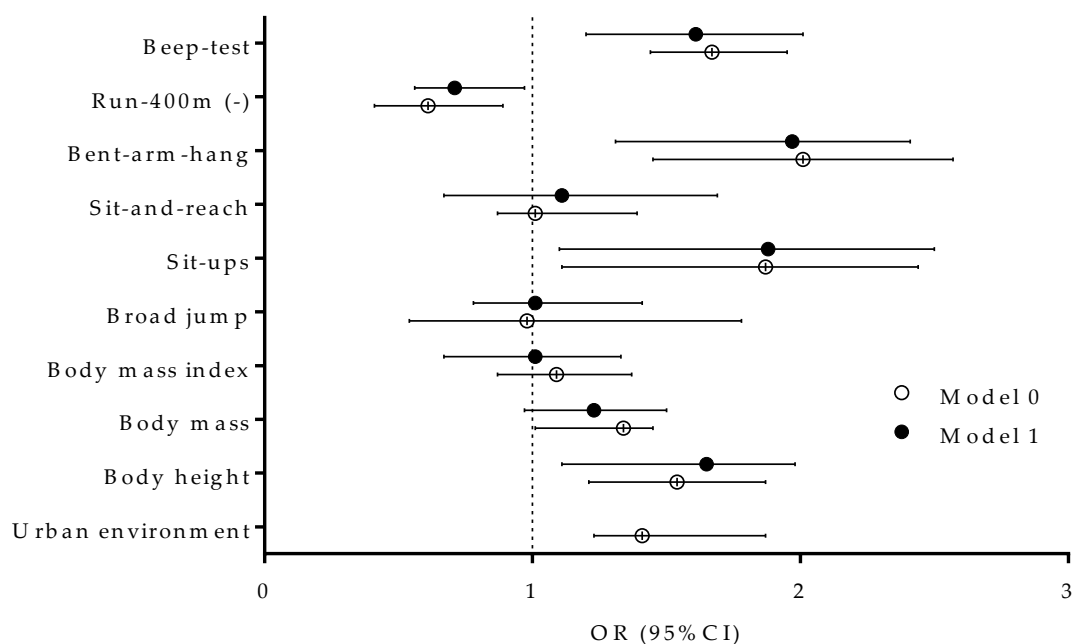


Figure 3. Predictors of normal PAL at baseline (Model 0 – crude logistic regression, Model 1 – logistic regression controlled for urban/rural environment as confounding factor)

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. However, when urban/rural environment was included in the logistic regression calculation as covariate (Model 1), no significant correlation between predictors and PAL was evidenced (Figure 4).

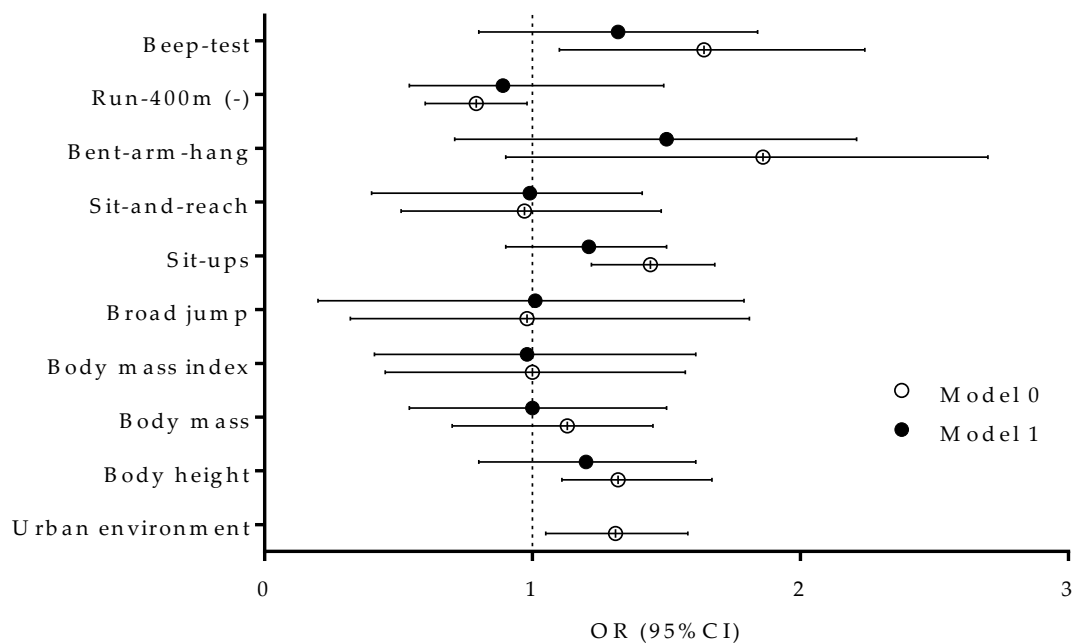


Figure 4. Predictors of normal PAL at follow-up (Model 0 – crude logistic regression, Model 1 – logistic regression controlled for urban/rural environment as confounding factor)

4. Discussion

There are several most important findings of the study. First, the PALs of studied adolescents significantly decreased, but this was mostly influenced by a 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 the factor of the living environment. Therefore, we may support our initial study hypothesis.

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, and the decrease in PAL as a result of social distancing due to the 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 the findings of 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 [39]. 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 [39]. 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 [40].

Cross-sectional

analyses showed better fitness status among Croatian urban children/adolescents than in their rural peers [41]. 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 [42–44]. In brief, the U.S. data also conform to these findings, i.e., that rural adults are less physically active than their urban counterparts [43,44]. Portuguese rural boys were also found to be less physically active than urban boys, but this was not confirmed in girls [42]. 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 socioeconomic differences) [42,45].

Considering the baseline-PAL status, it is not surprising that the PAL of urban adolescents decreased more than in rural adolescents simply because social distancing measures influenced the opportunity to practice organized sports. Specifically, although the influence of social distancing measures was probably not so pronounced for competitive sports (please see later discussion on correlates of follow-up-PAL), the 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 [19]. Therefore, 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.

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 evident influence of the living environment of established relationships. A higher baseline PAL was observed in adolescents who were taller, heavier, and had a higher body mass index and who had better fitness. The baseline PAL being related to anthropometrics is a simple consequence of the higher level of PA among adolescents involved in sports. For the sports that are the most popular 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 [46,47]. For 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 [48]. As a result, the noted association between baseline PAL and anthropometrics 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 discussed in light of the previously discussed association between anthropometrics and baseline PAL (i.e., better fitness, and higher PALs among adolescents involved in sports). Indeed, 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 a better physical fitness status among those adolescents who practice organized and/or non-formal sports [49]. 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. However, this study expands upon previous knowledge since the correlation between physical fitness status and

(baseline) PAL is not influenced by the living community, 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. Irrespective of the fact that measures of social distancing were imposed, the follow-up testing was performed when our participants were not under a strict lockdown (i.e., an emergency protocol that prevents people from leaving the area). In Croatia, authorities provided social distancing guidelines but did not declare a rigid lockdown. Schools, sports clubs, restaurants, and places of social gatherings were closed, and public transportation was limited and was exclusively for work and emergency transport. On the other hand, 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 [50,51]. 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.

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. Additionally, this study

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 (that were not strictly prohibited if social-distancing was respected).

Our study is one of the rare studies where PAL and changes in PAL in the period during the COVID-19 pandemic are shown specifically for urban and rural adolescents. The physical fitness variables were tested as part of a well-organized project by experienced evaluators, and the 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.

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 the COVID-19 pandemic. A disturbing consequence of the measures was that both groups did not meet the recommended NPAL during the crisis. Not surprisingly, the results showed a significant influence of the 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 the 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 their 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, policymakers should introduce strategies that would prevent a 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 promote adolescents being physically active without risking infection of 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.

While this study examined one specific sample of the population (e.g., adolescents), future studies should evaluate changes in PAL for other populations and world regions. Additionally, studies examining the changes in PAL after the COVID-19 pandemic, and factors associated to such changes are warranted. In doing so, special attention should be placed on sociodemographic factors, which could influence the established relationships.

Author Contributions: Data curation, B.G. and M.B.; Formal analysis, N.Z., R.T., D.M., H.P., and D.S.; Investigation, M.B.; Methodology, N.Z. and B.G.; Supervision, D.M.; Writing—original draft, N.Z., R.T., B.G., M.B. and D.S., H.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: Authors are particularly grateful to all children who voluntarily participated in the study. Special thanks go to school authorities who approved the investigation and supported it.

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

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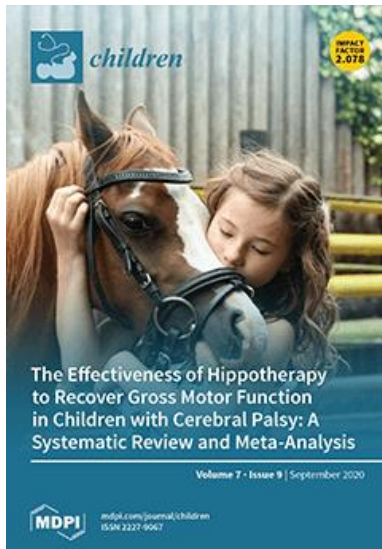
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Study 3: Contextualizing Parental/Familial Influence on Physical Activity in Adolescents before and during COVID-19 Pandemic

Gilić, B., Ostojić, L., Čorluka, M., Volarić, T., Sekulić, D. (2020). Contextualizing Parental/Familial Influence on Physical Activity in Adolescents before and during COVID-19 Pandemic: A Prospective Analysis. *Children*, 7(9): 125. doi.org/10.3390/children7090125



Children

Children, 7(9): 125.

doi.org/10.3390/children7090125

Manuscript submitted for publication: 12 August 2020

Manuscript accepted for publication: 3 September 2020

Journal impact factor: 2.078

Indexed/Abstracted in: Current Contents Connect (CCC); Web of Science Core Collection (WoSCC); Science Citation Index Expanded (SCI-EXP); SCI-EXP, SSCI i/ili A&HCI; Emerging Sources Citation Index (ESCI)

ISSN/eISSN: 2227-9067

Article

Contextualizing Parental/Familial Influence on Physical Activity in Adolescents before and during COVID-19 Pandemic: A Prospective Analysis

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Received: 12 August 2020; Accepted: 2 September 2020; Published: 3 September 2020



Abstract: Parental and familial factors influence numerous aspects of adolescents' lives, including their physical activity level (PAL). The purpose of this study was to evaluate the changes in PAL which occurred during the COVID-19 pandemic, and to evaluate influence of sociodemographic and parental/familial factors on PAL levels before and during pandemic in adolescents from Bosnia and Herzegovina. The sample included 688 adolescents (15–18 years of age; 322 females) who weretested on two occasions: in January 2020 (baseline; before the COVID-19 pandemic) and in April 2020 (follow-up; during the COVID-19 pandemic lockdown). Variables included PAL (measured by the Physical Activity Questionnaire for Adolescents–PAQ-A) as well as sociodemographic-, parental-, and familial factors. A significant decline in PALs was recorded between baseline and follow-up (t -test: 11.88, $p < 0.001$). Approximately 50% of adolescents underwent sufficient PAL at baseline, while only 24% of them were achieving sufficient PAL at the time of follow-up measurement. Paternal education was positively correlated (OR (95%CI): baseline: 6.63 (4.58–9.96), follow-up: 3.33 (1.19–7.01)), while familial conflict was negatively correlated (baseline: 0.72 (0.57–0.90), follow-up: 0.77 (0.60–0.99)) with PALs before and during the pandemic. This study highlights the importance of the parent–child relationship and parental/familial support in promoting physical activity both during regular life and during crises and health challenging situations like the COVID-19 pandemic.

Keywords: parenting; crisis; risk factors; protective factors; puberty; social distancing

1. Introduction

Physical activity is defined as any movement of the body that results in energy expenditure. It can be categorized as occupational, transportational, sports activity, household activities, and leisure-time activities [1]. Maintaining an adequate physical activity level (PAL) is essential for sustaining and improving metabolic, and psychological functions, as well as the overall health and life quality of a human being [2]. Physical activity has a positive influence on the immunological system and can decrease the incidence of communicable diseases such as bacterial and viral infections [3]. However, due to technological advancement, physical activity in modern life has drastically reduced, directly contributing to the development of many non-communicable diseases (e.g., diabetes, cardiovascular diseases, obesity) [4].

Adolescence is considered to be a critical period with regard to maintaining appropriate PAL over the lifespan. First, the trend of PAL decline during aging is evident, with the greatest decrease evidenced during adolescence [5,6]. Globally, 77.6% of boys and 84.7% of girls aged 11 to 17 years achieve an inadequate PAL [7–9]. Second, considering the fact that low PAL in childhood and adolescence has numerous severe health consequences, movement habits attained during this life period impact the maintenance of adequate PAL later in adulthood [10]. Not surprisingly, a great number of studies have investigated the trends of changes in PAL, and factors that influence such trends, with the intention to develop precise and adequate interventions for maintaining/improving PALs in adolescence [11,12]. At the beginning of the year 2020 there was a rapid expansion of the COVID-19 virus, and by March 11, a pandemic had been declared [13]. Countries all around the globe imposed several measures for stopping and slowing down the spread of the disease. Since the virus spreads by saliva droplets, one of the most frequently employed measures was so-called “social distancing” [14]. In general, social distancing is the practice of maintaining a greater than usual physical distance (2 m) from other people or avoiding direct contact with people or objects in public places. The main intention is to minimize exposure and reduce the transmission of infection. In the real world, it meant that kindergartens, schools, universities, sports clubs, and fitness centers were closed. Due to the mentioned measures and related to the movement restrictions and closing of sport and recreation facilities, a decline in PAL was expected and evident [15]. Concerning the fact that there is generally inadequate PAL under normal life circumstances, this kind of movement limitation was naturally considered to have serious health consequences and possibly impair future healthy life habits [16]. Indeed, studies clearly pointed to a significant decrease in PAL

as a result of COVID-19-induced measures of social distancing [17,18]. Factors such as gender, age, social support from parents and peers, parental education, motivation,

self-esteem, knowledge of exercising, and the environment impact the PAL among children and adolescents [19–21]. It would be logical to expect that similar factors influence the PAL during crises like the COVID-19 pandemic. Supportively, recent studies have shown that the pre-pandemic fitness status, gender, and living environment are factors that influenced changes in PAL during the COVID-19 pandemic [17,18,22]. Specifically, a higher fitness status has been associated with a higher PAL before and during the pandemic in Croatian adolescents [17], and a greater PAL decline has been noted for boys in comparison with girls [17]. Similar conclusions were provided in an Italian study [18]. Furthermore, the PALs of adolescents living in urban environments declined more than those of their rural peers due to the closure of sport facilities in urban communities as well as the lower pre-COVID PALs in rural adolescents [22].

Family factors such as parental education, parental social support, and family structure, greatly impact the health-related habits of children, including their PALs [23,24]. Specific to the COVID-19 pandemic, Moore et al. recently reported that parental encouragement and parental co-participation are highly associated with healthy movement behaviors of Canadian children and adolescents during the COVID-19 pandemic [25]. Indeed, parents have an extremely important role in providing guidelines for maintaining adequate PAL, which are crucial for developing healthy movement habits in their children [23]. Due to the stay-home recommendations during the pandemic, youth have been spending more time at home with their parents and are under greater parental influence. Therefore, it is important to elucidate/detect the exact parental and familial factors that influence the PALs of youth in order to create the most appropriate interventions to increase PALs during future similar crises.

Collectively, there is evidence that the COVID-19 pandemic has negatively influenced the PAL among adolescents due to imposed measures of social-distancing and lockdown [15,17,18,22]. However, there is a lack of international data regarding the changes in PAL in adolescents, especially taking into account factors influencing PAL and COVID-19-induced changes in PAL. Finally, previous studies noted familial factors as important determinants of PAL, but the problem is understudied with regard to the COVID-19 pandemic [23,25]. As a result, this study aimed to evaluate the dynamics of changes in PAL among adolescents from Bosnia and Herzegovina (B&H) and to evaluate sociodemographic, and parental/familial factors which may influence PAL before and during the COVID-19 pandemic and imposed lockdown.

2. Materials and Methods

2.1. Participants and Study Design

Participants were 688 adolescents (322 females) from B&H. They were 17 years old at the baseline period of the study (15–18 years of age) and were attending high school. At baseline, all participants were healthy and attended regular physical education classes 2 times per week, and some adolescents also took part in extracurricular sports activities. The sample comprised adolescents residing in three counties, and of the total sample, 65% (445 participants; 202 females) resided in urban centers, and 35% resided in rural communities. Characteristics of the sample are in more details presented in Supplementary Table S1. This study is part of another large study (“Physical activity, substance misuse, and factors of influence in adolescence”) which was previously initiated and approved by Ethical Board of Faculty of Kinesiology, University of Split (EBO: 2181-205-05-02-05-14-005); hence, participants were already informed about the study aims, benefits, and risks, and parental consent was collected before the baseline period of this study.

This study involved two testing occasions: (i) baseline testing conducted before the implementation of measures of social distancing due to the COVID-19 pandemic (January 2020) and (ii) follow-up testing conducted during the time when social distancing measures were implemented (late April 2020) (Figure 1).

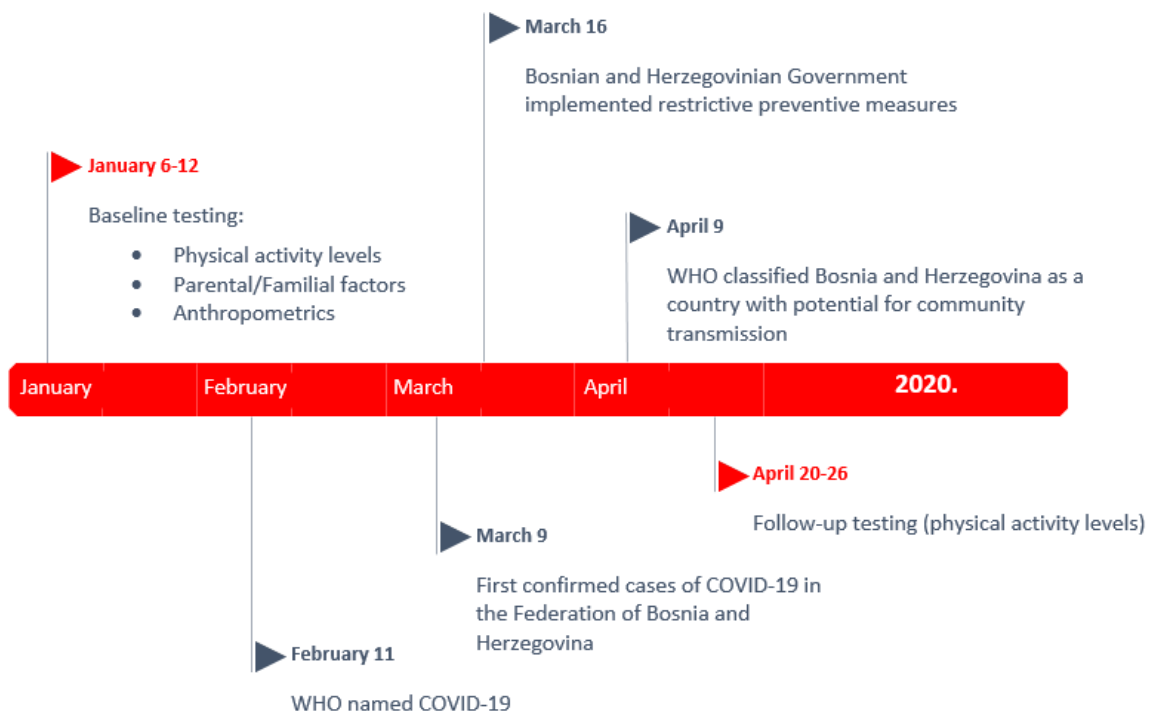


Figure 1. Timeline of the investigation with the most important dates considering COVID-19 globally and in Bosnia and Herzegovina.

The baseline testing included sociodemographic-factors, parental/familial factors, and baseline PALs. The follow-up testing only included follow-up PAL measures. It is important to mention that during the baseline testing, adolescents had generally regular routines, they attended school, sports clubs were open, and there were no traveling bans in B&H. However, during the follow-up testing period, measures of social distancing had been imposed, including the closing of schools, sports clubs, fitness centers, and shopping malls, and public gatherings were restricted. Although the testing was anonymous, to pair the responses in two testing waves, participants were instructed to use anonymous codes for identification purposes. Baseline testing was performed by paper-pen questionnaires as explained in detail previously [26]. Follow-up testing was done using online Google Forms, and participants were contacted by e-mail and asked to participate in the survey while using the identification code used previously for baseline testing. At baseline, the 744 participants were tested, and at follow-up 695 participants responded to questionnaire. However, because of the inconsistency in identification codes, 7 participants of those tested at follow-up were not included in this study, altogether resulting in total sample of 688 participants and retention rate of 92%.

2.2. Variables

Variables included in this study were basic sociodemographic variables (age and gender), familial/parental factors (predictors), and PALs (criteria).

Familial/parental factors consisted of questions about paternal and maternal education level (university degree, college degree, high school, elementary school) and the financial status of the family (under average–average–above average), as well as responses to the following questions: (i) “How often do you have a conflict with your parents/family?” (never–rarely–from time to time–regularly/frequently); (ii) “How often are your parents/family members absent from home, including for their work obligations?” (never–rarely–from time to time–regularly/frequently); (iii) “How often do your parents/family members ask you questions about your friends, scholastic achievements, problems, and other personal issues?” (never–rarely–from time to time–regularly/frequently); and (iv) “How would you rate how much your parents/family care about you and your personal life?” (Very poor care–Low care–My parents/family care about me–My parents/family care about me a lot). The variables were previously applied and found to be reliable and valid in evaluation of the familial/parental factors in similar samples [26].

The Physical Activity Questionnaire for Adolescents (PAQ-A) was used to assess PALs at baseline (baseline-PAL), and at a follow-up measurement period (follow-up-PAL). The PAQ-A has been demonstrated as reliable and valid in a sample of adolescents from Croatia and Bosnia and Herzegovina [8,22]. PAQ-A is a 7-day recall and self-administered questionnaire that was developed to measure the PAL of adolescents aged 14 to 19 years. Item 1 assesses physical activity during spare time (e.g., bicycling, walking, running, dancing, football); Item 2 assesses physical activity during physical education classes; Item 3 assesses physical activity during lunch break; Item 4 assesses physical activity right after school; Item 5 assesses physical activity during the evenings; Item 6 assesses physical activity during the weekend; Item 7 assesses general physical activity during free time (“describes you best”); Item 8 questions the involvement in physical activity on each day of the week; and Item 9 is used to identify participants who are sick, injured, or have any other cause for reduced physical activity and is not used in the final score. Items 1 to 8 are scored on a scale from 1 to 5, with 1 representing no activity or a low activity level and 5 representing a high activity level. The final theoretical PAQ-A score is calculated as the arithmetic mean of the scores from the first 8 items [27]. Apart from the raw PAQ-A results, for the purpose of statistical analyses in this study (details described later in the paper), the results of the baseline-PAL and follow-up-PAL were dichotomized, and scores below 2.73 were considered low-level-PAL, while scores above 2.73 were considered appropriate-PAL, as suggested in previous studies [28,29].

2.3. Statistical Analyses

The normality of the distribution was checked with the Kolmogorov–Smirnov test. Afterwards, means and standard deviations were calculated for PAQ-A (PAL) and age, while percentages and frequencies were calculated for other variables.

Differences between baseline- and follow-up-PAL for the sample as a whole and separately for boys and girls were identified by t-tests for dependent samples. Differences between boys and girls for PAL results and age were calculated by t-tests for independent samples, and for remaining variables by Mann Whitney U test.

To identify associations between predictors (sociodemographic- and parental/familial-variables) and dichotomized PAL-criteria, logistic regressions were calculated, with Odds Ratios (ORs) and corresponding 95% CI values reported. Since girls were slightly older than boys and preliminary statistics identified significant influence of age and gender on PAL (please see previous text on participants, and later Results for details) logistic regressions were

calculated as crude models (Model 0), and additionally controlled for gender and age as covariates (Model 1). The model fit was checked by the Hosmer Lemeshow test (a statistically significant test indicates that the model does not adequately fit the data). A p-value of 0.05 was applied, and the statistical package Statistica ver. 13.5 (Tibco Inc., Palo Alto, CA, USA) was used for all calculations.

3. Results

The PAL decreased significantly from baseline to the follow-up testing period in the sample as a whole (from 2.98 ± 0.71 to 2.31 ± 0.68 ; t -test: 11.88, $p < 0.001$), as well as when observed separately among girls (2.69 ± 0.49 to 1.95 ± 0.56 ; t -test: 8.88, $p < 0.001$) and boys (from 3.12 ± 0.56 to 2.50 ± 0.44 ; t -test: 10.01, $p < 0.01$). Boys had higher level of PAL than girls at baseline (t -test: 12.55, $p < 0.001$) and at the follow-up measurement period (t -test: 11.99, $p < 0.001$) (Figure 2).

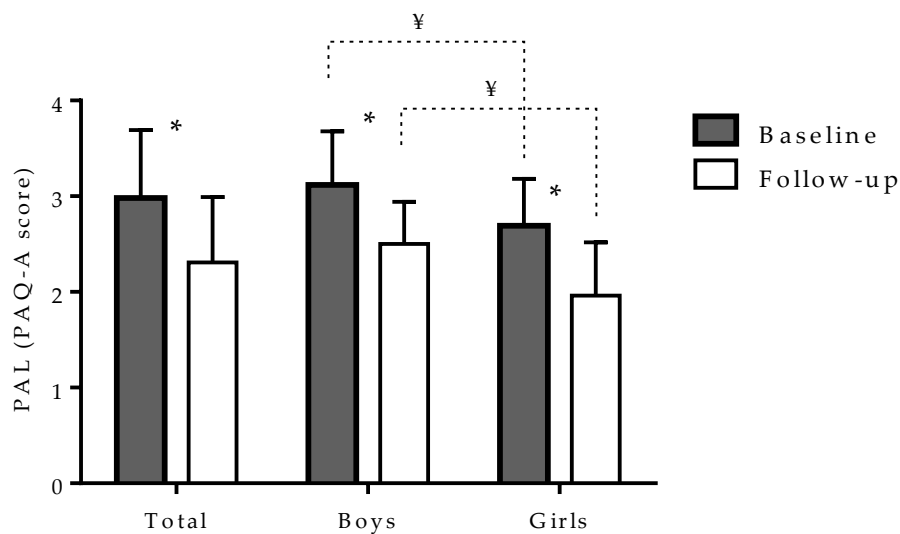


Figure 2. Physical activity levels (PAL) at baseline (before COVID-19 pandemic), and at follow-up (during COVID-19 pandemic) with significant t-test differences (¥ indicates significant ($p < 0.05$) differences between groups, * indicates significant ($p < 0.05$) differences within groups)

Girls were slightly older than boys (17.92 ± 2.00 and 16.96 ± 1.98 , t -test: 1.66, $p = 0.048$). Differences between boys and girls in studied predictors (sociodemographic-, parental/familial-variable) are presented in Supplementary table 1. Boys and girls differed significantly in most

of the studied variables, including: paternal education (higher level reported in boys), maternal education (higher in boys), self-estimated conflict with parents/family (higher in girls), parental/familiar questioning (higher in girls), and parental/familiar care (higher in girls).

Correlates of baseline-PAL are presented in Figure 3. Since crude logistic regression provided evidence of significant influences of gender and age on baseline-PAL, with a higher likelihood of sufficient PAL among boys (OR: 2.50, 95%CI: 1.54–3.03) and lower likelihood of sufficient PAL among younger participants (OR: 0.81, 95%CI: 0.66–0.99), we briefly present only the results of logistic regression model controlled for gender and participants' age as covariates (Model 1). Paternal education was associated with sufficient baseline-PAL (OR: 1.40, 95%CI: 1.10–1.77), while a lower likelihood of a sufficient level of PAL at baseline was found for adolescents who reported a higher level of conflict with parents/family members (OR: 0.72, 95%CI: 0.57–0.90).

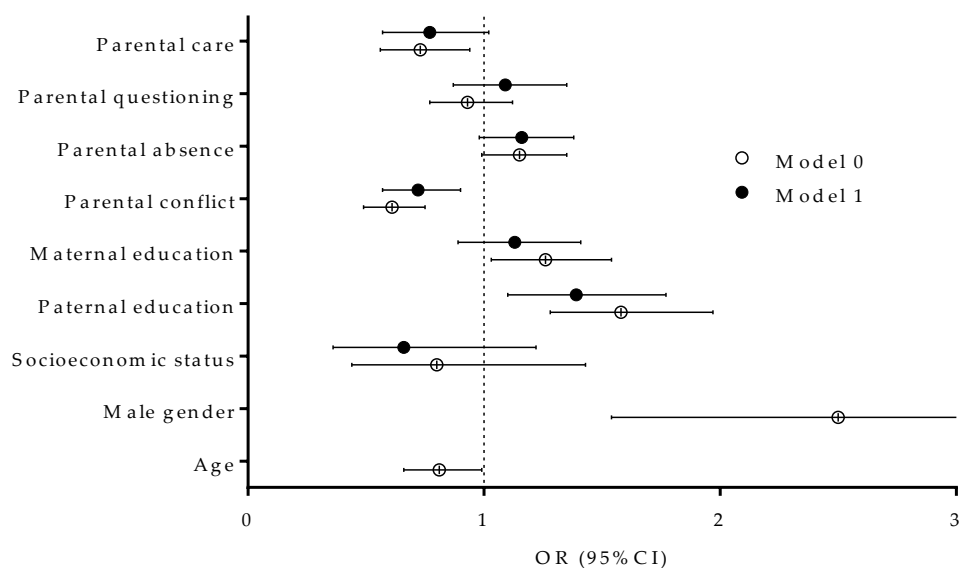


Figure 3. Correlates of sufficient physical activity levels before COVID-19 pandemic (Model 0 – crude logistic regression model non-controlled for covariates, Model 1 – logistic regression controlled for gender and age)

Male gender was positively related to follow-up-PAL, with higher likelihood for sufficient PAL in boys (OR: 2.41, 95%CI: 1.11–4.01). When gender and age were included as covariates in the regression analysis (Model 1), significant correlations were found between familial conflict and follow-up-PAL (OR: 0.77, 95%CI: 0.60–0.99), with a lower likelihood of sufficient PAL at the time of follow-up among adolescents who reported higher level of conflict with their

parents/family. Also, adolescents whose fathers were better educated were more likely to achieve a sufficient PAL during the COVID-19 pandemic and imposed rules of social-distancing (OR: 1.33, 95%CI: 1.19–2.01) (Figure 4).

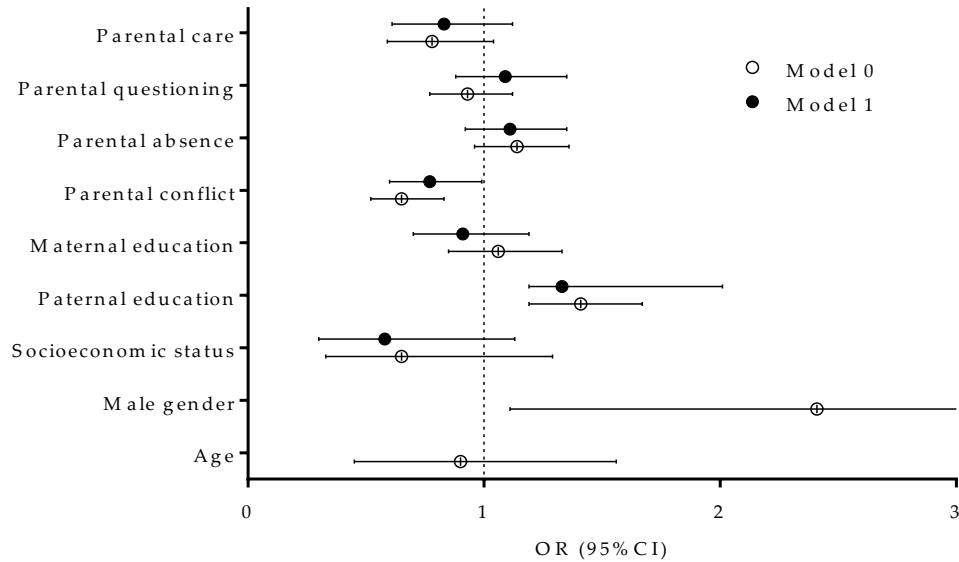


Figure 4. Correlates of sufficient physical activity levels during COVID-19 pandemic (Model 0 – crude logistic regression model non-controlled for covariates, Model 1 – logistic regression controlled for gender and age)

4. Discussion

The most important findings of this study are as follows: (i) PALs significantly decreased during the COVID-19 pandemic, (ii) paternal education was associated with PALs before and during the pandemic, and (iii) conflict with parents/family was a factor that decreased the PAL before and during the pandemic.

4.1. Changes in Physical Activity Levels

The decrease in the PAL as a result of the COVID-19 pandemic and imposed measures of social distancing was expected and already confirmed [15,30,31]. Very recent studies conducted on adolescents from Croatia and Italy have registered significant declines in their PALs [17,18,22]. Specifically, while using the same measurement tool as the one applied here, a Croatian study reported a decrease from 2.99 ± 0.70 to 2.67 ± 0.60 [17]. Therefore, we may highlight that the decline in PALs for adolescents from B&H is somewhat more evident (from 2.98 ± 0.71 to 2.31

± 0.68). There are two plausible explanations for differences between Croatian adolescents and the B&H adolescents studied here: the first is related to differences in the epidemiological situation, and the second is related to the geographical location and differences in climate between the two countries.

First, according to official reports, the epidemiological situation related to the COVID-19 pandemic that occurred in B&H was less favorable than the epidemiological situation in Croatia. Precisely, in B&H, at the time of writing, there have been more than 12,000 confirmed cases of COVID-19 disease, while in Croatia (country with similar population of approximately 4 million residents), there have been less than half as many cases (about 5300 confirmed cases) [32]. Consequently, measures regarding the pandemic in B&H, including movement restrictions, were more rigorous. The more rigorous lockdown measures resulted in greater precaution among people which led to minimized time spent outside of homes, altogether resulting in an even greater decline in PAL for B&H adolescents than for their Croatian peers.

Second, it has been documented that the PAL varies based on region, climate, weather, and season [33]. Specifically, children and adolescents who live in regions with warmer temperatures spend more time outdoors and have higher PALs [33]. Although Croatia and B&H share a long border, B&H is a country with many mountain massifs and valleys and where a temperate-continental climate prevails [34]. This study sampled adolescents from various territories, including continental and mountain parts of B&H. On the other hand, comparative Croatian studies have been conducted in coastal areas with a mild Mediterranean climate [17,22]. Therefore, adolescents observed in recent Croatian studies have been exposed to a mild Mediterranean climate (temperature mostly higher than 10°), and consequently, the weather conditions during the studied period of COVID-19 pandemic were very favorable, so adolescents were able to spend some time outdoors participating in recreational activities while respecting the mandatory measures of social distancing [22]. Collectively, it is likely that the adolescents from B&H studied herein experienced greater declines in PAL than adolescents from Croatia because of (i) the stricter restrictions and measures of social distancing and (ii) the less favorable climate, which together led to lower PALs during the COVID-19 lockdown.

4.2. Paternal Education and Physical Activity Levels

One of the most important findings of our research was that paternal education was associated with the PAL in both testing waves, with a higher PAL in children whose fathers were better educated. Before explaining specific influence of paternal education status on the PAL of their

children, a brief overview of parental influence on a child's PAL is needed. Generally, it is relatively well documented that fathers have a more pronounced influence on the sport-participation and physical activity of children than mothers [35]. Almost 30 years ago, Moore et al. established that children with more active fathers have a 3.5 times greater likelihood of being physically active in comparison to children with inactive fathers [36]. This was confirmed later by Yang et al., who reported that the PAL of fathers is significantly correlated with their children's PAL [37].

Hence, it is considered that children whose fathers are more active are more likely to have greater participation in sports activities than children who have inactive fathers, and the influence of the father is considered to be an important socializing agent for children in relation to sports activities [37]. Supportively, a review study by Beets et al. noted that fathers more frequently initiate and engage in physical activity with their children and use physical activity as a way of socializing and bonding with children [38]. Nowadays, it is accepted that fathers use their own physical activity patterns to directly influence their children's physical activity habits [39]. With regard to differences between maternal and paternal influence, two issues should be contextualized. First, it is deemed that fathers provide a better example and model of sports skills, since men are generally more involved in sports activities than women/mothers [40]. Second, it seems that maternal influence on their children's behavior decreases with age, while the father-child relationship is relatively stable in terms of the PAL [23].

While previous discussion has explained the paternal influence on children's PAL, the specific influence of paternal education level is probably a result of the following factors: first, better paternal education might imply higher consciousness and knowledge of the health benefits of frequent and adequate physical activity. Supportively, previous research has recorded that a higher paternal level of education is associated with better health status of children [41]. Therefore, it is likely that better educated fathers are aware of the benefits of proper PAL during childhood and adolescence and are concerned about the PAL of their children [42]. Second, higher paternal education can lead to a favorable occupational status that contributes to a better financial status, while a better financial status of the family provides appropriate resources for allowing children to participate in organized sports activities [43].

4.3. Familial Factors and Physical Activity Levels

Family conflict was found to have a negative association with PALs among adolescents in both testing waves (before and during COVID-19 pandemic). Although these results are not

surprising, the background should be specifically explained given the overall importance of PAL in adolescence. Under normal circumstances, parents and children usually spend a lot of time together. Parents determine and influence their children's life habits [44], and this logically transfers even to physical activity habits [23]. More specifically, parents have a crucial role in the development of the social customs of their children. Therefore, parental activity habits and support are major determinants of children's physical activity behaviors [45], and such parental influence can be both direct and indirect, influencing the social-cognitive, socio-economic, physical, and cultural environments [46].

There are several main aspects of parental influence on children's PALs [47]. The first one is role modeling which represents the efforts of parents to be active and their interest in physical activity [21]. Concerning social-cognitive theory, modeling is thought to promote observational learning and provide information about what is important and expected [48,49]. Parental role modeling, therefore, represents a parent's activity patterns, attitudes, and efforts to model movement behaviors that their children observe and possibly imitate [50]. Role modeling can also include active involvement of parents in physical activity with their children (co-physical activities) which promotes healthy behavior of both the child and parent [51].

In the already-mentioned review by Gustafson et al., it was stated that parental PALs are positively correlated with increases in children's PAL [50]. It is considered that children whose parents are more active are more likely to be sufficiently active [50]. Additionally, Fuemmeler et al. recorded that the number of active parents influences children's PALs [52]. More precisely, higher attained PALs were found to be achieved by children whose parents were both active, somewhat lower PALs were observed in children who had only one active parent, and the lowest PALs were recorded for children whose parents were both inactive [36,52].

The second aspect of parental influence on children PALs is parental support, which consists of parental encouragement, involvement, and facilitation [21]. Specifically, parental encouragement was positively correlated with various aspects of physical activity (e.g., the intensity of physical activity, attraction to sports, intention to be active, perceived benefits from physical activity, perceived competence, sports participation, and amount of PA) and is considered to be one of the key determinants of children's PAL [38,53]. Furthermore, parental involvement, which represents a more overt level of parental support that includes playing with the child and coaching, has a positive influence on children's PALs [50]. Finally, facilitation represents providing access and opportunities for activity, transportation to sports activity,

payment of the club fees, equipment provision, and providing opportunities for outdoor recreational activities [50].

According to Welk et al., parental facilitation is the most significant predictor of children's involvement and interest in physical activity [47]. A child's participation in sports activities usually demands on parental financial support; therefore, it is logical that youth largely depend on this kind of parental support [54]. It is expected that more active parents will provide more support for sports involvement, provide more sports equipment, and will be personally involved in more frequent outdoor family time activities, through which they can also influence children's physical activity habits [38,50]. Collectively, it is unquestionable that parental influence in forms of role modeling, social support, and social influence affect a child's attraction to physical activity and their perceived competence, through which a child's PAL can be influenced [47]. In challenging situations such as the COVID-19 pandemic, all of the previously explained factors are probably even more pronounced.

In order to explain why family conflict has been found to negatively influence PALs, family cohesion, the opposite phenomenon, is described. Family cohesion is defined as "emotional bonding that family members have toward one another" [55]. It represents normal family functioning, including caring for other family members, familial support, and affection [56]. Trost et al. observed several constructs that can determine family cohesion: family functioning, family connectedness, family bonding, family control, family expressiveness, and parent-child communication [45]. It is expected that families with better family cohesion will create a more supportive environment for healthy-lifestyle habits, including physical activity habits [45]. Supportively, a positive correlation between family cohesion and children's PAL has been recorded, which has been explained by the theory that children from better-functioning families get more support and encouragement to be physically active [45]. This was also confirmed by Ornelas et al. who found positive associations of family cohesion, parent-child communication, and parental engagement in physical activity with PAL [57]. Prospective research by Bigman et al. showed a correlation between family cohesion and conflict with PALs among Mexican adolescents [58]. Adolescents who reported high family cohesion had a 32% greater likelihood of having a higher PAL than adolescents who reported lower family cohesion [58]. In contrast, a significant correlation between family conflict and PAL was not found [58]. Collectively, parents who are physically active, and those who support, encourage, and are personally involved in their children's physical activity, will more likely positively influence their children's engagement in various types of PAL, irrespective of the situation. This is particularly

possible if parents provide children with their own example and create a supportive environment for participation in activity [36]. On the other hand, in situations of conflict between parents and children, the transfer of positive parental behavior (even if such positive behavior exists) to children will not occur.

All of the previously discussed factors probably explain our findings about the negative association between familial conflict and PAL at the baseline and follow-up measurement periods. Specifically, concerning the fact that children and adolescents do not have access to finances and have limited methods of transportation, if parental cooperation does not occur, their involvement in sports activities will be limited. Additionally, the likelihood of spending time in outdoor recreational activities is certainly limited if children are in conflict with their parents, because the parents are the ones who can provide them such activities. It is expected that due to conflict, some children do not have adequate parental influence and, therefore, do not have appropriate support and guidelines for being physically active.

A very recent Canadian National Survey on the Impact of the COVID-19 virus outbreak on movement and play behaviors of Canadian children and youth concluded that as a result of stay-home policies during the pandemic and limited access to sports-recreational facilities, families tried to create new hobbies and activities for maintaining healthy movement habits [25]. Precisely, parents reported that children were more involved in indoor activities, like household chores and activities including dance and physical education exercises, and outdoor activities, like riding a bicycle, walking, playing badminton, street basketball and hockey [25]. The same study established that parental encouragement and co-participation were associated with increases in both indoor and outdoor physical activity [25]. Our results clearly support such considerations, even for adolescents from southeastern Europe.

Naturally, the associations between familial variables and PAL were stronger at baseline than in the follow-up testing period (see Results for details). Indeed, it is likely that all real-life influences appear in regular (i.e., “real-life”) situations. In our case, baseline testing occurred during a period of regular life, when regular physical activities were possible. However, habits developed in such regular situations (pre-pandemic period) are logically translated even to irregular and challenging situations (period of lockdown). Therefore, although correlations obtained between familial factors and PAL at follow up were not so profound, it is still important to point out a certain “transfer of influence”, as already suggested for other indices of overall well-being [17].

4.3. Study Limitations and Strengths

The most important limitation comes from the fact that the investigation is based on self-reporting of the data. Therefore, participants may lean toward socially acceptable answers. However, knowing that the study was absolutely anonymous, there is a lower possibility of such bias. In addition, as in any other studies with self-reported data, there is a question of objectivity. While this is possible for some questions (i.e., parental conflict, socioeconomic status), some questions are less likely to be influenced (i.e., parental education). Additionally, this study did not take into account the possibility that some of the studied adolescents had to prepare for the final exam at the end of high school (e.g., maturita exam) and, therefore, probably had less time and opportunities to be physically active. Finally, this study observed adolescents who were involved in regular schooling system and who were able to respond to follow-up questioning using their own technological resources (i.e., smart phones, computers), which almost certainly influenced the participation at both testing waves and presented results. Therefore, associations between scholastic factors and PAL changes during pandemic should be examined in future

This is one of the first studies which investigated the problem of parental influence on PAL during COVID-19 pandemic, and probably the first one which examined the problem in B&H. Results were comparable to previous studies using the same measurement tools. Therefore, although this study is not the final word on this topic, the authors believe that the findings will improve the knowledge about the problem and initiate further studies.

5. Conclusions

Family conflict was negatively associated with PALs before and during the pandemic. It is logical to assume that children who generally disagree with their parents will not get adequate support for being physically active, which includes financial support, transport to activity, encouragement, and social support in general. In addition, depression, stress, and anxiety, which commonly occur during home-confinement, probably increased existing familial conflict.

During the pandemic and similar challenging health situations, children are at home with their parents more. Therefore, it is important to develop strategies and methods for sustaining and promoting the PAL among all family members, with special attention on youth. However, during the pandemic, many parents were forced to work from home, and therefore, were more

submissive to their children. This increased screen-time and decreased the PAL. Therefore, it is essential to teach parents that they have a key role in influencing children's PAL and that they should put more effort in the form of support, co-participation, and encouragement to ensure children stay active.

This study clearly highlights that it is of utmost importance to promote the significance and benefits of physical activity. We suggest that educative content developed by health and sports professionals that promotes physical activity should be offered through social networks, online apps, and platforms and should be widely promoted and distributed free of charge or with acceptable fees. Furthermore, solutions for providing similar content for people without access to technology and internet should be developed. Additionally, providing the support to participate in sporting organizations for youth is needed as sport is commonly used for promoting socialization, cooperation, respectful competition, and managing conflict. In addition, the provision of psychological support, ensuring that there are sufficient open spaces and encouraging people to get outdoors and try new outdoor activities as much as possible while respecting social-distancing propositions would be beneficial as well. It is important to note that such activities should be available to everyone in terms of financial, transportational, and security aspects (hand hygiene, maintaining proposed social distancing measures) in order to enable participation.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2227-9067/7/9/125/s1>, Table S1: Frequencies (F) and percentages (%) in studied sociodemographic-, parental- and familial factors with differences between boys and girls (MW—Mann Whitney test).

Author Contributions: Data curation, B.G., L.O., M.C. and T.V.; Formal analysis, B.G. and D.S.; Investigation, L.O. and M.C.; Methodology, B.G. and D.S.; Resources, M.C.; Software, T.V.; Writing—original draft, B.G., L.O. and D.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: Authors are particularly grateful to all children who voluntarily participated in the investigation, and their parents. Special thanks goes to school authorities who approved the investigation.

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

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Study 4: Evidencing the Influence of Prepandemic Sports Participation and Substance Misuse on Physical Activity During the COVID-19 Lockdown: a Prospective Analysis Among Older Adolescents

Gilić, B., Zenić, N., Separović, V., Jurčev Savičević, A., Sekulić, D. (2021). Evidencing the influence of prepandemic 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*, 34(2):151-163. <https://doi.org/10.13075/ijomeh.1896.01733>



International Journal of Occupational Medicine and Environmental Health

Int J Occup Med Environ Health, 34(2): 151-163.

doi.org/10.13075/ijomeh.1896.01733

Manuscript submitted for publication: 26 September 2020

Manuscript accepted for publication: 16 December 2020

Journal impact factor: 1.843

Indexed/Abstracted in: Web of Science Core Collection (WoSCC); Science Citation Index Expanded (SCI-EXP), SCI-EXP, SSCI i/ili A&HCI; Scopus; MEDLINE

ISSN/eISSN: 1232-1087/1896-494X

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

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Abstract

Objectives: The physical activity level (PAL) has significantly decreased as a result of the social distancing and lockdown related to the COVID-19 pandemic, but there is a lack of knowledge on the correlates of PAL during the pandemic. The aim of this research was to examine the influence of pre-pandemic sports participation and substance use and misuse (SUM) on PAL during the COVID-19 pandemic. **Material and Methods:** The study included 661 high-school students from Bosnia and Herzegovina (aged 15–18 years, 292 females). The investigation included 2 testing waves: before the COVID-19 pandemic (baseline, January 2020) and during the COVID-19 lockdown (follow-up, April 2020). The variables included PAL as measured by the *Physical Activity Questionnaire for Adolescents*, sports factors, and SUM. **Results:** Sports factors at baseline were positively correlated with PALs at both baseline and follow-up. Smoking tobacco negatively affected PALs at both baseline and follow-up. Alcohol consumption was positively correlated with PAL at baseline but had no effect on PAL at follow-up. **Conclusions:** This study confirmed the importance of sports participation in maintaining PAL during challenging situations, such as the COVID-19 lockdown. The substance-specific influence of SUM on PAL before and during the lockdown points to evident social and cultural aspects of SUM behaviors in adolescents. Further studies evidencing the cumulative effects of PAL decline during the lockdown are warranted. *Int J Occup Med Environ Health.* 2021;34(2)

Key words:

risk factors, tobacco, health behavior, exercise, teenagers, virus diseases

Funding: this study was supported by the Croatian Science Foundation (grant No. DOK-2018-09-1940 entitled “Young Researchers Career Development,” grant manager: Prof. Damir Sekulic).

Received: September 26, 2020. Accepted: December 16, 2020.

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1. Introduction

At the end of 2019, the COVID-19 virus appeared and rapidly spread worldwide, which led to the declaration of a pandemic on March 11, 2020 [1]. Countries around the globe enacted different measures and methods for stopping or slowing the spread of the COVID-19 disease; however, numerous countries imposed measures of self-isolation, home-confinement, and limited social interactions for several weeks or even months. The most important measure undertaken (besides emphasizing hygiene) was enforced social distancing, which included closing daycares, schools, universities, fitness centers, and sports and recreation clubs and limiting social gatherings [1]. As a result of the implied moving restrictions, it was expected that physical activity levels (PALs) would decline. Indeed, studies have confirmed such expectations worldwide [2,3]. This negative trend was particularly evident in adolescents because the COVID-19-induced “lockdown” negatively influenced their life habits to the greatest extent [4]. Therefore, in parallel with investigating changes in PALs, factors that have influenced PALs in adolescents during the COVID-19 pandemic have been examined.

Specifically, recent studies have reported the influence of gender, age, fitness status, living environment and family factors on changes in PALs among adolescents during the COVID-19 pandemic [3-5]. For example, better fitness status was associated with higher PALs among Croatian adolescents before and during the pandemic [4]. The authors of that study explained such findings by theorizing that adolescents with better fitness status have greater knowledge and awareness about staying physically active and exercising (i.e., possess better “physical literacy”), which allowed them to be active even during the lockdown [4]. Additionally, a more evident PAL decrease was found among boys than among girls, probably because of the type of activities that boys partake under regular circumstances (i.e., team sports such as football, basketball, handball) and the fact that sports-recreational facilities were closed during the lockdown [4]. Furthermore, PAL decline was more evident among adolescents from urban living environments than among their rural peers [3]. This finding was explained by the higher prepandemic PALs of urban adolescents and their more frequent participation in organized sports before the pandemic [3]. Finally, a very recent study evidenced paternal education as being positively correlated and family conflict as being negatively correlated with PAL in adolescents both before and during the pandemic [5]. This highlighted the importance of the parent-child relationship and parental support for maintaining PALs among adolescents in challenging situations, such as the COVID-19 pandemic [5].

In regular circumstances, numerous factors influence the maintenance of PALs in youth (i.e., gender, socioeconomic status, living environment, life habits) [6,7]. However, during childhood and adolescence, sports involvement is known to be one of the most influential factors [8]. Indeed, practicing sports is considered one of the main sources of PALs in youth; that is, participating in organized sports activities determines a large share of the total PAL [8]. As evidence of this, it has been recorded that youth who participate in sports activities have higher total PALs than their peers who are not involved in sports [9]. However, there is an evident lack of research that has examined the influence of sports-related factors (sports involvement, achieved sports result, type of sports) on PAL during the COVID-19 pandemic. This is a particularly intriguing issue because during COVID-19 lockdown, regular sports activities were quite limited because of the closing of sports facilities.

The consumption of psychoactive substances (cigarettes, alcohol, drugs; substance use and misuse – SUM) is another factor that can influence PAL. However, there is no conclusive evidence about the relationship between SUM and PAL in adolescents, even under “normal” circumstances. For example, smoking cigarettes has been recorded as a predictor of decreased PALs among US adolescents [10]. On the other hand, a recent study with adolescents from Bosnia and Herzegovina (B&H) concluded that cigarette smoking is not a predictor of PAL, but the authors noted a lower PAL among adolescents who consumed illicit drugs [11]. The association of frequent alcohol consumption among adolescents with higher PALs was recorded among African adolescents, and this is actually supportive of studies that reported high alcohol consumption in sports communities [12]. Therefore, given the previously recorded impact of SUM on PAL in regular and normal circumstances, it is important to evaluate the potential association between SUM and PAL during the COVID-19 pandemic, especially knowing that emerging situations (i.e., crises, weather disasters, and health emergencies), are known to be associated with the increased prevalence of SUM [13].

From the previous brief literature overview, it is clear that negative trends in PAL during the COVID-19 pandemic deserve particular attention. Namely, while a decrease in PAL as a result of the lockdown seems to be unavoidable, it is important to examine the factors related to such trends. Previous studies have evidenced certain protective factors as well as some risk factors for changes in PAL during the COVID-19 pandemic [3,4]. The aim of this research was to extend the knowledge about the problem and to prospectively examine the influence of (i) pre-pandemic sports participation and (ii) pre-pandemic SUM on PAL during the COVID-19 pandemic among adolescents from Bosnia and Herzegovina of:

- Pre-pandemic sports participation
- Pre-pandemic SUM on PALs.

2. Materials and Methods

2.1. Participants

This research included 661 high-school students aged 15–18 years old (292 females) from four counties in Bosnia and Herzegovina (Tuzla, Zenica-Doboj, Herzegovina-Neretva, and West Herzegovina Canton). All of the participants were in good health, regularly participated in physical education classes at least 2 times weekly, and possibly participated in organized sports outside of the school curriculum in the period before the COVID-19 pandemic. Participants were informed about the aims and study protocols and gave their informed consent before the beginning of the study (a parent/legal guardian signed the consent for participants under the age of 18 years). This study is part of a larger study (“Physical activity, substance misuse, and factors of influence in adolescence”) that was approved by Ethical Board of University of Split, Faculty of Kinesiology (EBO: 2181-205-05-02-05-14-005).

This study involved two testing waves:

- before the social distancing measures due to the COVID-19 pandemic were implemented (baseline),
- while the measures were being enforced (follow-up).

During the first testing wave, participants were assessed for sports factors, substance use and misuse, and physical activity levels before the pandemic. The second testing point was during the imposition of movement restriction measures and included only the testing of PALs (Figure 1).

2.2. Variables

Apart from age at baseline and gender (male, female), this study included sport factors, SUM, and PALs.

The *Physical Activity Questionnaire for Adolescents* (PAQ-A) was used for the assessment of PALs at baseline (PAL-baseline) and follow-up (PAL-pandemic). The PAQ-A is a questionnaire that involves questions about the last seven days of activity; it is self-administered and is used for assessing PALs among 14- to 19-year-old adolescents [14]. The PAQ-A results

were observed at baseline and during pandemic. Although being continuous in nature (1– 5), for the needs of this research, the PAL was observed as binomial. The binomial variable is represented with two categories: low/insufficient PAL for results <2.73 and normal/sufficient PAL for results >2.73 as already suggested [15].

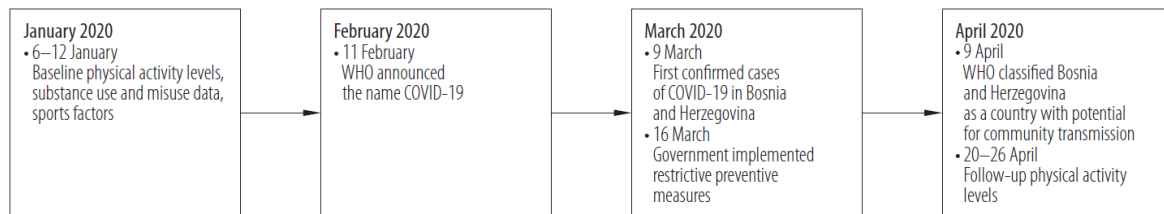


Figure 1. Timeline of the research and most important dates with regard to COVID-19 pandemic in Bosnia and Herzegovina

The sports status was assessed by questions regarding the following:

- participation in individual sports,
- participation in team sports (with the following answers: never been involved, quit, currently involved);
- best competitive result (with the following answers: never participated/competed, local competitions, national competitions, international competitions);
- years of sports involvement (with the following answers: never been involved, less than 1 year, 2-5 years, more than 5 years).

Substance use and misuse were assessed by questions about cigarette smoking, alcohol consumption, and drug consumption. Cigarette smoking was detected by questions about the respondents' smoking habits with the following possible answers: have never smoked, have quit smoking, smoke from time to time, smoke on a daily basis <10 cigarettes, smoke on a daily basis ≥ 10 cigarettes. Alcohol consumption was detected by the Alcohol Use Disorders Identification Test (AUDIT). Participants were divided into two groups: harmful drinkers and nonharmful drinkers, according to a referent score of 11 pts in the AUDIT [16]. For the evaluation of drug consumption, the participants were asked about the consumption of several different drugs (hashish, marijuana, heroin, cocaine, sedatives, ecstasy, amphetamines) with 7 potential answers ranging from “never used”, “tried once”, or “tried more than once” to “consumed > 40 times.” Participants were divided into consumers (ever tried) and non-consumers based on these answers [17].

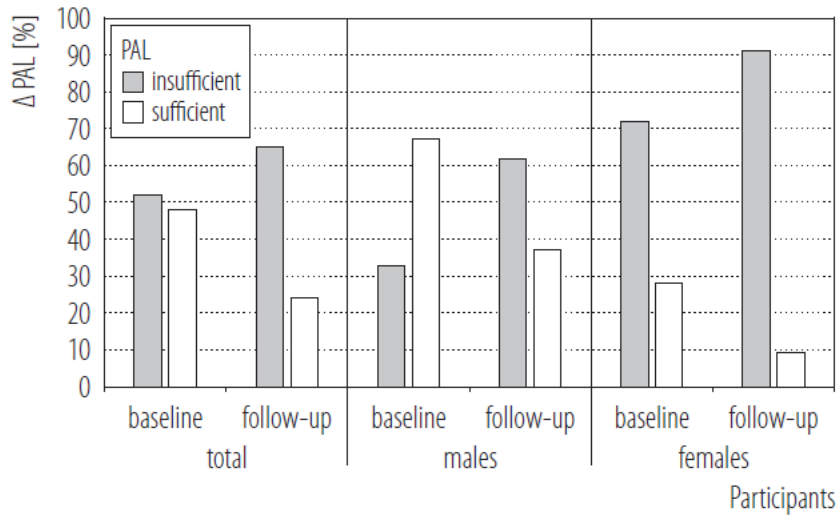
All variables were previously determined to be valid and reliable among a similar sample of participants [15,17].

2.3. Statistics

Descriptive statistics included calculation of frequencies and percentages for all variables. Differences between baseline and follow-up PAL were determined by χ^2 test. Further, differences between groups of adolescents according to the achieved PAL (an insufficient vs. sufficient PAL) at baseline and follow-up were determined by Mann Whitney Z test (for ordinal variables; MWZ), or χ^2 test (for nominal variables). The associations between sports factors and SUM, with dichotomized PALs at baseline and follow-up were determined by logistic regression. Specifically, a sufficient PAL was coded as “1”, and an insufficient PAL as “0”. The numeration of independent variables in logistic regression is presented in Tables. The Odds Ratio (OR), with corresponding 95% Confidence Interval (95%CI) were reported. The Hosmer-Lemeshow test was used to evaluate the model fit, and a statistically significant test indicates that the model does not adequately fit the data). The statistical package Statistica ver. 13.5 (Tibco Inc., Palo Alto, CA, USA) was used for all calculations. For all analyses a p-value of 0.05 was applied.

3. Results

Differences between PALs at baseline (before the COVID-19 pandemic lockdown), and follow-up (during lockdown) are presented in Figure 2. Overall, 48% of adolescents achieved a sufficient PAL at baseline, while only 24% of them achieved sufficient PAL at follow-up. The percentage of boys who had sufficient PAL decreased from 67% at baseline, to 37% at follow-up. The 28% of girls had sufficient PAL at baseline, while only 9% achieved sufficient PAL at follow-up. All differences were significant as indicated by χ^2 test (Figure 2).



For all groups $\chi^2 = 20.56, p < 0.001$.

Figure 2. Changes in the physical activity levels (PALs) from baseline (before the pandemic) to follow-up (during the pandemic), and differences between measurements for the adolescents involved in the study

Table 1 presents descriptive statistics of the studied variables and differences between groups of adolescents according to their PAL at baseline (before the COVID-19 imposed rules of social distancing). Significant differences between the groups were evidenced in individual sport participation (MWZ: 7.83, $p < 0.001$), team sport participation (MWZ: 8.59, $p < 0.001$), experience in sport (MWZ: 8.03, $p < 0.001$), and sports achievement (MWZ: 5.75, $p < 0.001$). In all cases, a sufficient PAL was found in adolescents with higher scores on sports factors. Further, harmful alcohol drinking was higher ($\chi^2 = 4.54, p = 0.03$), while smoking was lower in adolescents who achieved a sufficient PAL at baseline.

Table 1. Descriptive statistics and differences between those adolescents with sufficient- and those with insufficient- physical activity levels (PAL) in the period before (January 2020) and during COVID-19 pandemic lockdown (April 2020) in Bosnia and Herzegovina

	Physical activity levels										Z/ χ^2	p		
	pre-pandemic					pandemic								
	insufficient PAL		sufficient PAL		MW/ χ^2		insufficient PAL		sufficient PAL				MW/ χ^2	
	F	%	F	%	Z/ χ^2	p	F	%	F	%			Z/ χ^2	p
Individual sport					7.83	0.001					6.65	0.001		
yes, still participating (1)	27	8.8	109	34.4			68	14.8	68	41.5				
yes, but quit (2)	101	32.9	103	32.5			155	33.7	49	29.9				
no, never (3)	179	58.3	105	33.1			237	51.5	47	28.7				
Team sport					8.59	0.001					7.95	0.001		
yes, still participating (1)	24	7.8	117	36.9			69	15.0	72	43.9				
yes, but quit (2)	132	43.0	121	38.2			189	41.1	64	39.0				
no, never (3)	151	49.2	79	24.9			202	43.9	28	17.1				
Experience in sport					8.03	0.001					7.48	0.001		
never involved (1)	117	38.1	49	15.5			148	32.2	18	11.0				
< 1 year (2)	74	24.1	63	19.9			107	23.3	30	18.3				
2–5 years (3)	78	25.4	94	29.7			130	28.3	42	25.6				
>5 years (4)	38	12.4	111	35.0			75	16.3	74	45.1				
Sport achievement					5.75	0.001					6.78	0.001		
never been involved/competed (1)	200	65.2	132	41.6			280	60.8	48	29.1				
local competitions (2)	95	30.9	160	50.5			157	34.1	98	59.8				
national competitions (3)	13	4.2	23	7.3			20	4.3	16	9.8				
international competitions (4)	1	0.3	4	1.3			3	0.7	2	1.2				
Smoking					1.76	0.03					1.56	0.04		
never smoked (1)	202	65.8	208	65.6			303	65.9	107	65.2				
quit (2)	15	4.9	15	4.7			19	4.1	11	6.7				
1–2 cigarettes but not daily (3)	53	17.3	66	20.8			88	19.1	31	18.9				
daily smoking <10 cigarettes (4)	14	4.6	18	5.7			20	4.3	12	7.3				
>10 cigarettes daily (5)	23	7.5	10	3.2			30	6.5	3	1.8				
Alcohol drinking ^a											0.47	0.49		
non-harmful drinking (1)	282	91.9	273	86.1			412	89.6	143	87.2				
harmful drinking (2)	25	8.1	44	13.9	4.65	0.03	48	10.4	21	12.8				
Illicit drugs ^a														
no (1)	296	96.4	306	96.5	0.02	0.88	447	97.2	155	94.5	1.79	0.18		
yes (ever tried) (2)	11	3.6	11	3.5			13	2.8	9	5.5				

MW – Mann Whitney Z test.

Numbers in parentheses present numerical values for each response in single variables (later used in logistic regression calculation).

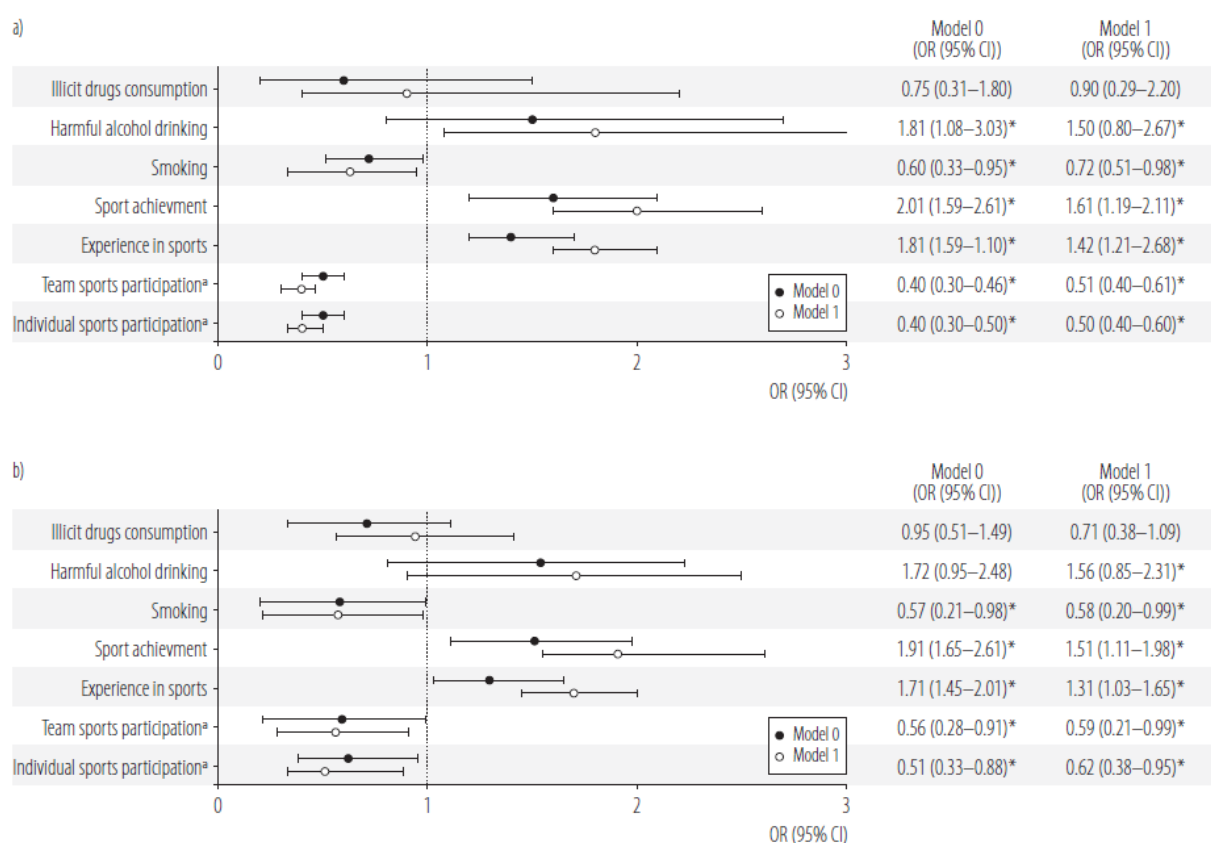
^a Variables where differences between groups were evaluated by χ^2 test.

Individual sports participation, team sports participation, experience in sports and sports achievement observed at baseline were higher in those adolescents who achieved a sufficient PAL at follow-up (MWZ: 6.65, 7.95, 7.48, and 6.78 respectively, all $p < 0.01$). Meanwhile, smoking prevalence was higher in adolescents with insufficient PAL during COVID-19 pandemic lockdown (MW: 1.56, $p = 0.04$).

The logistic regression calculated for dichotomized PAL criteria are presented in Figure 3. While preliminary calculations indicated strong association between male gender and PAL at baseline and at follow-up (OR: 4.11 and 3.98; 95% CI: 2.32-7.11 and 2.11-8.23 for baseline and follow-up, respectively), logistic regressions were calculated as crude model (Model 0), and a model controlled for gender as a covariate (model 1).

When non-controlled for gender, PAL at baseline was correlated to individual sport, team sports participation, experience in sports, sports achievement, smoking, and harmful drinking when non-controlled for gender (Figure 3a).

Correlates of PALs at follow-up (during the lockdown) are presented in Figure 3b. Individual sports participation, team sports participation, experience in sports, and sports achievement were positively correlated with a sufficient PAL. Meanwhile, smoking was lower in those adolescents who had a sufficient PAL at follow-up.



Model 0 – a crude model non-controlled for covariates; model 1 – a logistic regression model controlled for gender as a covariate.

* $p < 0.05$.

^a Variables with opposite metrics (numerical values for each predictor are presented in Table 1).

Figure 3. Correlates of the physical activity levels (PALs) a) before the pandemic and b) during the COVID-19 lockdown, in the adolescents involved in the study – logistic regression results for dichotomized PAL criterion (insufficient PAL – sufficient PAL)

4. Discussion

The main findings of this study were as follows:

- pre-pandemic sports factors were correlated with PAL at both baseline and follow-up,
- smoking cigarettes had a negative effect on PAL at both baseline and follow-up,
- alcohol consumption had a positive effect on baseline PAL, but it had no effect on PAL during the lockdown,
- drug consumption did not have an effect on PAL.

4.1. Sports factors and PAL

These results showed that all sports factors were associated with PALs at baseline and follow-up. It is clear that adolescents who are involved in organized sports activities are generally more active, which explains the association of sports with PAL at baseline (i.e., before lockdown). Therefore, these results support the findings of previous studies that evidenced similar associations in adolescents worldwide [8]. From the perspective of this research, it is important to mention a recent study that evidenced the positive influence of fitness status on PAL before and during the pandemic in Croatia [4]. The authors of that study explained their results highlighting the issue of physical literacy and its influence on PAL [4].

Physical literacy is defined as “the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life” [18]. It is clear that sports participation promotes physical literacy, and it is described as having four main interacting domains:

- physical fitness,
- fundamental motor skill proficiency,
- physical activity behaviors,
- psycho-social factors, including feelings, knowledge, and attitudes [19].

The association between sports participation and physical literacy is frequently confirmed, with higher physical literacy among children actively involved in sports [20]. Altogether, these findings logically explain the positive influence of pre-pandemic sports participation and PAL at baseline.

Moreover, it has been proven that a frequent and long-lasting involvement in organized sports influences the development of motor skills, abilities, attitudes and motivation, which are

important for future physical activity [21]. According to Telama, one of the theories of tracking physical activity, called the ability and readiness hypothesis, states that previous experiences and participation in sports and physical activities make it easier to continue with physical activity or start again after a potential break, even if the types of practiced activity differ [21]. This explanation is plausible here for the established relationship between pre-pandemic sports factors and PAL during the pandemic.

Additionally, adolescents who participate in sports likely have a greater need for activity than their peers even during the pandemic and during periods of restricted movement because they have developed the habit of increased PAL, felt positive physiological changes during the physical activity and are aware of the positive effect of that activity on their health. As physical literacy is observed to affect the capacity for maintaining an active and healthy lifestyle [18], the positive influence of sports participation on PAL during the lockdown becomes even clearer. Therefore, we may anticipate that adolescents who have a sports background are more capable of creating and choosing appropriate activities even during home confinement and situations with limited access to sports facilities and equipment.

For the purposes of this research, it is important to explain another possible influence of sports participation on PAL before and during the COVID-19 lockdown. Namely, as far as authors are aware, even though all sports facilities were closed, sports clubs and coaches were creating different ways to keep their members active to decrease the detrimental effects of reduced physical activity and sports involvement on physical capacity and abilities. Numerous sports clubs organized online training sessions through web-based communication platforms such as Skype, Zoom, and Google Meet and developed adjusted training programs, which is also confirmed among US adolescents [22]. Although the frequency and intensity of the training sessions were definitely not the same as before the pandemic, such strategies certainly helped to maintain PALs during the pandemic among adolescents who were members of sports clubs in the prepandemic period.

4.2. Substance use and misuse and PAL

Studies have rarely investigated the effect of SUM on PAL in adolescents, and to the best of our knowledge, no study has explored this problem specifically for the pandemic period. Thus, it is difficult to compare the results obtained in this study with results from other studies. However, when explaining the obtained results, the overall situation in the country where participants live should be taken into account. In Bosnia and Herzegovina, smoking is socially

acceptable behavior, and the country has one of the highest prevalences of adolescent smoking in Europe: 37% of adolescents smoke cigarettes, and 20% are daily and regular smokers [23]. Similarly, >20% of adolescent boys from B&H are classified as “harmful drinkers” [23]. However, the prevalence of drug usage is low, and with a prevalence of <7% (“have ever tried” drug consumers), the drug consumption rate among adolescents in Bosnia and Herzegovina is among the lowest in Europe [23].

This research noted that cigarette smoking negatively impacted PAL in both testing waves. In other words, youth who reported smoking cigarettes had lower PAL both before and during the pandemic. This could be interpreted in several ways. First, it is well known that cigarette smoking has negative effects on physical performance and functional capacities. More precisely, athletes and active populations are well aware of the fact that smoking leads to immediate and chronic detrimental effects on lung and heart functions that decrease/reduce cardiovascular fitness and physical capacity [24]. Second, smoking cigarettes is not proclaimed or accepted in the social groups of people who practice sports and similar activities, and it does not fit in the social norms of that population [25]. Third, cigarettes are more associated with at-risk youth who care less about their health. More precisely, youth who are characterized as deviant or risk-taking are generally less physically active and are more involved in activities and behaviors that are not good for their health, including smoking cigarettes [26]. The latter can be explained by the opposite phenomenon, that is, youth who regularly participate in physical activity have better health-related behaviors, including healthy eating and lower rates of cigarette smoking [27]. Therefore, together with the previously discussed positive association of sports factors with PAL, the negative correlation between smoking and PAL before and during the pandemic becomes clear.

The finding that alcohol consumption is associated with increased baseline PAL is in accordance with the findings of previous studies. Namely, several studies have shown that adolescents who drink reach higher PALs than their peers who do not drink [28]. Specifically, drinking alcohol is a social activity and is frequently associated with the social and team nature of the physical activity [28]. Additionally, sports celebrations, mass-media alcohol promotions related to sports events, and the influence of active peers (athletes are considered role models) are factors that impact the positive association of alcohol with PAL [25].

The most significant factor associated with alcohol is considered to be post-exercise drinking, or, more precisely, gatherings after sports or other physical activities that include alcohol [25]. Since adolescents during the baseline testing had regular life routines, and restrictive measures

had not been imposed, they were able to participate in all regular social activities including sports and socializing (bars, night clubs) with their peers. On the other hand, an association between drinking and PAL during the pandemic was not found. This is almost certainly related to the fact that overall PAL decreased as a result of pandemic. This decrease was certainly mostly influenced by decrease of PAL in group of competitive athletes, who often consume alcohol. Regarding the previously mentioned social aspect of alcohol consumption after sports, the finding that alcohol did not affect PAL during follow-up is logical.

The finding that illicit drug use did not affect PALs either at baseline or at follow-up may be observed as surprising. Specifically, a review by Kwan et al. [29] recorded a low prevalence of illicit drug use among athletes in the majority of observed studies with the exception of marijuana, which showed equivocal findings. Most likely, the main reason for the negative association of illicit drug use with physical activity and sports participation is that active adolescents are aware of the immediate detrimental physical and psychological effects of illicit drug use on exercise and sports performance [30]. Specifically, illicit drug consumption is associated with time disorientation, confusion, cardiac and respiratory arrest, and decreased concentration, coordination, and reaction time [30]. Additionally, drug use is not an approved behavior or norm among active adolescents and athletes; therefore, it is not socially accepted [26].

However, although one could expect that illicit drug consumption would be negatively correlated with PALs in our study, the lack of association could be explained by the low prevalence of adolescents who use illicit drugs (<4%). Consequently, simply because of mathematical issues (i.e., the small number of subjects in the “positive” group), the OR could not reach statistical significance (95% CI).

4.3. Limitations and strengths

This study involved adolescents from only 1 country included in a regular scholastic system. Also, follow up testing was specific, and availability of the personal IT resources (i.e., computer, smartphone) limited the possibility that all children who were tested at baseline would participate in follow-up testing. Therefore, the results are generalizable to similar samples. In addition, the study did not evidence some potentially important correlates of PAL (i.e., educational and scholastic factors), which almost certainly limited the possibility of a more elaborated discussion. The most important limitation comes from the fact that participants may have leant towards socially acceptable answers. However, the strict anonymity of the testing

and authors' previous experience probably limited this bias. This study is one of the first which evaluated pre-pandemic sport participation and substance misuse, with PALs during the COVID-19 pandemic. Moreover, the study was conducted in the country where substance misuse in adolescence is already evidenced as an important public-health problem. Finally, the use of the measuring instruments which had been previously validated in similar samples of the participants was an important strength of the investigation. Therefore, the authors believe that, while not being the final word on the topic, the investigation will provide new information regarding the problem and will initiate further research.

5. Conclusions

The COVID-19 pandemic, which is a global crisis of an unprecedented scale, has resulted in many restrictions on daily living including social distancing, isolation, and home confinement. Emerging data point out at a considerable decrease in global physical activity levels during the period of social isolation implemented worldwide to reduce disease transmission.

This study adds a significant body of evidence on the pandemic impact on PAL and SUM among adolescents. It has been shown that pre-pandemic sports factors are significantly associated with PALs at baseline and follow-up during the pandemic. While smoking cigarettes has a negative effect on PAL in general, alcohol has initial positive effects which was not observed during follow-up. An interesting finding is that illicit drug use has no association between PAL at all. We assume that the low prevalence of adolescents who use illicit drugs may be a proper explanation.

It is clear that this pandemic will not stop easily. Therefore, urgent actions are needed to normalize and restore physical activity among this population. As an academic and as a medical society, we have to encourage a national strategy to minimize pandemic negative health effects related to reduced physical activity and increased sedentary behavior. Healthy lifestyle behavior, including the absence of substance misuse, should be promoted on a large community scale. Moreover, health-promotion strategies directed at routine physical activities, as well as sports participation, may be helpful to recuperate adolescents from the stress and anxiety they experienced while in lockdown during the COVID-19 crisis. It would be of public health benefit not during this outbreak and crisis recovery period, but as a recommended prevention of health-related impact during any future pandemics, too.

ACKNOWLEDGMENTS

The authors are particularly grateful to their colleagues from the University of Mostar, Bosnia and Herzegovina, for their help and support in the investigation.

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GENERAL CONCLUSIONS

This research brought forth several important conclusions. The PAL drastically changed because of the COVID-19 lockdown in adolescents from Croatia and Bosnia and Herzegovina. The most notable negative change in PAL was observed in boys and urban adolescents, probably influenced by the lack of organized sports activities that were limited during the lockdown. Further, adolescents with better-educated parents and less conflict in the family had an increased likelihood of maintaining their PAL during the pandemic. This finding emphasizes the role that parental support and role modeling have in influencing adolescents' PAL. Moreover, concerning substance use and misuse, adolescents who drink alcohol had increased PAL at baseline, while drinking alcohol did not influence PAL during the pandemic. This is explained by the fact that drinking is a part of gathering after sports activities, which were restricted during the pandemic. Further, smoking was negatively associated with PAL at baseline and follow-up, confirming that smoking is not socially accepted among the active population.

Probably one of the most important findings of this research is that adolescents with better pre-pandemic fitness status and previous sports participation managed to maintain their PAL during the pandemic. This could be explained by the theory that such adolescents have better developed physical literacy skills. Physically literate individuals have motivation, confidence, movement competence, and knowledge and understanding for maintaining physical activities throughout their life course (Whitehead, 2013). As recorded in several studies, adolescents with better physical fitness and those involved in sports activities possess better physical literacy (Lang et al., 2018; Westerbeek & Eime, 2021). This is probably related to increased awareness, motivation, and self-esteem for PA participation among more competent adolescents. Moreover, it is important to emphasize that the cognitive domain of physical literacy, which includes knowledge and understanding of the importance of PA for health, is closely related to fitness status and sports participation (Jefferies et al., 2021; Lang et al., 2018). This means that not only movement competence but also knowledge of PA plays an important role in maintaining sufficient PAL.

Concerning the importance of PA on health status, it is not surprising that numerous studies investigated PAL changes and their correlates during the COVID-19 pandemic in countries all around the globe. Indeed, even several review papers have been published to date (Caputo & Reichert, 2020; Knight et al., 2021; Stockwell et al., 2021; Woods et al., 2020; Yomoda &

Kurita, 2021). Precisely, a study on Spanish children and adolescents aged 3-16 years noted a significant PAL reduction during the lockdown (López-Bueno et al., 2020). A study on participants aged 24±9.33 years from Kosovo reported a higher decrease in PAL among males, younger adolescents, and urban-living participants (Gjaka et al., 2021). Adolescents aged 16-19 years from Italy, Spain, Chile, Brazil, and Colombia decreased PAL during the lockdown, with the most evident decline in adolescents whose mothers were better educated (Ruíz-Roso et al., 2020). Also, a study on adolescents aged 19-20 years from the continental part of Croatia (Zagreb) reported a decline in PAL as a result of COVID-19 lockdown, with the most evident decline in adolescents with previously high PAL (Karuc et al., 2020).

This research has several important practical implications. Precisely, public health authorities can create and design more specific and targeted programs based on the results of our studies. Further, the finding that sports participation and better fitness prevented a more significant decline in PAL, which is most likely related to their physical literacy skills, opens up the space for implementing and investigating the influence of physical literacy on PAL. Indeed, physical literacy facilitates positive health behavior, including increasing PAL (Cairney et al., 2019). Thus, public health authorities, health specialists, and physical education teachers should consider developing programs to improve adolescents' physical literacy. Considering that parents influenced adolescents' PAL during the pandemic, it is important to teach parents about their role in influencing adolescents' PAL and that they should put more effort into co-participation, support, and encouragement. This kind of research, and consequently the interventions, are crucial in the modern world where we are witnessing that the whole population, with emphasis on adolescents, is more and more inactive and has reduced quality of life.

Strengths and limitations

This research has several strengths. The first study included in this doctoral thesis is the first study prospectively investigating the changes in PAL during the COVID-19 pandemic and implemented social distancing measures in Croatia, and probably among the first ones in Europe. Also, this thesis included numerous factors (demographic, environmental, fitness, sports, parental/familial) that were related to PAL during the COVID-19 lockdown, which provides extensive scientific evidence regarding this research problem. Moreover, included studies investigated a large sample of adolescents from Croatia and Bosnia and Herzegovina. Also, measuring instruments (i.e., questionnaires, physical fitness tests) used in this research were previously validated in similar samples and commonly used in related research. Thus, the results of this study can be compared with other studies from different regions, countries, and settings and can encourage further research.

However, there are a few limitations of this doctoral thesis. The most important limitation is the self-reporting of PAL and not objective evaluation. Self-reporting may lead to bias due to the possibility of leaning toward socially desirable answers. The self-reporting bias was reduced by making the questionnaires anonymous (students reported self-designed codes for the possibility to connect the responses from both testing points). Further, this study did not consider the possibility that adolescents in the final grade of high school had to prepare for the final exam (i.e., matura exam) and had less time for PA. As follow-up testing was conducted during the lockdown and adolescents were not in school, there was a possibility that some adolescents had limited personal IT resources (i.e., computer, smartphone), which potentially prevented them from participating in the follow-up testing.

Perspectives for future research

The COVID-19 pandemic is probably not the last public health crisis of this magnitude. Thus, future research should investigate in more detail all factors that could have an influence on PAL in children, adolescents, and older populations, to be able to identify them even in a crisis situation. This will enable public health authorities to recognize the crucial factors they must influence for their fight against the high prevalence of insufficient PAL, which is already one of the main problems of modern lifestyle. Also, the focus should be placed on prospective studies investigating the effects of programs created for developing physical literacy skills of adolescents, as this is probably one of the most important concepts for improving PAL, both during the crisis and during normal life circumstances. Indeed, the concept of physical literacy is not included in the physical education (or other) curriculum in the here investigated countries (Croatia and Bosnia and Herzegovina) and should be better investigated and developed in the future. Therefore, this doctoral thesis opens the space for further research regarding identifying key problems responsible for inadequate PAL, creating programs for improving PAL, and investigating the effectiveness of these programs.

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Biography



Barbara Gilić Škugor is born on September 22nd, 1994, in Split, Croatia. She finished primary and secondary school in Split and continued her education at the Faculty of Kinesiology, University of Split. She enrolled in the Faculty of Kinesiology and was among the best students. She earned the Deans and Rectors award for excellence for the academic year 2012/2013 and was the recipient of the Scholarship of the University of Split from 2015 till 2018. She graduated in 2018 and earned the title of Master of kinesiology. In 2019 she enrolled in a postgraduate doctoral study of Kinesiology at the University of Zagreb. She works as a research assistant at the Faculty of Kinesiology. She published more than 20 research articles cited in the Web of Science database. Her main research interest is investigating physical activity, physical fitness, and physical literacy in adolescents. Probably the most important scientific articles are related to investigating physical activity during the COVID-19 pandemic. She was awarded with the Croatian state science award for research fellows in social sciences in 2020, along with other scientific awards. She was an active sports climber; she was a Croatian champion in 2012, 2013, 2014, 2016, and 2017 and a member of the Croatian sports climbing national team.

Curriculum vitae

Personal information

Croat, born on 22nd September 1994. in Split, Croatia.

e-mail: barbara.gilic@student.kif.hr

Mother tongue: Croatian. Other languages: English (advanced), Italian (beginner)

Education

- 2019-today: Doctoral student (Faculty of Kinesiology, University of Zagreb, Croatia)
- 2016-2018: Master's degree (Faculty of Kinesiology, University of Split, Croatia)

Master's Thesis title: Relationship Between Vitamin D Status and Physical Activity in Preschool Children

- 2013-2016: Bachelor's degree (Faculty of Kinesiology, University of Split, Croatia)

Grants and awards

- Croatian state science award for Research fellows in social science for 2020, Ministry of Science and Education, Republic of Croatia
- University of Split award for Scientific contribution for 2020
- FIEP Vladimir Findak Award for Young Researchers 2019/2020
- Young Researchers Award at the 18th Annual Scientific Conference of Montenegrin Sports Academy and 16th FIEP European Congress „Sport, Physical Education, Physical Activity and health: Contemporary perspectives“, 2021
- Deans award for excellence for academic year 2013/2014 from Faculty of Kinesiology, University of Split
- Rectors award for excellence for academic year 2013/2014 from University of Split
- Award for the best student of the generation at Bachelor's (2016) and master's degree study (2018), Faculty of Kinesiology, University of Split
- Recipient of the scholarship for excellence from the University of Split (2015-2018)

Occupational activities:

- **2022-present: Teaching assistant (Faculty of Kinesiology, University of Split, Croatia)**
- **2019-2022: Researcher/assistant (Faculty of Kinesiology, University of Split, Croatia)**

Researcher at project supported by the Croatian Science Foundation: “Change of direction speed (CODS) and reactive agility (RAG); development of the specific measurement tools, identification of predictors, and evaluation of training effects.”

- **2016-present: Kinesiotherapist (Fitness center Joker, Split, Croatia)**

Kinesiotherapy with people with postural disorders and rehabilitation of sports injuries

Selected publications:

1. **Gilic, B.**, Malovic, P., Sunda, M., Maras, N., & Zenic, N. (2022). Adolescents with Higher Cognitive and Affective Domains of Physical Literacy Possess Better Physical Fitness: The Importance of Developing the Concept of Physical Literacy in High Schools. *Children*, 9(6), 796. <http://dx.doi.org/10.3390/children906079>
2. Sunda, M., **Gilic, B.**, Sekulic, D., Matic, R., Drid, P., Alexe, D. I., Cucui, G. G. (2022). Out-of-School Sports Participation Is Positively Associated with Physical Literacy, but What about Physical Education? A Cross-Sectional Gender-Stratified Analysis during the COVID-19 Pandemic among High-School Adolescents. *Children*, 9(5), 753. <http://dx.doi.org/10.3390/children9050753>
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4. Roklicer, R., Rossi, C., Bianco, A., Štajer, V., Maksimovic, N., Manojlovic, M., **Gilic, B.**, Trivic, T., & Drid, P. (2022). Rapid Weight Loss Coupled with Sport-Specific Training Impairs Heart Rate Recovery in Greco-Roman Wrestlers. *Applied Sciences*, 12(7), 3286. <https://doi.org/10.3390/app12073286>

5. Vrdoljak, D., **Gilic, B.**, Kotic, D. (2022). Fitness Profiling in Top-Level Youth Sport Climbing; Gender Differences. *Sport Mont*, 20(2), 111-116.
6. Kesic, M. G., **Gilic, B.**, Zovko, I. C., Drid, P., Korovljev, D., & Sekulic, D. (2021). Differential impact of COVID-19 lockdown on physical activity in younger and older adolescents—prospective study. *Medycyna pracy*, 72(6), 633-643.
7. Sekulic, D., Ostojic, D., Decelis, A., Jezdimirovic, T., Drid, P., Ostojic, L., & Gilic, B. (2021). The Impact of Scholastic Factors on Physical Activity Levels during the COVID-19 Lockdown: A Prospective Study on Adolescents from Bosnia and Herzegovina. *Children*, 8(10), 877.
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9. Bendic, V., **Gilic, B.**, Lastre, D., Peric, I., & Sekulic, D. (2021). Analysis of the associations between variables derived throughout velocity-based training device and jumping performances in youth soccer players: Multiple regression study. *Acta Gymnica*, 51, e2021.019. <https://doi.org/10.5507/ag.2021.019>
10. Sekulic, D., Ostojic, D., Decelis, A., Castro-Piñero, . José ., Jezdimirovic, T., Drid, P., Ostojic, L., & **Gilic, B.** (2021). The Impact of Scholastic Factors on Physical Activity Levels during the COVID-19 Lockdown: A Prospective Study on Adolescents from Bosnia and Herzegovina. *Children*, 8(10), 877. <https://doi.org/10.3390/children8100877>
11. Blažević, M., **Gilić, B.**, Perić, I., Sekulić, D. (2021) Physical activity before and during COVID-19 pandemic; analysis of changes and correlates in Croatian adolescents. *Kinesiology Slovenica*, 27(2):5-17.
12. **Gilić, B.**, Kosor, J., Jimenez-Pavon, D., Markić, J., Karin, Ž., Domić, D.Š., Sekulić, D. (2021). Associations of Vitamin D Levels with Physical Fitness and Motor Performance; A Cross-Sectional Study in Youth Soccer Players from Southern Croatia. *Biology*, 10(8), 751. <https://doi.org/10.3390/biology10080751>

13. Šunda, M., **Gilić, B.**, Perić, I., Jurčev Savičević, A., & Sekulić, D. (2021). Evidencing the Influence of the COVID-19 Pandemic and Imposed Lockdown Measures on Fitness Status in Adolescents: A Preliminary Report. *Healthcare*, 9(6), 681. <http://dx.doi.org/10.3390/healthcare9060681>
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20. Krolo, A., **Gilić, B.**, Foretić, N., Pojskić, H., Hammami, R., Spasić, M., Sekulić, D. (2020). Agility Testing in Youth Football (Soccer) Players; Evaluating Reliability, Validity, and Correlates of Newly Developed Testing Protocols. *International Journal of Environmental Research and Public Health*, 17(1), 294.

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