Patterns of physical activity during secondary school

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DOCTORAL THESIS

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SUPERVISOR INFORMATION

Maroje Sorić was born in 1979 in Zagreb (Croatia). He is an Assistant Professor at the Faculty of Kinesiology at the University of Zagreb (Croatia) and a Research Associate at the Faculty of Sport, University of Ljubljana (Slovenia). He qualified as a medical doctor at the Zagreb School of Medicine (Croatia) in 2003 and earned his PhD in Biomedicine at the same institution in 2010. His main scientific interests relate to the measurement of physical activity and the relationships of physical activity and inactivity with health and disease. Besides, he investigates the variability of physical activity level during growth and the associations with health and disease. As a member of the NCDRisC collaboration he co-authored a paper on global trends in elevated blood pressure published in Lancet in 2017. In addition to this, he has published more than 30 scientific papers up to date. He was an invited speaker at several international scientific meetings and an active participant in more than 20 national and international scientific conferences. He acts as a reviewer in 8 scientific journals indexed in Web of Science database. According to the Web of Science, his work has been cited more than 900 times, h-index=9. At the same time, Scopus documents more than 1000 citations and Google scholar includes a wider range of publications and totals more than 2200 citations to his work (h- index=12).

Currently he is leading the work package on physical activity in Science and Technology in childhood Obesity Policy (STOP) – a project funded under Horizon2020 program. In addition to this, he is an investigator on another large scientific project - Collective wisdom driving public health policies (CrowdHEALTH),also funded under Horizon 2020 program.

He leads a project within early stage career development program and is one of the principal investigators in the Croatian physical activity in adolescence longitudinal study (CRO-PALS) funded by the Croatian Science Foundation.

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List of abbreviations:

95% CI – 95 percent confident interval

AEE – active energy expenditure

ANCOVA – analysis of covariance

BMI – body-mass index

CRO-PALS – Croatian Physical Activity in Adolescence Longitudinal Study

EE – energy expenditure

GEE – generalized estimating equations

LPA – light physical activity

MET – metabolic equivalent

MPA – Moderate physical activity

MVPA – moderate-to-vigorous physical activity

OR – odd ratio

PA – physical activity

PAEE – physical activity energy expenditure

RM ANCOVA – repeated measures analysis of covariance

S4SF – sum of 4 skinfolds

SB – sedentary behavior

SES – socioeconomic status

SHAPES - School Health Action, Planning and Evaluation System

SP – sport participation

SPSS – Statistical Package for Social Sciences

ST – screen-time

SWA – Sense Wear Armband^{TM}

TEE – total energy expenditure

T_{max} – maximal daily temperature

TSB – total sedentary behavior

TV – television viewing

VO_{2max} – maximal oxygen uptake

VPA – vigorous physical activity

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ABSTRACT

Aim The main aim of the doctoral thesis is to describe the patterns of physical activity during high-school. Three specific goals for three independent studies (Study 1, Study 2 and Study 3) were set. Study 1 aimed to evaluate: (1) the objectively assessed physical activity (PA) patterns in urban 15-year-old male and female adolescents according to school type and (2) to assess the differences in PA between school days and weekend days. Study 2 aimed to evaluate PA, SBs and SP changes between 1st and 2nd grade of secondary school in urban adolescents. Study 3 aimed to evaluate the extent of tracking of physical activity (PA), sports participation (SP) and sedentary behaviors (SB) over 4 years of secondary school education among the Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS) cohort. ***Study 1 methods*** In this cross-sectional study, participants were 187 secondary-school male and female adolescents (61.4% females) attending grammar and vocational schools. Patterns of PA were objectively evaluated using a multi-sensor body monitor for 5 consecutive days. Confounders assessed included biological age, socio-economic status, sum of 4 skinfolds, maximal temperature and the amount of rainfall. ***Study 1 results*** Males and females from grammar schools achieved higher total daily energy expenditure (TEE) and active energy expenditure (AEE) compared to their peers from vocational schools (TEE: 50 ± 12 kcal/kg/day vs. 47 ± 12 kcal/kg/day, $p = 0.02$; AEE: 23 ± 5 kcal/kg/day vs. vocational = 21 ± 6 kcal/kg/day, $p = 0.04$). No differences in time spent in light (LPA), moderate (MPA) or vigorous (VPA) physical activity were noted between the two groups ($p = 0.16$–0.43). Next, a significant decline in TEE and MPA between school days and weekends was observed ($p < 0.001$ and $p = 0.02$, respectively), while VPA remained the same throughout the week ($p = 0.76$). Weekly patterns of PA did not show differences by school type or gender (p for interactions = 0.21–0.50). In addition, significantly lower amount of MPA was accumulated during weekends compared to school days, resulting in lower TEE, regardless of school type or gender. ***Study 1 conclusion*** Policies and strategies on PA in adolescents should focus vocational schools and weekend days. ***Study 2 methods*** In this one year follow-up study, participants were 81 secondary-school students (28 boys and 53 girls) aged 15.5 years at the baseline. PA was assessed with the SenseWear Armband multi-sensor activity monitor, while SBs were assessed by using School Health Action, Planning and Evaluation System (SHAPES) physical activity questionnaire. SHAPES questionnaire was supplemented with 2 questions

inquiring about SP in organized sports in school and outside of school. ***Study 2 results*** PA decreased markedly in both genders between the 1st and 2nd grade of secondary school. Total energy expenditure was reduced by 13 kcal/kg/day on average in boys and by 10 kcal/kg/day in girls (p for both <0.001), while mean daily active energy expenditure decreased by 7 kcal/kg/day (p<0.001) and 3 kcal/kg/day (p=0.04) in boys and girls, respectively. Similarly, the amount of moderate physical activity declined by 49 min/day in boys and 21 min/day in girls (p for both <0.001). At the same time vigorous physical activity was cut by 14 min/day (p<0.001) and 3 min/day (p=0.003) in boys and girls, respectively. Conversely, time spent in SBs did not show any change. ***Study 2 conclusion*** In conclusion, a decline in PA between 1st and 2nd grade of secondary school was marked, but was not accompanied with an increase in SBs. Policies aimed at increasing PA should be targeting the period of entering secondary school in order to offset the observed drop in PA. ***Study 3 methods*** In this investigation, participants were 844 secondary school students (15.6 years at baseline; 49% girls). SHAPES questionnaire was used to assess PA, SP and SB at ages 15, 16, 17, and 18 and continuous tracking was assessed by stability coefficients and odds ratios calculated using generalized estimating equations. ***Study 3 results*** Tracking coefficients for the duration of moderate and vigorous PA and physical activity energy expenditure (PAEE) were similar in both genders and indicated moderate tracking (0.49-0.61), while the stability of SB tended to be somewhat higher over the 4 years of follow-up (0.60-0.72 in boys and 0.60-0.70 in girls). In addition, youth that participated in sports at baseline had16 to 28 time higher odds of continued participation at follow-up, depending on sport type and gender. Finally, both low physical activity and high screen time showed strong tracking in both genders. ***Study 3 conclusion*** In conclusion, PA and SB tracked moderately between age 15 and 18, the tracking of SB being slightly stronger compared to PA. Moreover, strong tracking of low PA and high screen time indicates that detection of these risk factors at the beginning of secondary school should be strongly recommended.

Key words: children, adolescence, epidemiology, SenseWear Armband, secondary school, energy expenditure, secondary school, students, lifestyle habits, exercise, screen time, longitudinal analysis, sitting-time, physical inactivity, sustainability, generalized estimating equations

SAŽETAK

Cilj Glavni cilj ove doktorske disertacije je proučiti obrasce tjelesne aktivnosti tijekom srednje škole. Tri specifična cilja su postavljena za tri nezavisne studije (Studija 1, Studija 2 i Studija 3). Studija 1 je imala cilj za utvrditi: (1) obrasce objektivno mjerene tjelesne aktivnosti kod petnaestogodišnjaka oba spola s obzirom na tip školovanja i (2) razlike u tjelesnoj aktivnosti između školskih dana i dana vikenda. Studija 2 imala je za utvrditi promjene u razini tjelesne aktivnosti i sedentarnih ponašanja između prvog i drugog razreda srednje škole. Studija 3 imala je za cilj utvrditi praćenje tjelesne aktivnosti, sudjelovanja u sportu i sedentarnih ponašanja tijekom četiri godine srednje škole. ***Studija 1 metode*** U ovoj poprečno-presječnoj studiji sudjelovalo je 187 muških i ženskih ispitanika (61.4% djevojaka) koji su pohađali gimnazije i strukovne škole. Obrasci tjelesne aktivnosti mjereni su objektivno koristeći multisenzorni uređaj tijekom 5 uzastopnih dana. Kovarijati korišteni u studiji bili su biološka dob, socioekonomski status, potkožno masno tkivo, maksimalna temperatura i količina padalina. ***Studija 1 rezultati*** Dječaci i djevojčice iz gimnazija ostvarili su veću ukupnu dnevnu količinu utrošene energije (UEP) i aktivne količine utrošene energije (KUE) s obzirom na učenike iz strukovnih škola (UEP: 50 ± 12 kcal/kg/danu vs. 47 ± 12 kcal/kg/danu, $p = 0.02$; KUE: 23 ± 5 kcal/kg/danu vs. strukovne = 21 ± 6 kcal/kg/danu, $p = 0.04$). Nisu pronađene značajne razlike u niskoj, umjerenoj i visokoj tjelesnoj aktivnosti između dvije grupe ($p = 0.16–0.43$). Nadalje, značajno smanjenje UEP i umjerene tjelesne aktivnosti je pronađeno ($p< 0.001$ and $p = 0.02$), dok je razina visoke razine tjelesne aktivnosti ostala nepromijenjena ($p = 0.76$). Tjedni obrasci tjelesne aktivnosti se nisu razlikovali po tipu škole ili spolu (p za interakciju = 0.21-0.50). Značajno manja razina umjerene tjelesne aktivnosti je zabilježena tijekom dana vikenda s obzirom na školske dane, rezultirajući manjom potrošnjom ukupne količine energije, bez obzira na tip škole i spol. ***Studija 1 zaključak*** Strategije za tjelesnu aktivnost bi se trebale koncentrirati na povećanje razine tjelesne aktivnosti u strukovnim školama i tijekom dana vikenda. ***Studija 2 metode*** U ovoj jednogodišnjoj studiji, ispitanici su bili dječaci i djevojke (81, 28 dječaka i 53 djevojke) u prosječnoj dobi od 15.5 godina na početku. Tjelesna aktivnost je mjerena uz pomoć Senswear multisenzornog uređaja, dok su se sedentarna ponašanja mjerila uz pomoć SHAPES upitnika. Upitniku su se dodala dva pitanja o sudjelovanju u sportu u školi i van škole. ***Studija 2 rezultati*** Razina tjelesne aktivnosti značajno se smanjila u oba spola između prvog i drugog razreda

srednje škole. Ukupna energetska potrošnja smanjila se za 13 kcal/kg/danu u prosjeku kod dječaka i za 10 kcal/kg/danu kod djevojaka (*p* vrijednost za oboje <0.001), dok se prosječna dnevna aktivna količina utrošene energije smanjila za 7 kcal/kg/danu (*p*<0.001) i za 3 kcal/kg/danu (*p*=0.04) kod dječaka i djevojaka. Slično, količina umjerene tjelesne aktivnosti smanjila se za 49 min/danu kod dječaka i za 21 min/danu kod djevojaka (*p* za oboje <0.001). U isto vrijeme, razina visoke razine tjelesne aktivnosti smanjila se za 14 min/danu (*p*<0.001) i za 3 min/danu (*p*=0.003) kod dječaka i djevojaka. Vrijeme provedeno u sedentarnim ponašanjima se nije značajno promijenilo. ***Studija 2 zaključak*** U zaključku, smanjenje razine tjelesne aktivnosti između prvog i drugog razreda srednje škole je bilo značajno, ali nije bilo popraćeno povećanjem razine sedentarnih ponašanja. Strategije kojima je za cilj povećanje razine tjelesne aktivnosti umjesto vremena provedenog u sedentarnim ponašanjima bi trebale ciljati populaciju učenika koji upisuju srednju školu. ***Studija 3 metode*** U ovoj studiji, ispitanici su bili 844 učenika srednjih škola (prosječna dob 15.6 godina na početku, 49% djevojaka). SHAPES upitnik je korišten za prikupljanje informacija o razini tjelesne aktivnosti, sudjelovanja u sportu i sedentarnih ponašanja u dobi 15, 16, 17 i 18 godina na temelju kojeg je izračunato sudjelovanje koeficijentima praćenja i omjerima vjerojatnosti koristeći generalizirane jednadžbe. ***Studija 3 rezultati*** Koeficijenti praćenja za trajanje umjerene i visoke razine tjelesne aktivnosti bili su slični za oba spola i označavali su umjereno praćenje (0.49-0.61), dok je stabilnost sedentarnih ponašanja bila nešto viša tijekom četverogodišnjeg praćenja (0.60-0.72 u dječaka i 0.60-0.70 u djevojčica). Mladi koji su sudjelovali u sportu na početku su imali 16 do 28 puta veću vjerojatnost da će se nastaviti baviti sportom, s obzirom na tip sporta i spol. Konačno, niska razina tjelesne aktivnosti i visoka razina vremena provedenog pred računalom, televizijom i mobitelom je pokazala jako praćenje u oba spola. ***Studija 3 zaključak*** U zaključku, tjelesna aktivnost i sedentarna ponašanja pokazala su umjereno praćenje između 15.-te i 18.-te godine, gdje je praćenje bilo malo jače kod sedentarnog ponašanja s obzirom na tjelesnu aktivnost. Nadalje, jako praćenje niske razine tjelesne aktivnosti i visoke razine vremena provedenog pred računalom, televizijom i mobitelom naglašava da je otkrivanje tih rizičnih čimbenika preporučeno na početu srednje škole.

Ključne riječi: djeca, adolescencija, epidemiologija, Senswear Armband, tip škole, utrošak energije, srednja škola, učenici, životne navike, vježbanje, longitudinalne analize, vrijeme provedeno sjedeći, tjelesna neaktivnost, održivost, generalizirane jednadžbe

INTRODUCTION

Context

Physical inactivity has become a major public health problem worldwide (Hallal et al., 2012; Kohl et al., 2012; Lee et al., 2012; Janssen & LeBlanc, 2010), leading to cardiovascular, metabolic and mental diseases and overall mortality (World Health Organization, 2010; Warburton et al., 2006). Available data from 122 countries (representing approximately 88.9% of the world's population) showed that the prevalence of self-reported physical inactivity, defined as not meeting (1) 30 minutes of moderate physical activity (MPA) for 5 days every week, (2) 20 minutes of vigorous physical activity (VPA) for 3 days every week or (3) an equivalent combination of both, was 31.1% in adult population (between ages 18-64) (Hallal et al., 2012).
In children and adolescents, physical inactivity has potential negative health outcomes, including increase in cholesterol and blood lipids, blood pressure and body weight, causing being overweight/obese and having higher likelihood for metabolic syndrome (Janssen & LeBlanc, 2010). In addition, physically inactive children are facing also a greater of non-optimal brain development and cognitive functioning (Chaddock-Heyman et al., 2014). The prevalence of physical inactivity, defined as 60 minutes of MVPA per day, was 80.3% derived from the data from 105 countries (Hallal et al., 2012), with special emphasizes on girls being less active (95%), compared with boys (56%). Using the same cut-off point in Croatia, studies have shown that the prevalence of 'insufficient' PA is 78% and 92% among 15-year old boys and girls, respectively (Currie et al., 2012). Another independent study conducted among 2,869 children and adolescents in Croatia showed similar prevalence of 'insufficient' PA (66.8% in boys and 86.2% in girls) (Jureša et al., 2010). However, the criterion for classification of 'insufficient' PA was defined as not participating in 4 x/week in VPA.

Physical activity also plays an important role in preventing from mental health problems in children and adolescents. Specifically, a systematic review by Biddle and Asare (2011) showed that PA had beneficial effects in reducing the prevalence of depression and anxiety and could potentially improve self-esteem, at least in the short-term. In terms of academic needs higher energy expenditure in secondary school students led to higher levels of physical fitness and

better academic achievement (Pellicer-Chenoll et al., 2015). Participation in extracurricular activities leads to the increased opportunity to socialize with each other, which additionally leads to better academic achievement (Morales et al., 2011). Sport is also one component of PA. Coakley (2011) reported that sport was the effective way to create motor-specific skills convertible into PA, improve health and self-esteem and create positive body image and encouragement, leading to higher social capital and socialization in general. One Croatian study showed that higher levels of family and informal social capital were associated with higher odds of participating in regular MVPA in boys, yet only informal social capital was associated with overall PA in girls (Novak, Doubova and Kawachi, 2016).

Time spent in PA during early childhood is low, due to mean low intensity of PA (Hoos et al., 2003). When children enter primary school, PA significantly increases with approximately 77% and 90% of the total PA being appointed to moderate-intensity and vigorous-intensity PA (Baquet et al., 2007). The peak of PA level is at the age of 13, after which steadily decreases (Van Dijk et al., 2016). Previous studies have shown, that the biggest decline of PA starts at ages 14/15 (Jurakić and Pedišić, 2010). During the period of secondary school (mainly adolescence) PA declines annually for about 7-8% (Dumith et al., 2011). In general, previous studies have shown that children in secondary schools are less likely to meet the PA recommendations of ≥60 minutes of MVPA daily compared to the children in primary schools (Jurakić and Pedišić, 2010). Thus, from the abovementioned evidence it can be seen that the majority of secondary school children do not meet the WHO recommendations and patterns that determine the level of PA should be carefully studied.

As for physical inactivity, time spent in sedentary behavior (SB) has a negative impact on health outcomes (Fornias Machado de Rezende et al., 2014). Specifically in adult population, SB is associated with all-cause mortality, cardiovascular diseases and metabolic syndrome (Fornias Machado de Rezende et al., 2014). In addition, moderate evidence between SB and incidence rates of ovarian, colon and endometrial cancers was found (Fornias Machado de Rezende et al., 2014). In children and adolescents, the same systematic review has shown that SB is strongly associated with obesity, yet moderate association between SB and blood pressure, total cholesterol, self-esteem, social behavioral problems, physical fitness and academic achievement

was found (Fornias Machado de Rezende et al., 2014). Also, higher levels of SB are associated with lower health-related quality of life (Yun Wu et al., 2017). One recent systematic review showed, that children and adolescents spent between 41-51% of the after-school period sedentary and adolescents were more sedentary than children (57%) (Arundell et al., 2016). Also, 26% of that period children and adolescents spent on screen-time, while other non-screen based sedentary behaviors (socialization, motorized transport, homework or reading) comprised 54% of the after-school period (Arundell et al., 2016). In minutes, one previous study conducted among 3,556 adolescents showed that they spent 450 min/day on average in sedentary behaviors, of which 30% engaged in television viewing >2 hours (Carson, Staiano and Katzmarzyk, 2015).

Research aims and questions

In children and adolescents, both physical inactivity and SB lead to negative health outcomes, pointing out that specific pattern of both behaviors need to be studied, especially in a critical period such as adolescence.

Thus, the main aim of the doctoral thesis is to determine patterns of physical activity during secondary-school. Based on the main aim, this thesis aimed to answer 3 specific research questions:

1) Is school type (grammar vs. vocational school) associated with physical activity in the 1st grade of high-school?;

2) Does physical activity patterns change during a one year period between 1st and 2ndgrade?;

3) How well can we track physical activity level, SB and sports participation during 4 years of high-school education?

List of research studies

To answer the aforementioned questions, this thesis includes three studies. All studies were published in international peer-reviewed journals. The studies are listed according to the date of submission:

1. Štefan, L., Sorić, M., Devrnja, A., Podnar, H., Mišigoj-Duraković, M. (2017). Is school type associated with objectively measured physical activity in 15-year-olds? *International Journal of Environmental Research and Public Health, 14*(11), 1417.
2. Štefan, L., Sorić, M., Devrnja, A., Petrić, V., Mišigoj-Duraković, M. (2018). One-year changes in physical activity and sedentary behavior among adolescents: the CRO-PALS study. *International Journal of Adolescent Medicine and Health,* DOI: https://doi.org/10.1515/ijamh-2017-0223.
3. Štefan, L., Mišigoj-Duraković, M., Devrnja, A., Podnar, H., Petrić, V., Sorić, M. (2018). Tracking of physical activity, sport participation, and sedentary behaviors over four years of high school. *Sustainability, 10*(9), 3104.

Thesis outline

Chapter one provides an introduction to the thesis;

Chapter two provides an overview of physical activity (PA) and sedentary behavior (SB) with their multidimensional patterns.

Chapter three presents the research manuscripts included in this thesis. First manuscript aims to determine the objectively assessed physical activity patterns in urban 15-year-old male and female adolescents according to school type and (2) to assess the differences in PA between school days and weekend days. Second manuscript aims to determine PA, SBs and SP changes between the 1st and 2nd grades of secondary school in urban adolescents. Third manuscript aims to determine the extent of tracking of physical activity (PA), sports participation (SP), and sedentary behaviors (SB) over four years of secondary school education among the Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS) cohort.

Chapter four makes a conclusion to the dissertation by summarizing each of the three presented papers. Also, we included the conclusion of each paper and describe their mutual relation, the strengths and limitations of the study and possible directions for future research and practice.

LITERATURE REVIEW

Concept and definitions of physical activity

Physical activity (PA) is often defined as ‘any bodily movement produced by skeletal muscles that result in energy expenditure’ (Caspersen, Powell and Christenson, 1985). Another definition defines PA as ‘any bodily movement which results in significant energy increment that is higher than the level of consumption in the rest phase’ (Fletcher et al., 1996). Total volume of PA is calculated from its frequency, duration and intensity. Frequency represents the number of movements per day, duration is associated with recorded minutes of actual movement, while intensity means every effort to achieve the movement. Such components are influenced by different physiological, psychological, socio-cultural and environmental factors (Goran, Kaskoun and Schuman, 1995). Most important physiological factors that impact PA are growth and maturation. Motivation is the most important part of psychological component while friends and family create socio-cultural component. Finally, environmental component is comprised of many recreational facilities that individual has access to and in general, infrastructure. PA can be defined as caloric contribution which occurs at work and at leisure (Montoye, 1975). Leisure-time PA is defined as activity of an individual doing at leisure. Leisure-time PA has several sub-domains, such as sport, strength and conditioning exercises, household tasks and other activities (Caspersen, Powell and Christenson, 1985). Moreover, leisure-time physical activities can be organized (i.e., different types of aerobic programs) or non-organized (riding a bike). Occupational PA (PA at work) represents the amount of activity during the job and is remotely related to it (Caspersen, Powell and Christenson, 1985). Physical activity is measured in metabolic equivalents (METs). One metabolic equivalent is defined as ‘the amount of oxygen consumed while at sitting at rest and is equal to 3.5 mlO_2/kg/min. For adult population, 3-6 METs represents being in MPA and >6 METs being in VPA. However, for children, time spent in activities requiring 4–7 METs is categorized as MPA, whereas activities requiring >7 METs are classified as VPA. Light physical activity (LPA) is classified as time spent between 1.5 and 4 METs. Measurements of PA are many. The golden standard in estimating the level of energy expenditure is direct calorimetry, which can be used in control settings but has a rather limited use in living conditions. Very similar method to direct calorimetry is doubly-labeled water,

which tracks water filled with radioactive isotopes of oxygen and hydrogen and measures the production of carbon dioxide. Also this method is useful in controlled settings, but not applicable on large-scale researches of PA in living conditions. In population-based studies, accelerometers, heart rate monitors and multi-sensors are often used as objective methods. Nowadays, new multi-sensor devices are available, such as SenseWear Armband, which estimates the level of PA with five different sensors and are much more precise than standard accelerometers (Welk et al., 2007). Finally, subjective methods (questionnaires, interviews, diaries) are often used in large epidemiological studies, yet are less reliable and valid, leading to measurement error (Shepard, 2003).

Physical activity recommendations for children and youth aged 5-17

World Health Organization (2010) established recommended levels of PA for children aged 5-17, adults aged 18-64 and adults aged over 65. Since our targeted population in this doctoral thesis is children, PA for them includes play, games, sports, active transportation (by bike, skateboarding, rollerblading, walking), chores or planned exercise (World Health Organization, 2010). Children and youth aged 5-17 should accumulate at least 60 minutes of moderate- to vigorous-intensity physical activity (MVPA) daily with special emphasis on aerobic-type activities. Strength-related activities should be incorporated at least 3 times per week (World Health Organization, 2010). Centers for Disease Control and Prevention (2008) reported the same recommendations, where children aged 6-17 years should participate in ≥60 min of PA/day. Australia's physical activity and sedentary behavior guidelines for children aged 13-17 years also propose 60 minutes of MVPA every day (Australian Government, Department of Health, 2012). Thus, from the abovementioned evidence, it can be seen that similar PA cut-off points are proposed.

Physical activity during childhood and adolescence

The level of PA during early childhood is generally low, due to mean low intensity of PA (Hoos et al., 2003). After entering the primary school (approximately 6 to 7 years of age), PA significantly increase. It has been well-documented that 75-80% of moderate-intensity PA and 90% of vigorous-intensity PA make the overall PA in that age, yet such level of intensity lasts for about 10 seconds (Baquet et al., 2007). Studies have shown that PA level is at its peak at the age of 13, after which steadily decreases (Van Dijk et al., 2016; Harding et al., 2015; Sagatun et al., 2008; Nelson et al., 2006). The steepest decline of PA starts to occur between primary and secondary school at ages 14/15 (Jurakić and Pedišić, 2010). During the adolescence period, mean annual decline of PA is about 7-8% (Dumith et al., 2011). In general, previous studies have shown that children in secondary schools are less likely to meet the PA recommendations of ≥60 minutes of MVPA daily compared to the children in primary schools (Jurakić and Pedišić, 2010). According to The Health Behavior in School-aged Children (HBSC study), 23.1% of boys and 14.0% of girls reported at least 60 minutes of VPA daily (Kalman et al., 2015), although the HBSC questionnaire has a rather poorly defined questions regarding the intensity of PA and might produce the overestimation of MVPA.

Sport

Sport represents an extracurricular activity and is one part of overall PA. In general, sport can be defined as ‘an activity involving physical exertion and skill in which an individual or team competes against another or others for entertain’ (Oxford Dictionaries, accessed on September 18, 2018). Other authors define sport as ‘physical activity due to a competition, health preserving or fun, and as a number of sport disciplines which are based on certain rules, done by amateurs or professionals’ (Anić, 1998).

Sport is a smaller component of leisure-time PA and studies have shown, that participating in sport at a very young age is associated with reduced body-mass index (BMI) (Drake et al., 2012) and injury rates (DiFiori et al., 2014), greater motivation and less emotional stress (Gould, 2010),

higher persistence of doing sport at later age (Côté, Lidor and Hackfort, 2009) and greater enjoyment in sport and PA (Law, Côté and Ericsson, 2007). The Physical Activity Council's annual tracking report showed that fitness and sport activities had the highest participation rate; that is 64% of the U.S. population ages ≥6 years engaged in activities like running/jogging, training and swimming. Also, the highest percentage of children participated in outdoor sport and team sport (60.2% and 57.1%). In European Union, 40% of Europeans exercise or play sport at least once a week, while 46% never exercise or play sport. By country, the highest proportion of people from Finland (69%), Sweden (67%) and Denmark (63%) reported playing sport regularly, while 68% of people from Bulgaria, Greece and Portugal reported never exercising or playing any kind of sport on a regular basis. In Croatia, there has been a major decline in participating in sport between 2013 and 2017, especially in children and adolescents (European Commission, 2018).

During adolescence, most of the leisure-time PA is organized and takes the form of sport activity. It has been shown that the number of leisure-time sport activities is positively associated with leisure-time PA (Mäkelä et al., 2017). Specifically, it has been documented, that the mean weekly frequency of sport activities is 3.2 for boys and 2.8 for girls during the adolescent years (age 17), yet the same study showed that although girls participated significantly less than boys in weekly frequency of sport activities, they were engaged in a greater number of different sport activities compared to boys (Mäkelä et al., 2017).

As for PA, previous studies have shown, that the peak participation in sport is between ages 11-13 (primary school), after which the engagement starts to decline rapidly in middle and late adolescence (Zimmerann-Sloutskis et al., 2010; Department of Health and Aging, 2007). Among the number of reasons children and adolescence quit sport, the most common are lack of time and support from families and friends (Eime et al., 2015) and a shift towards academic achievement (Eime et al., 2013).

Concept and definitions of sedentary behavior

Sedentary behavior (SB) can be defined as time spent in sitting or lying down activities that require an energy expenditure of 1.0 to 1.5 basal metabolism rates (Pate, O'Neill and Lobelo, 2008). Activities of SB can be categorized as being done at work, during leisure or entertainment and commuting (Owen et al., 2011). Specifically, such activities include sitting, lying down or watching television. In terms of MET, activities that are <1.5METs are considered as being sedentary in adult population (Mansoubi et al., 2015). In children, the same cut-off of <1.5 METs is considered as SB. As for PA, measurements of SB are many. Atkin et al. (2012) showed, that SB could be measure with the subjective (questionnaires, diaries) and objective (accelerometry, posture monitors, combine sensors and multi-unit sensors). Similar to PA, objective methods provide more accurate and reliable data and a minimum of 10 hours has usually been required (Matthews et al., 2003). The SB domains often include total hours per week spending in front of (1) television, (2) computer, (3) doing homework and (4) other (Dearth-Wesley et al., 2017). Other SBs are often divided into listening to music, reading and playing instrument.

Sedentary behavior recommendations for children and youth aged 5-17

Systematic review by Tremblay et al. (2011) showed that spending 'more than 2 hours is associated with unfavorable body composition, decreased fitness, lowered scores for self-esteem and pro-social behavior and decreased academic achievement in school-aged children and youth (5-17 years).' That is, 'children and youth should watch less than 2 hours of TV per day during their discretionary time. Furthermore, children and youth should try to minimize the time they spend engaging in other sedentary pursuits throughout the day (e.g. playing video games, using the computer for non-school work or prolonged sitting)' (Tremblay et al., 2011). Similar recommendations have been proposed for Australian children and adolescents (Australian Government, Department of Health, 2012).

Sedentary behavior during childhood and adolescence

In the last 15 years, only a handful of studies have tried to explore longitudinal changes in SBs, especially in youth (Nelson et al., 2006; Sisson et al., 2009; Trang et al., 2013). Previous studies have reported, that the proportion of children aged 2-5 spending ≥2 h/day in front of television is 30%, around 3% play video-games and 35% spend in total screen-time (Sisson et al., 2009). By using the same variables, Sisson et al. (2009) showed that the prevalence of children aged 6-11 spending in front of television and playing video-games was 35% and 5% and for children/adolescents aged 12-15 the rates were at 35% and 12%, respectively. In both children and adolescents, total screen-time was predominantly driven by spending ≥2 hours/day in front of television and playing video-games (Sisson et al., 2009). Moreover, in one longitudinal study, Trang et al. (2013) reported an increase in SB by 21%, screen-time by 28% and other SB activities (i.e. listening to music, reading) for 14% between the ages 11-15. Recently, Janssen et al. (2016) conducted a longitudinal study among children aged 7 and were tracked till the age 15. Results of the study showed, that sedentary behavior increased by 20% from the baseline (from 51.3%) to 8 year of follow-up (74.2%). Specifically, time spent in SB increased by 4.2 % (-0.3-8.6) between ages 7 and 9 years (31.0 min/day), 9.2 % (4.8–13.5) between ages 9 to 12 years (95 min/day), 8.8 % (4.4–12.7) between ages 12 to 15 (58 min/day). On average sedentary time increased more in girls than in boys (22.8 % versus 22.2 %) (Janssen et al., 2016). In general, a systematic review by Arundell et al. (2016) showed, that both children and adolescents spent between 41% and 51% in sedentary behavior after school and that adolescents were more sedentary than children.

Croatian educational system

Before entering high-school, children have to complete obligatory 8-year primary school. Elementary school prepares children by providing knowledge and skills for future education (Guide through the Croatian education system, accessed on September, 19 2018).

After finishing elementary school, students have the opportunity to continue their education in secondary school. It is worthwhile to mention that the secondary school education is not obligatory in Croatia. Secondary school, like primary school, provides knowledge and skills for future education.

In Croatia, there are a few different secondary school programs students can choose from. Specifically, educational program is divided into grammar, vocational and artistic program. The grammar school program lasts for 4 years and after completing the grammar school program, students are obligatory to pass state graduation (matura exams). Grammar school program prepares students for continuing education, since it is assumed that after completing the grammar program, students will continue their education at the University. There are several grammar education programs as follows: (1) general secondary school, which includes a balanced ratio of general education subjects; (2) language secondary school, which includes learning a foreign language and after 2 years of a program (1^{st} and 2^{nd} grade) students can choose the extended foreign language programs; (3) grammar secondary school, where Greek and Latin in the 1^{st} and 2^{nd} are taught; (4) science and math secondary school, where school is directly focused on math, physics and computer science and (5) sport high school, where actively involved students can go in (Guide through the Croatian education system, assessed on September, 19 2018).

Duration of vocational education in secondary schools depends primarily on the type of curriculum and can last from one to five years. After completing the secondary vocational education, depending on the completion of the program, a student can be included into the labor market or fulfill certain conditions in order to continue his education at secondary or tertiary level. Vocational education provides knowledge, skills and competences required for the labor market with the aim of the professional recognition of qualifications, which also offers the possibility of progress in future education. There are several education programs as follows: (1) 4 to 5 year program, where after completing the matura exam, student can get a job or continue

education at the University; (2) 3-year program, which prepares students for getting a job in industry, economy or crafts and (3) lower level of qualification of education, which is similar as a 3-year program.

In 2014/2015, 53 652 students attended general high school program and in the same academic year, 76 211 students attended 4-year vocational program. The 3-year program was attended by 34 945 students and 117 384 students attended vocational education in year 2014/2015 in total (Guide through the Croatian education system, assessed on September, 19 2018). Thus, two times more students attended vocational than grammar schools.

The majority of PA level is often provoked at the physical education (PE) classes. According to the Croatian Educational System, the compulsory PE in grammar and 4-year vocational schools is held 2 x/week (1 x is 45 minutes) or 70 hours per year. Only in the final year of vocational schools annual hours of PE are reduced to 64, due to matura exams. In vocational-craft schools (3-year), the compulsory PE is held 1 x/week or 35 hours per year. In the final grade (3^{rd}), the PE schedule lasts 32 hours. In vocational schools that last 1 or 2 years, PE is often held in total of 1.5 x/week or 51 hours per year.

Differences in socio-demographic and health characteristics between high school and vocational students

Evidence showed no significant differences between students attending grammar and vocational program, in terms of BMI, self-rated health, and reported having body complaints (Alricsson et al., 2008a). However, previous studies have shown significant differences in socioeconomic status (SES) and lower perceived positive influence from parents to be physically active on the side of vocational school students (Westerstähl et al., 2005). On the other hand, van der Horst et al. (2009) found that overweight/obesity students and who consumed >2 glasses of soft drink and >2 times/day snack were more likely to attend vocational school program, compared to students attending grammar school program. Similar findings were found in a study by Sedej et al. (2016). This is worthwhile of mentioning, since previous studies have shown, that higher levels of SES could lead to higher participation in PA, especially in children and adolescents (Story, Neumark-Sztainer and French, 2002).

Differences in physical activity, sport participation and sedentary behaviors between high school and vocational students

Previous studies have shown that students attending vocational schools are less physically active (Loucaides et al., 2011), spend more time in front of television and computer (Van der Horst et al., 2009), and participate in sport less often (Alricsson et al., 2008a; Alricsson et al., 2008b), compared to their peers from grammar schools. Specifically, grammar-school girls were more physically active than their peers from vocational schools. Also, 16% of students from vocational schools and only 7% of students from grammar school did not participate in any kind of PA, while 8% of students from vocational schools and 18% of students from grammar schools reported participating in high PA (Alricsson et al., 2008a). For girls, 8% of those who attended grammar school program and even 25% of them in vocational school program reported no level of PA effort. Similar, students who walked <60 min/day during leisure-time, who did not play any sport during leisure-time and who viewed television >2 hours/day were more likely to attend vocational school program, compared to their grammar school peers (van der Horst et al., 2009).

ORIGINAL STUDIES

Study 1

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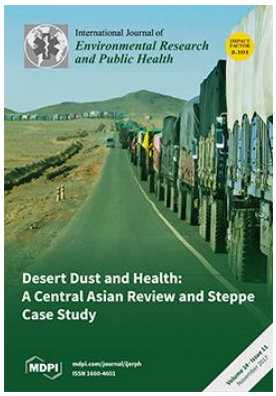

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Article

Is School Type Associated with Objectively Measured Physical Activity in 15-Year-Olds?

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Abstract: The main aims of this study were: (1) to determine the objectively assessed physical activity (PA) patterns in urban 15-year-old male and female adolescents according to school type and (2) to assess the differences in PA between school days and weekend days. In this cross-sectional study, participants were 187 secondary-school male and female adolescents (61.4% females) attending grammar and vocational schools. Patterns of PA were objectively evaluated using a multi-sensor body monitor for 5 consecutive days. Confounders assessed included biological age, socio-economic status, sum of 4 skinfolds, maximal temperature and the amount of rainfall. Males and females from grammar schools achieved higher total daily energy expenditure (TEE) and active energy expenditure (AEE) compared to their peers from vocational schools (TEE: 50 ± 12 kcal/kg/day vs. 47 ± 12 kcal/kg/day, $p = 0.02$; AEE: 23 ± 5 kcal/kg/day vs. vocational = 21 ± 6 kcal/kg/day, $p = 0.04$). No differences in time spent in light (LPA), moderate (MPA) or vigorous (VPA) physical activity were noted between the two groups ($p = 0.16$–0.43). Next, a significant decline in TEE and MPA between school days and weekends was observed ($p < 0.001$ and $p = 0.02$, respectively), while VPA remained the same throughout the week ($p = 0.76$). Weekly patterns of PA did not show differences by school type or gender (p for interactions = 0.21–0.50). In addition, significantly lower amount of MPA was accumulated during weekends compared to school days, resulting in lower TEE, regardless of school type or gender. Policies and strategies on PA in adolescents should focus vocational schools and weekend days.

Keywords: children; adolescence; epidemiology; Sensewear Armband; high school type; energy expenditure

1. Introduction

In the past two decades, lack of physical activity (PA) has become one of the major public health problems in the world [1]. A wealth of evidence has accumulated showing that regular PA reduces all-cause mortality and the incidence of cardiovascular diseases, type 2 diabetes and cancer, and enhances bone strength and psychological health [2].

The prevalence of insufficient PA in European school-going children is very high and ranges between 80 and 90% [1]. PA declines steadily during childhood, with the steepest drop being observed at the time of transition between primary and secondary school [3]. Consequently, the prevalence of physical inactivity is higher in secondary-school students compared to primary school students [4].

Correlates of PA are many [5], and recent studies have shown that the type of school can also influence adolescents' PA [6–10]. It has been reported that students attending vocational schools are less physically active [6], spend more time in front of television and computer [7], and participate in sport less often [8,9] compared to their peers from grammar schools. Another potential factor influencing PA related to the type of school is socio-economic status (SES) [11]. Specifically, parents

with lower educational level often have barriers to meeting the material costs of PA opportunities for their children [12]. Moreover, students attending grammar schools often report having higher SES, which potentially leads to higher participation in organized sports and lower prevalence of overweight [13]. Thus, it seems that both the type of school and SES contribute to PA levels in children and adolescents. Still, only a handful of studies have investigated the patterns of PA in children and adolescents according to school-type [6–10]. Furthermore, all these studies used subjective measures (questionnaires) to assess PA, which typically leads to overestimation of PA [14]. In order to create effective, school-oriented policies on PA, it is imperative to explore the impact of school type on children's PA. In addition, to better understand the association of PA and school type, it is necessary to use objective methods of PA assessment that enable more accurate estimation of energy expenditure (EE).

Thus, the main aim of this study was to examine the associations of objectively assessed levels and weekly patterns of PA and the type of school in urban 15-year-old male and female adolescents.

2. Materials and Methods

2.1. Study Participants

This investigation is a part of the Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS), an observational, longitudinal study designed to follow lifestyle habits of 15-year-old adolescents in the city of Zagreb (Croatia), during their secondary-school education. The sample size for the CRO-PALS study was estimated based on the assumption that primary analyses will comprise regression methods for longitudinal data. Sample size calculations performed with the Gpower [15] computer program suggested that a total sample of 311 individuals would be needed to detect small effects (f_2 = 0.02) with 80% power and with alpha set at 0.05. However, since the CRO-PALS also aimed to generate prevalence estimates of insufficient physical activity and other risk factors for non-communicable disease, we had to increase the targeted sample to 900 individuals in order to achieve a 3% precision in the estimate of prevalence (assuming a total adolescent population in the city of Zagreb $\cong$ 40,000 and the projected prevalence of insufficient activity $\geq$70%). We relied on stratified two-stage random sampling procedures to select an adequately large representative sample of urban adolescents. First, all 86 secondary schools in Zagreb area were stratified by type: grammar schools/vocational schools/private schools. Next, at the first stage of random selection, based on the proportion of different types of schools and the average number of students per school of around 1500, 13 public (8 vocational and 5 grammar schools) and 1 private school (grammar school) were selected. During the second stage of randomization, half of the first grade classes in each of the selected schools were randomly selected. Finally, all 1408 students enrolled in the selected classes were approached and 903 agreed to participate (response rate = 64%).

The current investigation is based on a subsample of CRO-PALS participants in whom the level of PA was further examined by using a multiple sensor activity monitor. The main constraint on conducting objective PA assessment on all CRO-PALS participants was the number of available monitors for objective PA measurement [16]. Thus, from 14 schools initially enrolled in the study, 5 schools (3 vocational and 2 grammar) were randomly selected, which resulted in a total of 276 students participating in the objective PA assessment. To examine if the representativeness of the CRO-PALS sample has been preserved in the subsample selected for objective PA assessment, we compared 276 participants of this study to the rest of the CRO-PALS participants. These analysis indicated similar proportion of boys and girls (p = 0.43) and vocational school and grammar school attendees in both these groups (p = 0.23), as well as comparable values of biological age, BMI, physical fitness and SES (p = 0.37–0.52).

According to the inclusion criteria (described in the section "Physical activity assessment"), data from 187 adolescents were finally included in the analyses. To assess possible drop-out bias, we examined differences between participants with valid and non-valid data in terms of gender, age, BMI, SES,

biological age, sum of 4 skinfolds (S4SF) and physical fitness (sit-ups/min and VO_2max estimated by the 20-m shuttle-run test). No significant differences were observed between participants with valid and non-valid data in terms of gender (valid = B(39%)/G(61%) vs. non-valid = B(51%)/G(49%), Chi-square = 0.09, $p = 0.09$), age (valid = 15 ± 0.3 years vs. non-valid = 15 ± 0.4 years, $t = 0.28$, $p = 0.78$), BMI (valid = 21 ± 3 kg/m^2 vs. non-valid = 22 ± 3 kg/m^2, $t = -1.90$, $p = 0.06$), biological age (valid = 2 ± 0.7 vs. non-valid = 2 ± 0.8, $t = 0.93$, $p = 0.35$), S4SF (valid = 42 ± 15 mm vs. non-valid = 46 ± 19 mm, $t = -1.86$, $p = 0.06$), VO_2max (valid = 41 ± 9 mLO_2/kg/min vs. non-valid = 43 ± 10 mLO_2/kg/min, $t = -1.33$, $p = 0.18$), sit-ups (valid = 21 ± 4x vs. non-valid = 21 ± 5x, $t = -0.03$, $p = 0.97$) and SES (valid: median = 2, IQR = 1–3 vs. non-valid: median = 3, IQR range = 2–4, Z = −0.58, $p = 0.56$).

2.2. Physical Activity Assessment

To objectively assess the level of PA, we used SenseWearArmband^{TM}Pro3 (SWA) physical activity monitor (BodyMedia Inc., Pittsburgh, PA, USA). It relies on pattern recognition to estimate EE and the duration and intensity of PA. This device uses non-invasive sensors to measure different physiological parameters, such as skin temperature or body temperature. Together with height, weight, age, gender and handedness, the data obtained by the sensors are put in proprietary algorithms for estimation of EE and PA duration. The SWA has been previously found to be a valid tool for estimating EE and different levels of PA in children and adolescents [17].

The SWA device was placed on the right arm, above the m. triceps brachii, halfway between the olecranon and acromion processes. Before the main usage of the device, basic anthropological status (gender, height, weight, handedness and gender) was programmed into the SWA. Participants were instructed to wear the device for 5 consecutive days (3 schooldays and 2 weekend days) during the entire day and night, except during water activities or showering. For the analysis of the SWA data, the latest, child-specific algorithms were used (SenseWear Professional software v. 8.1; BodyMedia Inc., Pittsburgh, PA, USA). Participants were also given a physical activity diary to record activities during non-wear time. Consequently, duration of PA and EE expended during the period participants were not wearing the device were added to the SWA data based on the diary and according to the Compendium of PA for children and youth [18]. For the recording to be labeled valid, both of the following conditions had to be met: (1) a minimum of 10 h of awake time recorded per day and (2) a minimum of 3 valid days (including one weekend day) [19].

The intensity of PA was described through metabolic equivalents (METs). Time spent in activities requiring 4–7 METs was categorized as moderate physical activity (MPA), whereas activities requiring >7 METs were classified as vigorous physical activity (VPA). Light physical activity (LPA) was classified as time spent between 1.5 and 4 METs. Total energy expenditure (TEE) was divided by body weight of the participant and expressed as kilocalories/kilograms per day (kcal/kg/day). Active energy expenditure (AEE) represented energy expended in activities of at least light intensity and was also divided by body weight and expressed as kcal/kg/day. To determine the weekly average of TEE, AEE, LPA, MPA and VPA we multiplied the average school day value by 5 and the average weekend day value by 2 and then divided the score by 7, according to formula:

$$\text{TEE, AEE, LPA, MPA, VPA} = ((\text{mean}_{\text{schooldays}} \times 5) + (\text{mean}_{\text{weekend days}} \times 2))/7 \quad (1)$$

2.3. Covariates

A list of covariates assessed includes BMI, subcutaneous body fat, biological age, socio-economic status and weather conditions.

Weight of the subjects was measured by using portable medical balanced scale to the nearest 0.1 kg. Subjects wore only shorts and T-shirts. Body height was taken by an anthropometer to the nearest 0.1 cm (GPM; Siber-Hegner & Co., Zurich, Switzerland). Body mass index (BMI) was calculated as body weight in kilograms divided by body height in meters squared (kg/m^2).

Harpenden skinfold caliper(British Indicators, West Sussex, UK) was used to measure skinfold thickness to the nearest 0.2 mm on the right side of the body [20]. Skinfolds were measured at four sites as follows: (1) triceps- between the olecranon process and acromion process, (2) subscapular- below the tip of the scapula, taken with approximately 45° to the lateral side of the body, (3) suprailiac- above the iliac crest at the level of the anterior axillary line, (4) calf- at the maximal circumference, on the medial side. All skinfold measures were taken in triplicate and median values were used for analysis. The sum of 4 skinfolds (S4SF) was chosen as an indicator of body fat.

Biological age was estimated from the ratio of sitting height and height according to the formula and expressed as the number of years elapsed since peak height velocity [21].

SES was self-reported and assessed with the question: "What do you think your socioeconomic status is, compared to other peers?" The responses were arranged along a Likert-type, five-point scale: (1) extremely above average, (2) above average, (3) average, (4) below average and (5) extremely below average.

Finally, data on the maximal daily temperature (T_{max}) and the amount of rainfall (mm of rainfall) during the days the SWA device was worn were obtained from the Croatian National Meteorological and Hydrological Service [22].

2.4. Data Analysis

Before the main analysis, we checked all variables for normal distribution by using Kolmogorov-Smirnov test. If certain variable was not normally distributed, logarithmic transformation was applied. Data are presented as mean (standard deviation) for normally, or as median (inter-quartile range) for non-normally distributed data. Differences in physical characteristics of adolescents from vocational and grammar schools were determined using analysis of variance (ANOVA) and Kruskal-Wallis test for numerical, and Chi-square test for categorical variables. The main effect of gender and school type in PA measures, as well as the interaction effect between gender and type of school, were analyzed by 2-way analyses of covariance (ANCOVA) adjusted for biological age, S4SF, SES, T_{max} and mm of rainfall. Next, differences in PA during the week (Monday–Friday) and on weekend days (Saturday–Sunday) were examined using repeated measures ANCOVA with gender and the type of school as between-subject factors and adjusted for the same covariates as above. Two-sided p-values were calculated and significance was set at $\alpha < 0.05$. All the analyses were performed using Statistical Packages for Social Sciences v.23 (SPSS, Chicago, IL, USA).

3. Results

Before performing main analyses, we wanted to explore possible effect of monitoring duration on the average level of participants' PA. Of 187 valid participants, 109 participants (58 %) completed the full 5 days of recording, 51 participants (27%) had 4 valid days of recording, while 27 (15%) of them had 3 days of recording. As no significant differences in any of the PA measures were found between groups of participants wearing the SWA device 3, 4 or 5 days ($p = 0.301$–0.935), all participants were pooled for further analysis. Next, very similar wearing time was recorded in adolescents from both types of school (grammar = 16.6 $\pm$ 3 h/day vs. vocational = 16.1 $\pm$ 3 h/day, $t = 1.03$, $p = 0.30$) and in both genders (boys = 16.6 $\pm$ 3 h/day vs. girls = 16.2 $\pm$ 3 h/day, $t = 0.87$, $p = 0.38$).

Basic characteristics of the study participants are presented in Table 1. Boys and girls attending vocational schools reported having slightly lower SES compared to their peers from grammars schools ($p = 0.01$). There were no significant differences in other characteristics assessed ($p > 0.05$).

Table 1. Basic characteristics of the study participants, stratified by the gender and the type of school.

Study Variables	Boys (*N* = 72)		Girls (*N* = 115)		*p*-Value
	Grammar (*N* = 41)	Vocational (*N* = 31)	Grammar (*N* = 64)	Vocational (*N* = 51)	
Age (years)	15.4 (0.4)	15.7 (0.4)	15.6 (0.3)	15.6 (0.4)	0.18
Height (cm)	178 (8)	176 (6)	167 (5)	165 (5)	0.09
Weight (kg)	66 (11)	67 (12)	59 (9)	57 (9)	0.08
BMI (kg/m^2)	21 (3)	21 (9)	21 (2)	20 (2)	0.06
Biological age (years from Peak Height Velocity)	1.8 (0.7)	2.0 (0.6)	2.9 (0.4)	2.8 (0.4)	0.93
S4SF (mm)	33 (15)	37 (16)	49 (16)	44 (13)	0.8
SES * (scale)	2 (2–3)	3 (2–4)	2 (2–4)	3 (2–4)	0.01

* median (lower quartile-upper quartile); *p*-values for the main effect of the type of school are presented.

Table 2 shows PA levels according to gender and school type (grammar vs. vocational). Boys had higher TEE and AEE and spent more time in both MPA and VPA than girls ($p \leq 0.001$–0.04). Next, boys and girls attending grammar schools exhibited higher values of TEE [50.3 (12.4) kcal/kg/day] compared to their peers vocational (TEE = 47.0 (12.0) kcal/kg/day) schools ($p = 0.02$). Moreover, adolescents from grammar schools had higher AEE compared with vocational students ($p = 0.04$). In contrast, no differences in PA duration of any intensity between male and female adolescents attending different types of school were found ($p = 0.16$–0.43). Finally, no significant interactions between gender and the type of school were found ($p = 0.21$–0.96).

Table 2. Physical activity measures stratified by gender and the type of school.

Study Variables	Boys (*N* = 72)		Girls (*N* = 115)		*p*-Values *		
	Grammar	Vocational	Grammar	Vocational	Gender	School	Gender * School
	N = 41	*N* = 31	*N* = 64	*N* = 51			
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)			
TEE (kcal/kg/day)	55.1 (12.6)	52.4 (10.2)	47.7 (11.5)	42.6 (9.8)	0.04	0.02	0.21
AEE (kcal/kg/day)	24.3 (5.2)	22.6 (6.5)	21.8 (5.6)	20.0 (6.9)	<0.01	0.04	0.96
LPA (min/day)	321 (89)	318 (123)	351 (111)	316 (128)	0.3	0.43	0.36
MPA (min/day)	114 (54)	111 (42)	81 (43)	70 (50)	<0.001	0.32	0.39
VPA (min/day) #	24 (9-47)	21 (7–39)	4 (1–12)	2 (0–8)	<0.001	0.09	0.42

median (lower quartile-upper quartile); * *p*-values from ANCOVA of the main effects of school and gender and for gender * school interaction adjusted for biological age, S4SF, SES, T_{max} and the amount of rainfall.

Figure 1 shows the differences in TEE, MPA and VPA between school days and weekend days stratified by gender and the type of school. The highest TEE values were recorded in grammar school boys during school days (57.9 ± 16.5 kcal/kg/day) and the lowest in grammar school girls on weekends (36.9 ± 8.2 kcal/kg/day). When both boys and girls were observed as a group, the main effect for time showed significant decrease in TEE from school day to weekend day (51.8 ± 15.3 kcal/kg/day vs. 39.3 ± 9.0 kcal/kg/day, $F = 12.66$, $df = 1$, $p < 0.001$, $\eta^2 = 0.07$). Non-significant time x gender x school type interaction suggests comparable magnitude of the decline in TEE in both genders and types of school ($F = 1.40$, $df = 3$, $p = 0.25$, $\eta^2 = 0.03$). Similarly, the duration of MPA was almost twice higher during the week (102 ± 58 min/day) compared to weekends (62 ± 50 min/day, $F = 5.19$, $df = 1$, $p = 0.02$, $\eta^2 = 0.03$). Specifically, boys from vocational schools accumulated the highest amount of MPA during school days (126 ± 48 min/day), while the lowest amount was recorded in girls from vocational schools on weekends (52 ± 46 min/day). Boys from vocational schools and girls from grammar schools accumulated approximately 45% less MPA on weekend day than during school day, while the corresponding difference in grammar school boys and vocational school girls amounted to approximately 30%. However, time x gender x school type interaction failed to reach statistical significance ($F = 1.63$, $df = 3$, $p = 0.18$, $\eta^2 = 0.03$). Finally, no significant time effect was observed between school days and weekends regarding VPA (8 (2–22) min/day vs. 2 (0–13) min/day, $F = 1.08$, $df = 1$, $p = 0.30$, $\eta^2 = 0.01$). However, the highest VPA values were observed in grammar school boys during school day (VPA = 22 (9–124) min/day) and the lowest in vocational school girls on weekends

(VPA = 2 (0–23) min/day). Again, non-significant time x gender x school type interaction indicated similar patterns of change in VPA in all 4 groups ($F = 0.05$, $df = 3$, $p = 0.83$, $\eta^2 < 0.001$).

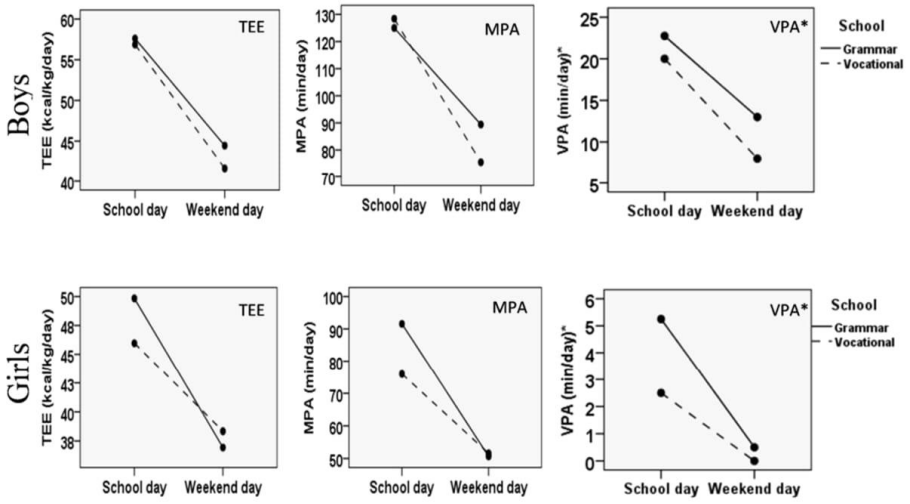

Figure 1. Changes in total energy expenditure (TEE), moderate physical activity (MPA) and vigorous physical activity (VPA) between school days and weekends in boys and girls attending grammar or vocational schools.

4. Discussion

This study investigated patterns of objectively assessed PA among 15-year-old male and female adolescents attending grammar and vocational schools. The main finding of this investigation was that boys and girls from grammar schools exhibited higher TEE and AEE compared with their peers from vocational schools, although no significant differences regarding the duration of daily LPA, MPA and VPA between these two groups of adolescents were found.

Similar to the present study, previous studies using subjective methods to assess PA have shown that compared with the vocational school program, boys and girls from grammar schools are more physically active [6], and participate in sports more often [8,9]. Although we noted higher AEE in grammar school adolescents compared to their peers from vocational schools, PA duration was not statistically different. However, due to a rather small sample size ($N = 187$), we have to acknowledge that the study may have been underpowered in some aspects. Specifically, with the power of 0.8, number of participants of 187 and alpha < 0.05, we could detect the effect size of 0.25, which is considered to be a medium-sized effect. Since variability in MPA, and especially VPA in study participants was quite high, only differences greater than 12 min/day between the two groups of adolescents could have been detected in our study. Despite observing non-significant school effect for the duration of LPA, MPA and VPA, we noted that the type of school had a significant effect on AEE, that is, adolescents from grammar schools expended more energy in physical activity compared with adolescents form vocational schools. AEE was defined as energy expenditure during non-sedentary time, which includes LPA, MPA and VPA combined. Thus, although the duration of PA was similar in adolescents from both school types, mean intensity of PA was obviously higher in adolescents attending grammar school. Next, as it was shown in some previous studies that students from vocational schools are less engaged in organized sports [8,9] this could also be a potential reason for the higher average

intensity of daily activities noted in grammar school students in our study. In this study, however, participation in out-of-school organized sports seems to be similar for both school types (data not shown), which is inconsistent with previous findings in Australian adolescents [8,9]. Such divergent findings possibly result from different social contexts, geographical settings, time of the year when the study was conducted and different methodology used in the aforementioned studies. Finally, despite similar PA duration being noted in both groups, lower TEE observed in male and female adolescents from vocational school peers compared to their peers from grammar schools could possibly translate to higher risk of weight gain during secondary school [23]. Indeed, larger prevalence of obesity in vocational compared to academic programs has been previously reported [9].

The average amount of PA in our study was significantly higher than the recommended 60 min of MVPA daily. Specifically, boys engaged in 142 min of MVPA on average, while girls averaged roughly 83 min of MVPA per day (data not shown). However, most of this PA was of moderate intensity, especially in girls. Our results can be compared with the PA patterns of 15-year-old students from 4 European countries [24]. In this study, 15-year-old boys engaged in approximately 100 min of MVPA, while girls accumulated around 70 min, which is somewhat lower than noted in this study. The reasons for this difference are multiple. First, it has been reported that the underestimation of EE during non-weight-bearing activities and activities involving upper body is much smaller for the SWA device used in this study compared to accelerometers used by Riddoch et al. [24]. Second, PA behavior tends to be differed across the year cycle, with the highest PA level during spring and the lowest during winter [25]. As highlighted before, our study was conducted between March and June, while the study by Riddoch et al. [24] was spread throughout the whole year [24]. Third, different geographical, social and environmental context could also be driving this difference [16].

In the present study, boys showed higher TEE, AEE, MPA and VPA compared to girls. This is consistent with numerous previous epidemiological studies that have used the objective methods to assess PA in similar age groups [24,26,27], although the difference between genders is not identical. Specifically, De Baere et al. [27] showed that boys spent approximately 15 min/day and 9 min/day longer in moderate and vigorous PA, compared with girls. Another study by Riddoch et al. [24] showed that boys engaged in 99 min/day and girls in 73 min/day of MVPA (−26%), which is lower compared with the mean difference in MVPA from our study (−42%) [24,27]. These differences partly stem from non-identical age groups and different PA assessment methods across the studies. However, the observed trend for adolescent boys engaging in more PA than girls is clear.

Finally, a significant decline in PA during weekend days compared to school days in both boys and girls and schools was observed. However, our results showed non-significant main effect for the type of school, indicating that male and female adolescents from both grammar and vocational schools had similar magnitude of change through the week. To the best of our knowledge no prior studies have explored the changes in PA between the school day and weekend day, according to school type. Studies that tracked PA behavior through the week have shown mixed results, with some reporting higher accumulation of PA during school days [16,28,29], while others reported higher amount of PA during weekend days [19,30].

This study has several strengths. First, we used a multi-sensor PA monitor to objectively evaluate PA patterns. Second, we adjusted for numerous covariates (biological age, SES, S4SF, T_{max} and the amount of rainfall). Biological age was included rather than chronological, since it has proven to be a better predictor of participation in PA [31]. Lastly, to account for seasonal variation of PA, not only that we confined PA assessment to 3 spring months, but we managed to account for weather conditions by adjusting for T_{max} and the amount of rainfall in the data analyses.

However, this study also has several limitations. First, although 5-day assessment period used in this study has been previously shown to yield reliable estimates of PA, by increasing the assessment period to the whole week more accurate estimates of PA patterns would be generated [32]. Second, SES is a very complex concept which has been shown to influence PA levels of adolescents. In this study, as a proxy of SES, we used a one-item question, thus ignoring the complex nature of SES. Although we

adjusted for it, we did not include more detailed information about the SES of students, such as parents' education, monthly income etc. Therefore, some residual confounding of the relationship between PA and school type by SES is possible. Third, the differences in PA cannot fully be attributed to school environment, since Sensewear Armband cannot analyze the domains of PA or the type of activity participants engaged in, but only intensity and duration. Thus, it is possible that out of school activities contributed the differences between the male and female adolescents from different schools. Future studies should provide more detailed information about the SES of the participants. Finally, we randomly selected schools and classes for the purpose of this study and achieved an acceptable response rate. Nevertheless, more physically active families are more prone to participating in the studies of such nature. Thus, potential selection bias cannot be excluded.

5. Conclusions

The average amount of PA observed in our study was rather high, although in girls very little VPA was recorded. Male and female adolescents attending grammar schools showed higher TEE and AEE compared to their peers from vocational schools, although the duration of PA was similar in children from both school types. In addition, we noted a significant decrease in PA on weekends compared to school days, regardless of the type of school or gender. Policies and strategies aimed at increasing PA should focus vocational schools. Moreover, interventions should be extended beyond the school-week to cover weekends also. Future studies using objective methods of PA assessment should include longer periods of monitoring and larger sample size in order to examine PA patterns across school-types more accurately.

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Author Contributions: Marjeta Mišigoj-Duraković and Maroje Sorić conceived and designed the study; Lovro Štefan contributed in data analysis; Lovro Štefan wrote the paper. Maroje Sorić, Antonela Devrnja, Hrvoje Podnar and Marjeta Mišigoj-Duraković commented the last draft of the paper. All authors approved the final version of the paper.

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

Abbreviations

AEE	active energy expenditure
ANCOVA	analysis of covariance
BMI	body-mass index
CRO-PALS	Croatian Physical Activity in Adolescence Longitudinal Study
EE	energy expenditure
LPA	light physical activity
MET	metabolic equivalent
MPA	moderate physical activity
PA	physical activity
SES	socioeconomic status
S4SF	sum of four skinfolds
TEE	total energy expenditure
VO_{2max}	maximal oxygen uptake

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Study 2

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One-year changes in physical activity and sedentary behavior among adolescents: the Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS)

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Abstract:
Background: Little is known about the concurrent change in physical activity (PA), sedentary behavior (SB) and sport participation (SP) during adolescence. The main purpose of this prospective and partly objective study was to simultaneously investigate PA, SBs and SP changes between the 1st and 2nd grades of high school in urban adolescents.
Methods: In this 1-year follow-up study, the participants were 81 secondary-school students (28 boys and 53 girls) aged 15.5 years at the baseline. PA was assessed with the SenseWear Armband multi-sensor activity monitor, while SBs were assessed by using School Health Action, Planning and Evaluation System (SHAPES) PA questionnaire. The SHAPES questionnaire was supplemented with two questions inquiring about SP in organized sports in school and outside of school.
Results: PA decreased markedly in both genders between the 1st and 2nd grades of high school. Total energy expenditure (TEE) was reduced by 13 kcal/kg/day on average in boys and by 10 kcal/kg/day in girls (p for both <0.001), while mean daily active energy expenditure (AEE) decreased by 7 kcal/kg/day ($p < 0.001$) and 3 kcal/kg/day ($p = 0.04$) in boys and girls, respectively. Similarly, the amount of moderate PA declined by 49 min/day in boys and 21 min/day in girls (p for both <0.001). At the same time vigorous PA was cut by 14 min/day ($p < 0.001$) and 3 min/day ($p = 0.003$) in boys and girls, respectively. Conversely, time spent in SBs did not show any change.
Conclusion: In conclusion, a decline in PA between the 1st and 2nd grades of high school was marked but was not accompanied with an increase in SBs. Policies aimed at increasing PA should be targeting the period of entering secondary school to offset the observed drop in PA.

Keywords: exercise, lifestyle habits, screen time, secondary school, students
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Introduction

Insufficient physical activity (PA) has become one of the most relevant public health problems in the world [1]. A wealth of evidence has accumulated to show that regular PA lowers the risk of death and reduces the incidence of cardiovascular, metabolic and mental illnesses [2].

There is strong evidence that beneficial lifestyle habits embraced during childhood and adolescents have positive effects on adults' health, indicating that the promotion of PA should start at young age [3]. The amount of daily PA declines steadily during childhood, with the steepest drop being observed at the time of transition between primary and secondary school [4]. Several studies have explored longitudinal changes in PA during the adolescent period [5], [6], [7], [8], [9], [10]. A recent systematic review showed that the mean annual change in PA during adolescence was −7% (−8.8% to −5.2%) [11]. Accordingly, an adequate level of PA has been shown to be less prevalent in secondary school students compared to primary school students [12]. Sport participation

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(SP) is considered to form a significant part of the overall PA of children and adolescents. Parallel with PA level, the rates of SP also decline markedly in adolescence [13].

Apart from inadequate PA and SP, inadequate sedentary behaviors (SBs) also increase the risk for cardiovascular, metabolic and mental diseases [14], [15]. In the last two decades, much attention has been given to exploring longitudinal changes in SBs, especially during adolescence [8], [16]. Specifically, Nguyen et al. [16] reported an increase in SB by 21%, screen-time (ST) by 28% and other SB activities (i.e. listening to music, reading) by 14% during a 5-year period. On the other hand, only a handful of studies investigated the changes in PA and SB among adolescents simultaneously [8]. In addition, available studies focused exclusively on ST, and have rarely included other SBs. Finally, most of these studies have relied on subjective methods, which could have led to potential bias [8].

Therefore, the main purpose of the present study was to investigate changes in SP, PA and SB between 1st and 2nd grades of secondary school among urban adolescents.

Materials and methods

Study participants

This investigation is a part of the Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS), an observational, longitudinal study designed to follow lifestyle habits of 15-year-old adolescents in the city of Zagreb (Croatia), during their secondary-school education. The protocol and the design of the study are described in detail elsewhere [17]. In short, we relied on a stratified two-stage random sampling procedure to select a representative sample of urban adolescents. First, all 86 secondary schools in the Zagreb area were stratified by type: grammar schools/vocational schools/private schools. Next, at the first stage of random selection, based on the proportion of different types of schools and the average number of students per school, 13 public (eight vocational and five grammar schools) and one private school (grammar school) were selected. During the second stage of randomization, half of the 1st grade classes in each of the selected schools were randomly selected. Finally, all 1408 students enrolled in the selected classes were approached and 903 agreed to participate (response rate = 64%). For an objective assessment of PA, we randomly selected five secondary schools totaling 276 participants. All measurements were performed between March and June in 2014 and again in 2015.

To assess possible drop-out bias, we calculated differences between participants with valid and non-valid wear time at follow-up. No significant differences between the group (n = 81) with valid vs. non-valid (n = 106) wear time in terms of total energy expenditure (TEE), active energy expenditure (AEE), vigorous physical activity (VPA) and MPA ($p = 0.37–0.90$) at baseline were observed. Next, we compared the two groups in terms of body mass index (BMI), physical fitness [sit-ups/min and maximal oxygen uptake (VO_{2max})], socioeconomic status (SES), chronological age, biological age, and the sum of four skinfolds (S4SF). VO_{2max} was estimated from the 20-m shuttle run test according to Ruiz et al. [18]. Student's t-test for independent samples showed no significant differences between the participants with valid and non-valid data in terms of BMI, VO_{2max}, SES, biological age, chronological age and S4SF ($p = 0.27–0.98$)

Physical activity assessment

TheSenseWearArmband™ (SWA) activity monitor (BodyMedia Inc., Pittsburgh, PA, USA) was used for objective assessment of PA. It relies on pattern recognition to estimate energy expenditure (EE) and the duration and intensity of PA. This device uses non-invasive sensors for measuring different physiological parameters (heat flux, galvanic skin response, skin temperature, near-body temperature and motion, determined from a biaxial accelerometer). The data from the sensors, together with gender, age, height, weight and handedness were incorporated into proprietary algorithms to estimate EE and PA duration. The SWA has been previously validated for estimating EE and the amount of PA [19]. The device was placed on the right upper arm, above the m. triceps brachii. The subject's gender, age, height, weight and handedness were programed into the SWA before it was activated. Participants were instructed to wear it for 5 consecutive days (3 school days and 2 weekend days) during the entire day and night, except during water-based activities or showering. The criteria for a valid recording were: (1) wearing the SWA for a minimum of 10 h of awake time per day and (2) minimum of 3 days (including at least 1 weekend day) with adequate wear time, as proposed by Trost et al. [20]. Data from all the sensors were averaged over 1-min periods, and these data were stored in the memory and subsequently downloaded to a computer. For the analysis of the SWA data, child-specific exercise algorithms were used (SenseWear Professional software v. 8.1; BodyMedia Inc., Pittsburgh, PA, USA). The duration and the EE

of activities during the period participants were not wearing the devices were added to the SWA data based on an activity diary, and according to the Compendium of PA for children and youth [21].

The intensity of PA was described through metabolic equivalents (METs). Time spent in activities requiring 4–7 METs was categorized as moderate physical activity (MPA), whereas activities requiring >7 METs were classified as VPA. Light physical activity (LPA) included time spent in activities requiring between 1.5 and 4 METs. TEE was divided by the body weight of the participant and expressed as kilocalories/kilograms per day (kcal/kg/day). AEE represented energy expended in activities of at least light intensity and was also divided by body weight and expressed as kcal/kg/day.

To determine the weekly average of TEE, AEE, LPA, MPA and VPA we multiplied the average school day value by 5 and the average weekend day value by 2 and then divided the score by 7, according to formula:

$$\text{TEE, AEE, LPA, MPA, VPA} = [(\text{mean}_{\text{schooldays}}*5) + (\text{mean}_{\text{weekend}}*2)]/7.$$

Sedentary behavior assessment

SB was examined by the School Health Action, Planning and Evaluation System (SHAPES) PA questionnaire, through seven items examining the average time spent: (1) playing computer/video games, (2) television viewing, (3) browsing the Internet, (4) doing homework and studying, (5) listening to music, (6) reading and (7) playing instruments. Responses were provided by indicating the number of hours and minutes in 15-min increments spent on a certain behavior [22]. We summed all seven SB domains to get the total SB time, and further subdivided SB activities into three categories: (1) screen-time (ST) (sum of the time spent playing computer games, TV viewing and browsing the Internet), (2) doing homework and studying and (3) other SB activities (i.e. listening to music, reading, playing instruments). Schooldays and weekends were examined separately, and the average daily time spent in particular SB was calculated according to the same formula described for PA:

$$\text{TSB, ST, studying, other SB} = [(\text{mean}_{\text{schooldays}}*5) + (\text{mean}_{\text{weekend}}*2)]/7.$$

Sport participation

The SHAPES questionnaire was supplemented with two questions inquiring about participation in organized sports in school and outside of school. For participants who reported SP, a comprehensive list of sport activities was offered, and participants selected all sports they participated in on a regular basis.

Confounders

A list of confounders assessed includes BMI, subcutaneous body fat, biological age, SES and weather conditions.

Subjects were weighed barefoot on a pre-calibrated portable medical balance scale to the nearest 0.1 kg wearing shorts and T-shirts. Body height was taken to the nearest 0.1 cm using an anthropometer (GPM; Siber-Hegner & Co., Zurich, Switzerland). BMI was calculated as body weight in kilograms divided by body height in meters squared (kg/m^2).

Skinfold thickness measures were taken to the nearest 0.2 mm using a Harpenden skinfold caliper (British Indicators, West Sussex, UK) on the right side of the body [23]. Skinfolds were measured at four sites as follows: (1) triceps-halfway between the acromion process and the olecranon process, (2) subscapular – about 20 mm below the tip of the scapula, at an angle of 45° to the lateral side of the body, (3) suprailiac – above the iliac crest at the level of the anterior axillary line, (4) calf – at the level of maximum calf circumference, on the medial aspect of the calf. All skinfold measures were taken in triplicate and median values were used for analysis. The S4SF was chosen as an indicator of body fat.

Biological age was estimated from anthropometric measurements according to the formula proposed by Mirwald et al. [24] and expressed as the number of years elapsed since peak height velocity.

SES was self-reported and assessed with the question: "How wealthy do you think you are, compared to your peers?". The responses were arranged along a Likert-type five-point scale: (1) substantially above average, (2) slightly above average, (3) average, (4) slightly below average and (5) substantially below average.

Finally, data on the maximal temperature (T_{max}) and the amount of rainfall (mm of rainfall) during the days the SWA device was worn were obtained from the Croatian National Meteorological and Hydrological Service [25]. Student's t-test and the Mann-Whitney U-test indicated no significant differences between two occasions in maximal temperature ($T_{max2014} = 22 \pm 4$°C vs. $T_{max2015} = 21 \pm 3$°C, $t = 1.85$, $p = 0.07$) and the amount of rainfall (2014 = 0.4 (0.01–3.2) mm vs. 2015 = 0.3 (0.1–1.5), $Z = 0.131$, $p = 0.90$).

Data analysis

Before the main analyses, all variables were tested for normality using the Kolmogorov-Smirnov test and by inspecting histograms and normal probability plots. If the assumption of normality was violated, appropriate data transformation was applied. Basic descriptive statistics are presented as mean (standard deviation) for normally distributed or geometric mean for non-normally distributed data. Categorical variables are presented as frequencies (N) and percentages (%). Differences in SP between baseline and follow-up were calculated by using the Chi-squared test, while the paired sample t-test (for normally distributed variables) and the Wilcoxon test (for non-normally distributed variables) were used for assessing changes in PA and SBs between baseline and follow-up. Next, differences in PA and SB between the baseline and follow-up were analyzed separately during school days and weekends using repeated-measures analysis of covariance (RM ANCOVA). Covariates included SES, S4SF, biological age, T_{max} and mm of rainfall at both occasions. All the analyses were stratified by gender. Two-sided p-values were calculated, and significance was set at $\alpha < 0.05$. All the analyses were calculated in Statistical Packages for Social Sciences v.23 (SPSS, Chicago, IL, USA).

Results

At baseline, 255 children wore the PA monitor, but only 187 participants met the criteria for valid wear time (see section "PA assessment and protocol"). Of these, 81 participants (43%) also had valid data at follow-up. Thus, the final sample consisted of 81 adolescents (28 boys and 53 girls).

Basic characteristics of the study participants at baseline are presented in Table 1.

Table 1: Basic characteristics of the study participants at baseline (1st grade of secondary school), stratified by gender.

	Boys (n = 28)	Girls (n = 53)
Chronological age, years	15.5 ± 0.3	15.6 ± 0.4
Biological age (years elapsed since peak height velocity)	2.6 ± 0.6	2.6 ± 0.5
Body mass index, kg/m^2	21.0 ± 2.9	20.0 ± 2.2
Socioeconomic status[a]	3 (2–3)	2 (2–3)
Sum of four skinfolds, mm	42.5 ± 13.2	40.5 ± 12.6

[a]Median (interquartile range, IQR).

Before performing the main analyses, we explored whether the duration of monitoring had any effects on the average level of participants' PA. Of 81 participants in 2014, 31 participants (28%) completed the full 5 days of recording, 28 participants (29%) had 4 valid days of recording, while 22 (23%) of them had 3 days of recording. In 2015, 26 participants (32%) completed the full 5 days of recording, 30 participants (37%) had 4 valid days of recording, while 25 (31%) of them had 3 days of recording. No significant differences in any of the PA measures were found between groups of participants wearing the SWA device between 3, 4 or 5 days ($p = 0.20$–0.73), so all participants were pooled for further analysis. Next, very similar wear time of the devices between the two measurement occasions was recorded (2014 = 17 ± 2 h/day vs. 2015 = 16.7 ± 2.5 h/day, $t = 0.40$, $p = 0.39$).

One-year changes in PA, SBs and SP are presented in Table 2. For both boys and girls, significant time effect for all PA variables was observed ($p < 0.05$). On the other hand, no change in any of the SB variables was observed ($p = 0.47$–0.89). Two boys and nine girls stopped being engaged in outside of school sport, while none of the boys left sport in school and two girls started participating in school sport.

Table 2: Changes in PA, SB and SP between baseline and follow-up, stratified by gender.

Study variables	Boys (n = 28)			Girls (n = 53)		
	Baseline	Follow-up	p-Value	Baseline	Follow-up	p-Value
Physical activity						
TEE, kcal/kg/day	54 (12)	41 (6)	**<0.001**	47 (12)	37 (9)	**<0.001**
AEE, kcal/kg/day	26 (7)	19 (7)	**<0.001**	19 (7)	13 (8)	**0.04**
VPA, min/day[a]	22 (9–44)	8 (3–18)	**<0.001**	5 (1–12)	2 (2–6)	**0.003**
MPA, min/day	121 (51)	72 (29)	**<0.001**	79 (41)	58 (41)	**<0.001**
Sport participation						
SP outside of school[b]	15 (54)	13 (46)	0.59	24 (45)	15 (28)	0.07
SP in school[b]	5 (18)	5 (18)	1.00	12 (23)	14 (26)	0.65
Sedentary behaviors						
TSB, min/day[a]	395 (260–626)	358 (261–719)	0.75	366 (279–532)	394 (256–566)	0.65
ST, min/day[a]	231 (130–381)	213 (124–488)	1.00	193 (107–315)	171 (122–281)	0.58
Studying, min/day[a]	100 (69–177)	93 (57–174)	0.52	146 (85–200)	137 (91–206)	0.86
Other SB activities, min/day[a]	30 (16–71)	32 (12–101)	0.90	34 (17–73)	34 (15–85)	0.92

[a]Median (lower-upper IQR). [b]Frequencies (N) and percentages (%). p-Values are given separate for boys and girls within two measurements and were calculated from a paired sample t-test (for normally distributed variables) or the Wilcoxon test (for not-normally distributed variables).

Figure 1 shows 1-year changes in PA and SB during school days and weekends in male secondary school students. A higher significant decline in TEE (18 kcal/kg/day, $p < 0.001$) and MPA (58 min/day, $p = 0.04$) was observed during school days compared with weekends (TEE = 17 kcal/kg/day vs. 3 kcal/kg/day, $p < 0.001$; MPA = 58 min/day vs. 29 min/day, $p = 0.04$). In AEE, a similar decline during school days (8 kcal/kg/day) and weekends (6 kcal/kg/day) was observed ($p = 0.82$). Boys declined in the time spent in VPA by 17 min/day during weekends compared with a 14 min/day decrease during school days ($p = 0.23$). Boys spent a similar amount of time in total sedentary behavior (TSB) ($p = 0.82$), ST ($p = 0.25$), studying ($p = 0.23$) and in other SBs ($p = 0.80$) during school days and weekends.

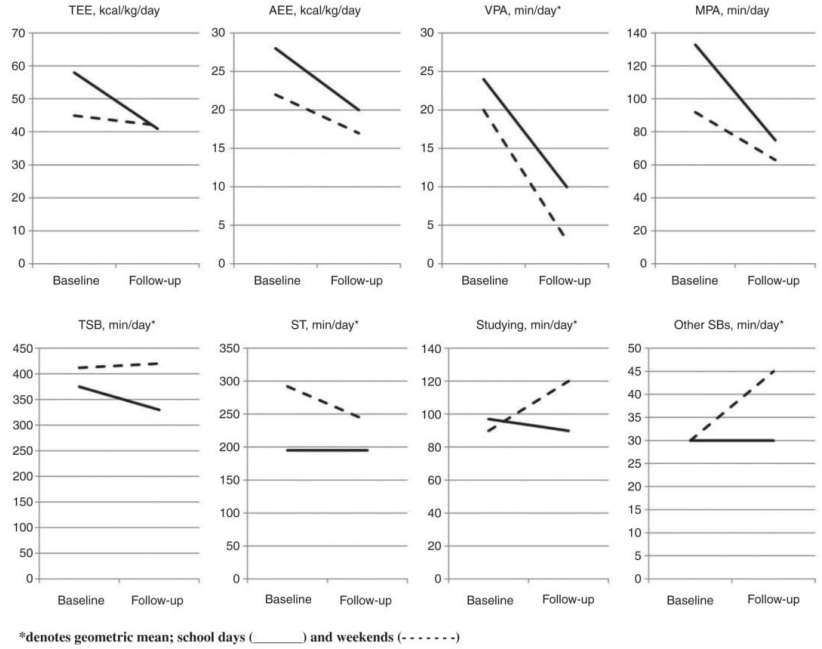

Figure 1: One-year changes in PA and SB during school days and weekends in male secondary school students.

Figure 2 illustrates 1-year changes in PA and SB during school days and weekends in female secondary school students. A higher significant decline ($p < 0.001$) in TEE (14 kcal/kg/day) and MPA (26 min/day) was

observed during school days compared with weekends (TEE = 2 kcal/kg/day and MPA = 7 min/day AEE was reduced by 4 kcal/kg/day during weekends compared with 6 kcal/kg/day during school days (p = 0.74). A similar amount of time was spent in TSB (p = 0.55), ST (p = 0.94), studying (p = 0.16) and in other SBs (p = 0.44) during school days and weekends.

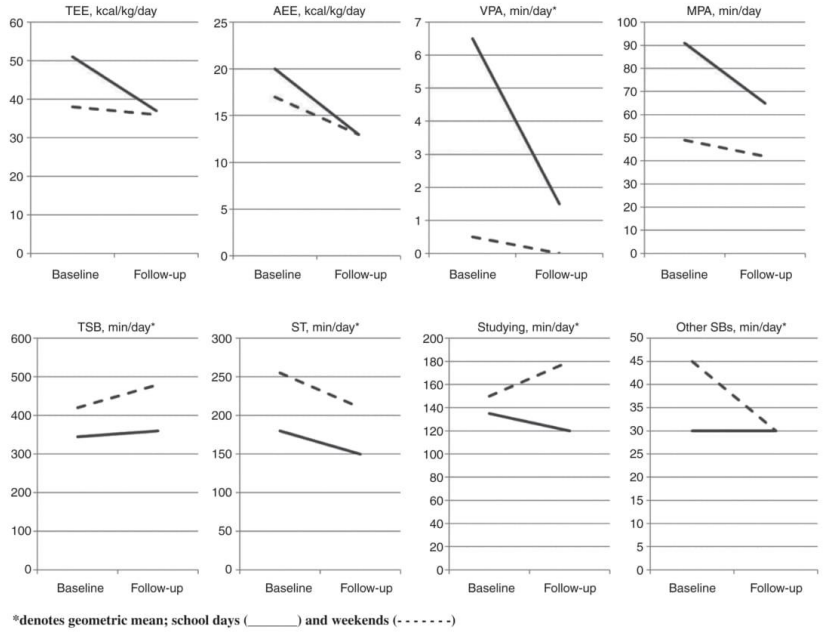

Figure 2: One-year changes in PA and SB during school days and weekends in female secondary school students.

Discussion

The main findings of the study were: (1) both the duration and the energy expended in PA declined markedly between the 1st and 2nd grades of high school in both genders, (2) in the same period the time spent in SBs did not change significantly, (3) the decline in PA was more pronounced during school days compared with weekends in both boys and girls.

The present study observed a significant decrease of PA levels during a year of follow-up in both boys and girls. This finding is consistent with previous studies [7], [8], [9], [26], [27]. In general, a systematic review by Dummith et al. [11] showed a mean decline in PA of 7% annually in boys aged 13–16 years. Similarly, in girls a decline in moderate-to-vigorous physical activity (MVPA) from 5.1 to 3.5 h/week during mid- to late adolescence was reported [8]. Finally, findings from Sagatun et al. [7] showed a significant decline in PA by 0.73 h/week in boys and by approximately 0.40 h/week in girls between 15 and 18 years of age. This is similar to the magnitude of decline in MVPA observed in this study over only 1 year of follow-up. Next, as our findings showed non-significant changes in SP, the observed drop in MVPA obviously stems from less non-organized PA being accumulated. Previous studies have shown that the prevalence of no sport and non-membership in a sport club increases with age, especially during adolescence [13], [28]. A study by Zimmermann-Sloutskis et al. [13] showed a decrease of 7% of sport membership in boys and 8.6% in girls between ages 14–16 and 17–19 years. Boys in our study showed a higher decline in PA compared with girls which is consistent with earlier findings [26], [29].

Our results showed that SB variables (TSB, ST, studying and other SB activities) remained similar at the baseline and after a year of follow-up between the school day and weekend day. Our results showed that SBs remained similar at baseline and after a year of follow-up between the school day and weekend day. Previous studies that investigated the SB pattern have consistently shown an increment in SBs over adolescence [8], [16]. Specifically, Nguyen et al. [16] reported an increment of TSB by 21%, ST by 28% and other SB activities (i.e. listening to music, reading) for 14% during a 5-year period. Another study by Nelson et al. [8] showed that in

girls, television/video viewing and leisure-time computer use increased by 1 h/week and almost 4 h/week between mid- and late adolescence, while in boys, television/video viewing remained the same and leisure-time computer use increased by 4 h/week during a follow-up of 5 years. However, those studies had longer periods of follow-up and investigated slightly younger children than the present study.

It should be noted that we used objective methods to assess PA variables (a multiple sensor activity monitor), while subjective methods (e.g. the SHAPES questionnaire) were used to assess SBs. Self-report measures tend to lead to considerable measurement error, recall bias and social desirability effect [30]. Reliability coefficients have been shown to be highly variable, yet demonstrate moderate reliability, but fair-to-moderate concurrent validity [31]. Finally, SB on weekdays is recalled with greater accuracy compared to weekends, perhaps because of the greater variability in behavioral patterns on weekends [32].

This study has several strengths. First, we used an objective measure of PA. Second, we adjusted for numerous covariates (biological age, SES, S4SF, T_{max} and mm of rainfall). Third, we analyzed PA and SB patterns during both the school day and the weekend day. Fourth, we examined different domains of SB: (1) ST, (2) homework and (3) other SB activities (i.e. listening to music, reading a book).

However, this study also suffers from several limitations. First, PA assessment was restricted to only 3–5 days (including 1 weekend day). Extending the monitoring period to more than 7 days would increase the reliability of the estimate [20]. Second, we had a large drop-out rate of the study participants. Although we compared participants with drop-outs in terms of basic characteristics and baseline PA level and found no significant differences, we cannot exclude the possibility that such a large drop-out would influence the inferences made, as well as the generalizability of our findings. Finally, although we randomly selected schools and classes for the purpose of this study, more physically active families are more prone to participate in the studies of such a nature. Thus, this might have led to potential bias in direction towards higher than average PA level of the children included in this study.

Conclusions

Our study showed that the level of PA decreased, while SBs remained unchanged between the 1st and 2nd grades of high school in both boys and girls. Also, the decline in PA was more marked during school days than at weekends. Thus, special interventions and policies that aim at increasing PA during school days at the beginning of secondary school are warranted. Future studies should use objective methods to assess both PA and SB and should include a longer follow-up period.

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Conflict of interest: The authors declare no conflict of interest.

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Study 3

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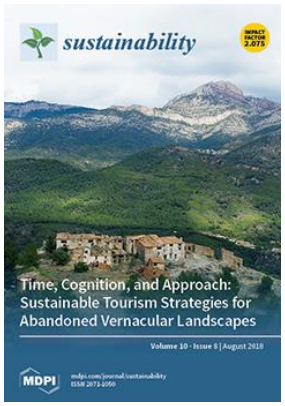

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Tracking of Physical Activity, Sport Participation, and Sedentary Behaviors over Four Years of High School

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Abstract: Background: The aim of the present study was to investigate the extent of tracking of physical activity (PA), sports participation (SP), and sedentary behaviors (SB) over four years of high school education among the Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS) cohort. **Methods:** In this investigation, participants were 844 high school students (15.6 years at baseline; 49% girls). The SHAPES questionnaire was used to assess PA, SP, and SB at ages 15, 16, 17, and 18 and tracking was assessed using generalized estimating equations. **Results:** Tracking coefficients for PA were similar in both sexes, ranged from 0.49 to 0.61, and indicated moderate tracking, while the tracking of SB tended to be somewhat higher over the four years of follow-up ($\beta = 0.60–0.72$). Youth that participated in sports at baseline had a 16 to 28 times higher odds of continued participation at follow-up, depending on the type of sport and gender. Finally, both low physical activity and high screen time showed strong tracking in both genders. **Conclusion:** PA and SB tracked moderately between ages 15 and 18. Moreover, the strong tracking of low PA and high screen time indicates that the detection of these risk factors at the beginning of high school should be advocated.

Keywords: longitudinal analysis; adolescence; sitting-time; physical inactivity; sustainability

1. Introduction

Physical inactivity is considered to be one of the most important public health concerns globally [1]. More recently, sedentary behavior (SB) has also been linked with an increased risk of mortality, independent of leisure-time physical activity (PA) [2]. In children, both low PA and high SB independently relate to adverse health outcomes [3,4]. Therefore, the World Health Organization recommends that children aged 5–17 years should accumulate at least 60 min of physical activity per day [1]. On the other hand, recent global studies have shown that this volume of PA is not achieved by the majority of contemporary youth, with the prevalence of inactivity rising with age [5]. Studies among school-going youth have consistently documented a steady decline in PA and an increase in SB throughout childhood [6–8]. The largest decline in PA has been spotted around the transition from primary to high school [9].

PA occurs in several domains, such as occupation, household, transportation, and leisure-time, which isthe one that contributes the most to total PA volume in children and adolescents [10].

The leisure-time domain has three aspects: mode (team sports, individual sports, organized but noncompetitive sports, and non-organized PA), setting (school, club, and neighborhood setting), and type (specific sports, such as swimming and volleyball) [11]. During teenage years, most of the leisure-time PA is organized and takes the form of sport activity. It has been shown that the number of leisure-time sport activities is positively associated with leisure-time PA, i.e., a higher number of sport activities that adolescents participated in was associated with a higher volume of leisure-time PA [12]. The same study also showed that the average weekly frequency of sport activities was 3.2 for boys and 2.8 for girls at the age of 17, yet girls engaged in a greater number of different sport activities than boys [12]. Longitudinal studies have shown that sport participation is the highest between ages 11–13, while after that period, it declines steadily throughout mid and late adolescence [13,14]. The decline is driven by a number of factors, such as lack of time and lack of support from families [15] and a shift towards academic achievements [16].

Given the importance of lifelong PA for health, interventions that promote physical activity and reduce sedentary behavior are one of the cornerstones of non-communicable disease prevention in children. If such interventions are to be effective in the long-term, the stability of PA and SB over time is assumed, i.e., these behaviors are expected to track well. Tracking is most often defined as: (1) "a tendency of individuals to maintain their rank within a certain group over a period of time" [17] and (2) "the ability to predict future observations based on earlier values" [18]. The most recent systematic reviews have documented weak to moderate tracking of PA and moderate tracking of SB, with the results being strongly dependent on age and the follow-up period [19,20]. Lower tracking was generally found with increasing follow-up interval [19]. Still, studies during late adolescence are scarce and the follow-up period studied has often been short, especially for SB. Furthermore, SB has usually been assessed through screen-time (ST), which represents just one domain of SB [21]. Finally, to the best of our knowledge, no study has simultaneously investigated the tracking of PA and SB in high-school-aged youth.

Therefore, the purpose of the present study was to investigate the extent of tracking of PA, sport participation (SP), and SB over four years of high school education.

2. Materials and Methods

2.1. Study Participants

The current study is part of the Croatian Physical Activity in Adolescence Longitudinal Study (CRO-PALS), an observational, longitudinal study that investigated behaviors of adolescents in the city of Zagreb (Croatia) throughout the four years of high school education. The sample size estimation and selection for the CRO-PALS study has been reported in detail elsewhere [22]. Briefly, a stratified two-stage random sampling procedure was employed to select an adequately large representative sample of urban adolescents. After having stratified all 86 secondary schools in the Zagreb area by type, grammar schools/vocational schools/private schools, 13 public (eight vocational and five grammar schools), and one private school (grammar school) were selected at the first stage of random selection, based on the share of different types of schools and the approximate number of eligible students per school of 150. All the invited schools agreed to participate, and during the second stage of randomization, half of the first grade classes in each school were randomly selected. Finally, all 1408 students enrolled in the chosen classes were contacted and 903 decided to join the study (response rate = 64%).To check for possible selection bias, we compared participants to non-participants regarding the body-mass index (BMI), sum of four skinfolds (S4SF), and physical fitness (sit-ups and shuttle-run test). No significant differences between the two groups were found in any of the characteristics (p = 0.21–0.34).

All measurements were performed yearly in the period 2014–2017, during April and May, thus totaling four assessments. Prior to the study, all participants and their parents had signed an informed written consent and all the procedures were in accordance of the Declaration of Helsinki.

The study was approved by the Institutional Review Board of the Faculty of Kinesiology, University of Zagreb, Croatia (No: 1009-2014).

2.2. Physical Activity Assessment

To assess PA and SB, we used a computerized version of the School Health Action, Planning and Evaluation System (SHAPES) questionnaire [23]. The validity and reliability of the SHAPES questionnaire for assessing PA and SB in primary and high school children has been investigated and the results were comparable to other PA questionnaires commonly used in this age group [23]. The questionnaire includes two items requesting a seven-day recall of moderate intensity PA (MPA) and vigorous intensity PA (VPA). VPA was defined as "jogging, team sports, fast dancing, jump-rope, and any other physical activity that markedly increased your heart rate and made you breathe hard and sweat", while MPA was defined as "lower intensity physical activities such as walking, riding a bike, and recreational swimming". Participants were instructed to specify the number of hours (0–4 h) and minutes in 15-min increments (0–45 min) that MPA and VPA were performed for each day of the previous seven days. For all days at which >4 h of MPA or VPA was reported, the duration of 4:15 h was assumed (of note, such days constitute around 1% of the total days). Weekly duration of time spent in MPA and VPA was calculated by summing the responses for each of the seven days recalled. Physical activity energy expenditure (PAEE) was calculated as proposed by Wong et al. [23], assuming an average intensity of four METs for MPA and seven METs for VPA.

2.3. Sedentary Behavior Assessment

SBs were also examined by the SHAPES questionnaire, through two items examining time spent in pre-specified SBs on an average school day and on a typical weekend day. Sedentary time was examined through seven different groups of behaviors: (1) playing computer/video games, (2) television viewing, (3) browsing the internet (excluding school-work), (4) homework and studying, (5) listening to music, (6) reading for leisure (excluding school-work), and (7) playing instruments. As for PA, responses were provided by indicating the number of hours and minutes in 15-min increments [23]. We summed all seven SB domains to get the total sedentary time (TSB) and further subdivided SB activities into three categories: (1) screen-time (ST) (playing computer games, TV viewing, browsing the internet), (2) doing homework and studying, and (3) other SB activities (i.e., listening to music, reading, playing instruments). As schooldays and weekends were examined separately, the average daily time spent in particular SB was calculated as follows:

$$\text{TSB, ST, studying and other SB activities} = [(\text{school day} \times 5) + (\text{weekend} \times 2)]/7.$$

2.4. Sport Participation Assessment

The original SHAPES questionnaire was supplemented with two YES/NO questions inquiring about regular participation in organized sports in school, as well as outside of the school. For participants who stated that they participate in organized sport, a comprehensive list of sport activities was offered, and participants identified all sports they participated in on a regular basis. Finally, a question about the weekly duration of sport activities (in 1-h increments) was also included.

2.5. Data Analysis

Tracking of PA and SB was assessed using generalized estimating equations (GEE), separate for each PA measure and each SB domain assessed. Specifically, to describe the extent of tracking of both PA and SB, we used the stability coefficient derived from the GEE analysis. When calculating a stability coefficient, the value of the baseline measurement was regressed on the entire longitudinal development of that variable from the second to the fourth measurement. The unique obtained regression (beta) coefficient is called the stability coefficient [24]. This coefficient ranges from 0 to 1, with 1 indicating perfect tracking and 0 indicating no tracking.

On the other hand, to evaluate the tracking of SP and behavioral risk factors (low PA and high screen time), we used odds ratios (ORs) derived from the GEE analysis. To track high physical activity (>75 percentile), low physical activity (<25 percentile), low screen time (<25 percentile), and high screen time (>75 percentile), we used binary regression analysis in GEE. Participants were grouped according to the sex-specific quartiles of PAEE and ST. Odds ratios with 95% confidence intervals (OR; 95% CI) were calculated by GEE to determine the odds of remaining in a certain group compared with the baseline group position. The working correlation matrix was set to exchangeable in all analyses, i.e., the same within-subject correlation between each time point was assumed. Two-sided *p*-values were used and significance was set at $\alpha < 0.05$. All the analyses were calculated in Statistical Packages for Social Sciences v.23 (SPSS, Chicago, IL, United States).

3. Results

The analyses in this study were based on 844 participants with data on PA, SP, and SB. Of these, 614 (73%) were present at all four assessments, 150 (18%) had three measurements, 44 (5%) two measurements, and 36 (4%) presented at only one occasion. The number of children involved dropped slightly during the study period. At first assessment, 843 children completed all the measurements (428 boys and 415 girls; 51.0%/49.0%); in second grade, there were 821 children present (413 boys and 408 girls; 50.3%/49.7%); that fell to 774 at the third year (394 boys and 380 girls; 51.0%/49.0%); and ended with 721 at the final, fourth, assessment (356 boys and 365 girls; 49.4%/50.6%). Basic characteristics of participants are presented in Table 1.

Table 1. Basic characteristics of the participants at baseline (first grade of high school), stratified by gender.

Basic Descriptive Variables	Boys (N = 429)	Girls (N = 415)
Age (years)	15.7 (0.4)	15.6 (0.4)
Biological age (years from PHV)	1.9 (0.7)	2.0 (0.4)
Body-mass index (kg/m^2)	21.9 (3.6)	21.4 (3.1)
Sum of 4 skinfolds * (mm)	37.3 (18.9)	50.0 (16.2)
PAEE (kcal/kg/day)	11.2 (7.0)	9.0 (6.1)
Screen time (min/week)	282.8 (165.3)	240.7 (147.4)

* Sum of triceps, subscapular, suprailiac, and calf skinfold; PHV = peak height velocity; PAEE = physical activity energy expenditure.

Average durations of PA and various SB activities over four years of high school are depicted in Figure 1. The pattern of change in PA was similar in both genders and for both MPA and VPA. The average duration of PA was stable in the first two years, and dropped progressively afterwards. Conversely, the patterns of change in various SBs were not uniform across genders, with similar average values over all four years in girls, and a noticeable decrease between the first and fourth grade in boys.

Table 2 shows stability coefficients for PA and SB derived from GEE. In general, stability coefficients were almost identical in both sexes and indicate moderate tracking of PA and moderate to strong tracking of SB. Specifically, stability coefficients for PA ranged between 0.49–0.61 and were somewhat higher for VPA compared to MPA. The corresponding coefficients for SB were 0.60–0.72 in boys and 0.60–0.70 in girls.

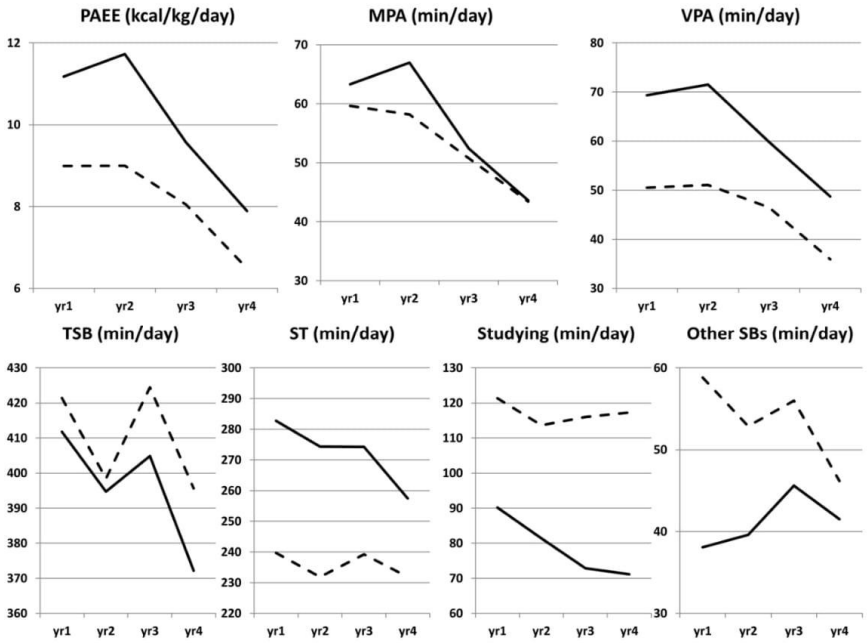

Figure 1. Average values of physical activity and sedentary behavior variables over four years of follow-up, in boys (——) and girls (- - - - -).

Table 2. Stability coefficients for physical activity and sedentary behavior, stratified by gender.

Study Variables	Boys (N = 429)			Girls (N = 415)		
	Tracking Coefficient	95% CI	*p*	Tracking Coefficient	95% CI	*p*
Physical activity						
VPA	0.61	0.54 to 0.67	<0.001	0.59	0.52 to 0.66	<0.001
MPA	0.49	0.43 to 0.56	<0.001	0.53	0.45 to 0.60	<0.001
PAEE	0.57	0.51 to 0.63	<0.001	0.59	0.52 to 0.67	<0.001
Sedentary behaviors						
TSB	0.63	0.57 to 0.69	<0.001	0.60	0.53 to 0.66	<0.001
ST	0.60	0.54 to 0.66	<0.001	0.64	0.58 to 0.70	<0.001
Studying	0.66	0.61 to 0.72	<0.001	0.70	0.65 to 0.76	<0.001
Other SB	0.72	0.64 to 0.81	<0.001	0.63	0.55 to 0.71	<0.001

VPA-vigorous physical activity; MPA-moderate physical activity, PAEE-physical activity energy expenditure; TSB-total sedentary behavior; ST-screen-time; Other SBs include reading for fun, listening to music, and playing an instrument.

Figure 2/Table 3 illustrates the tracking of risky behaviors, i.e., low physical activity and high screen time. The stability of high and low PA, as well as high and low ST, was very similar. About half of the children remained in both high and low groups between any two successive yearly assessments. The least active boys and girls at year 1 had 13.3 (CI = 9.8–18.1) and 11.6 (CI = 8.58–15.81) more odds of remaining in the least active quartile throughout the four years of high school compared to their peers, respectively. Similarly, boys with the highest PA level at year 1 were 12.9 (9.4–17.9), while girls were 14.9 (10.7–20.7) times more likely to remain in the most active group throughout high school. Boys who were in the highest screen-time quartile in first grade had 13.9 (CI = 8.7–16.3) more odds of reporting high screen time throughout four years of high school, while the corresponding odds in

girls were 15.5 (CI = 11.2–21.5). On the other side of the spectrum, the odds of persistently being in the lowest screen-time quartile amounted to 12.6 (CI = 9.1–17.4) in boys and 12.1 (CI = 8.8–16.5) in girls who reported the lowest screen time at baseline.

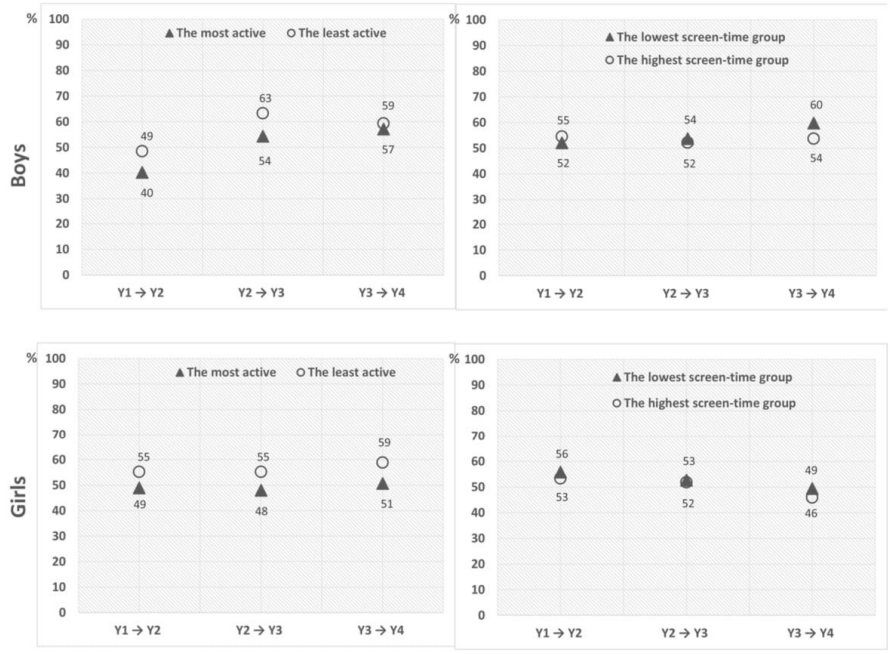

Figure 2. Tracking of low and high physical activity (the lowest and the highest sex-specific quartile of weekly physical activity energy expenditure, respectively), and low and high screen time (the lowest and the highest sex-specific quartile of weekly screen time, respectively), over four years of high school, stratified by gender. The numbers indicate the percentage of participants that remained in a specific group between two successive waves of assessment.

Table 3. Tracking of low and high physical activity (the lowest and the highest sex-specific quartile of weekly physical activity energy expenditure, respectively), and low and high screen time (the lowest and the highest sex-specific quartile of weekly screen time, respectively), over four years of high school, stratified by gender. The numbers indicate the percentage of participants that remained in a specific group between two successive waves of assessment.

	Boys			Girls		
	Y1 → Y2	**Y2 → Y3**	**Y3 → Y4**	**Y1 →Y2**	**Y2 → Y3**	**Y3 → Y4**
Physical activity	%	%	%	%	%	%
The lowest quartile	40	54	57	55	55	59
The highest quartile	49	63	59	49	48	51
Screen time						
The lowest quartile	54	52	53	56	53	49
The highest quartile	51	53	59	52	51	46

The numbers indicate the percentage of participants that remained in a specific category between two successive waves of assessment.

The number of youth engaged in school and out-of-school sports further classified by the type of sport (individual vs. team sports) over four years of follow-up is presented in Figures 3 and 4/Table 4. At baseline, 54% of boys and 44% of girls participated in any kind of sport and the rates of participation decreased steadily afterwards. Boys who participated in school and out-of-school sports in first grade were 18.3 (CI = 12.9–25.5) and 24.0 (CI = 16.8–34.3) times more likely to continue participating over the follow up-period, respectively. The analogous odds in girls were very similar and amounted to 18.7 (CI = 12.9–25.5) and 28.6 (CI = 19.5–42.1).The tracking of sport participation was higher for team sports compared to individual sports in boys, but the opposite was true in girls. Specifically, boys who participated in team sports in first grade were 27.2 (CI = 18.3–40.4) times more likely to continue participating over the follow-up period, while the corresponding odds for individual sports were 20.4 (CI = 14.3–29.0). On the other hand, girls who participated in team sports in first grade were 15.9 (CI = 10.1–24.9) times more likely to continue participating over the follow-up period, while the equivalent odds for individual sports were 23.6 (CI = 15.6–35.6). The most popular sports were soccer, basketball, dancing, combat sports, volleyball, athletics, and swimming (data not presented).

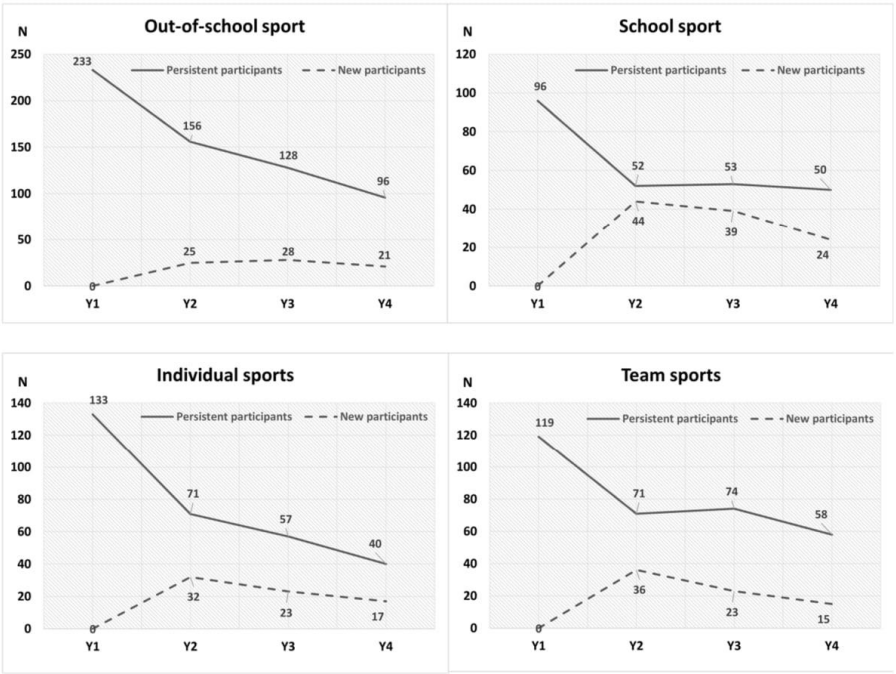

Figure 3. Persistence of sport participation over four years of high school in boys, stratified by school and out-of-school sport and by sport type (individual vs. team sports). The numbers show the frequency of children that participated in regular sport activities during a specific year. Solid line denotes participants who persistently participate in regular organized sport (Persistent participants) and dashed line represents children who were not participating in sports at baseline, but started participating in the specific year (New participants).

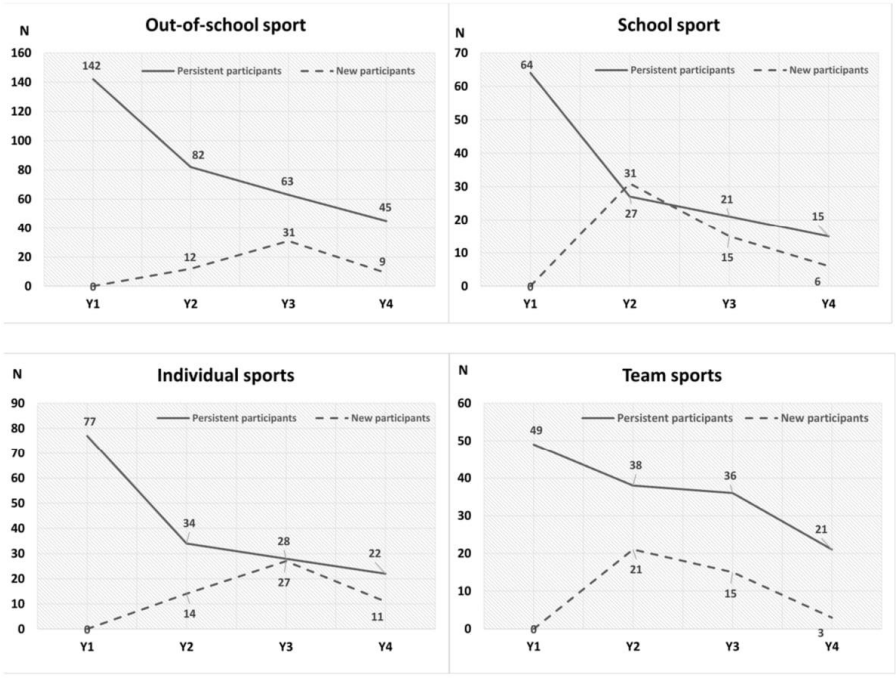

Figure 4. Persistence of sport participation over four years of high school in girls, stratified by school and out-of-school sport and by sport type (individual vs. team sports). The numbers show the frequency of children that participated in regular sport activities during a specific year. Solid line denotes participants who persistently participated in regular organized sport (Persistent participants) and dashed line represents children who were not participating in sports at baseline, but started participating in the specific year (New participants).

Table 4. Persistence of sport participation throughout four years of high school, stratified by school and out-of-school sport and by sport type (individual vs. team sports). The numbers indicate the frequency of participants that continued participating in sports (persistent participants) or started participating (new participants) in a specific year.

Study Variables	Boys		Girls	
	Persistent Participants	New Participants	Persistent Participants	New Participants
	N	N	N	N
Out-of-school sport				
Baseline	233	/	142	/
Year 2	156	25	82	12
Year 3	128	28	63	31
Year 4	96	21	45	9
School sport				
Baseline	96	/	64	/
Year 2	52	44	27	31
Year 3	53	39	21	15
Year 4	50	24	15	6

Table 4. *Cont.*

Study Variables	Boys		Girls	
	Persistent Participants	New Participants	Persistent Participants	New Participants
	N	N	N	N
Individual sports				
Baseline	133	/	77	/
Year 2	71	32	34	14
Year 3	57	23	28	27
Year 4	40	17	22	11
Team sports				
Baseline	119	/	49	/
Year 2	71	36	38	21
Year 3	74	23	36	15
Year 4	58	15	21	3

4. Discussion

The main goal of the present study was to investigate the extent of tracking of PA, SP, and SBs during four years of high school education. The main results of the study include: (a) PA showed moderate tracking across all intensities, while the tracking of SB was slightly higher, and could be interpreted as moderate to high; (b) the least active adolescents and those who spent the most time in front of the screens at year 1 were 12 and 15 times more likely to remain inactive and of exhibiting high screen time over four years of follow-up compared to their more active peers, respectively; (c) youth who participated in sport in school and outside of school at baseline were 16 to 28 times more likely to participate in sports throughout high school compared to children who were not involved in organized sport at the beginning of high school.

Like in this study, two previous studies among adolescents have also shown moderate tracking of PA [25,26]. However, Raustorp et al. [26] showed non-significant tracking coefficients for girls, while significant tracking coefficients for both boys and girls in the study by Aarnio et al. [25] were observed. As highlighted by Telama [19], of many factors influencing the value of tracking coefficients, the follow-up time, assessment method, gender, age, and the type of PA were the most important. Specifically, tracking coefficients were lower in girls compared with boys [19]. Possible reasons were a lower participation rate and major lifestyle transitions (schooling, obligations), which can also decrease tracking over a longer period of time [19]. In this study, we used a questionnaire to assess PA. The reasonably large measurement error related to PA assessment by questionnaires could lead to an underestimation of stability coefficients. In general, earlier studies have documented similar tracking regardless of the PA assessment method employed, pointing out that although objective methods measure PA more accurately, their ability to rank individuals and estimate tracking is not much superior to questionnaires [19].

Next, the stability coefficients for SB noted in this study indicate moderate to high tracking in both genders. This is in line with previous studies that aimed to track SB in similar age groups [27–29]. In general, moderate tracking of television viewing (TV), electronic games and/or computer use, and total screen time (ST) was observed, while the coefficients for TSB were notably smaller [27]. Tracking of SB generally shows similar patterns to tracking of PA, that is, an inverse association between the magnitude of tracking and the duration of follow-up [19].

A recent systematic review by Telama [19] noted that low activity or inactivity usually tracked better than activity. In the present study, however, both inactivity and high activity tracked well. To that end, inactive children should be identified at the beginning of high school and specifically targeted in order to prevent them remaining inactive. Conversely, good tracking of high activity levels

indicates that the increase in PA induced by interventions timed at the beginning of high school could be preserved throughout adolescence. Although interventions aiming to promote PA and reduce SB in adolescents have shown a relatively small effect to date, school environment was highlighted as the most potent setting for behavioral interventions [30,31]. Thus, the first year of high school should serve as a period for both the detection of physically inactive individuals, as well as for the introduction of PA interventions.

The current study documented a marked decline in sport participation over four years of high school. We also noted that participants who were not engaged in sporting activities at the beginning of high school are highly unlikely to start participating in sports later on. Moreover, it has been previously shown that sports participation could extend well beyond adolescence, as participants that engaged in club sports in adolescence were shown to be two times more likely to continue participating in sports after 14 years of follow-up [32]. Poor PA promotion has been highlighted as a major reason for drop-out from organized sport [33]. Thus, school policies that promote organized sport participation before and during high school are warranted. This was also the first study that contrasted the tracking of participation in team and individual sports in the adolescent period. A prior study in Finland has shown that, among teenage boys, participation in team sports leads to high or very high PA levels in adulthood, whereas in females, such an effect is provided by individual sports [34]. In line with that, we observed that tracking was stronger for team sports in boys, and for individual sports among girls.

This study has several strengths. First, we included a fairly large number of participants (N = 844). Second, we randomly selected schools, thus minimizing sample bias. Third, we followed our participants for all four years of high school, which was longer than the follow-up period in most of the previous studies among adolescents, particularly the ones examining SB activities. Fourth, unlike prior studies, we extended SB beyond screen time by including several other domains of sedentary time. Fifth, we succeeded in achieving a very low drop-out rate after four years of follow-up (N = 721/844; drop-out rate = 16%). Finally, we assessed both PA and SB simultaneously, which enabled us to directly compare the extent of tracking of these two behaviors.

However, this study also has several limitations worth addressing. The main limitation of the present study was the use of questionnaires to assess PA and SB, which typically leads to an overestimation of PA and underestimation of SB activities [35]. Although this could have led to an underestimation of stability coefficients derived from GEE, it had a negligible effect on risk behavior tracking which is based on ranking individuals. Next, although all four waves of assessments were performed during the same season (i.e., spring), it is possible that PA varied because of different weather conditions within and between the years. However, we took care that the measurements at a specific school were performed at approximately the same date across all four waves of assessment. In addition to this, we compared average daily maximal temperatures and the amount of rainfall during a specific month at each of the four waves of assessment and found no significant differences (data not shown; $p = 0.06–0.64$).

5. Conclusions

Moderate to strong tracking of both PA and SB between 15 and 18 years observed in this study was somewhat higher than previously reported for the similar period [14]. The fact that both low PA and high screen time tracked well indicates that the detection of these risk behaviors in the first grade of high school should be advocated. At the same time, the strong tracking of high PA and low screen time points to the fact that an increase in PA induced by interventions timed at the beginning of high school could probably be maintained at least to the end of adolescence. However, previous studies aiming to increase the level of PA in secondary-school children have only shown a small effect [24,25]. On the other hand, studies aiming to increase the level of PA in primary-school children have shown somewhat larger effect sizes for time spent in MVPA [36,37] and VPA [37] in an intervention group, compared to the control group. All this, along with the fact that both positive and risky behaviors related to energy expenditure remained stable throughout high school in this study, indicates that

it might be more advisable to intervene at the primary school level. However, this remains to be confirmed by experimental evidence. Lastly, we noted that more than half of the participants that were engaged in organized sports in first grade had quit sports by the end of high school and that adolescents who were not engaged in sports at the beginning of high school were highly unlikely to start participating in sports later on. Thus, school policies that promote organized sport participation both before and during high school are warranted. Future studies should use objective methods in order to decrease the measurement error in assessing PA and SB.

Author Contributions: Conceptualization, M.M.-D. and M.S.; Methodology, M.M.-D. and M.S.; Software, L.Š.; Validation, M.S. and L.Š.; Formal Analysis, L.Š.; Investigation, M.M.-D., M.S., L.Š., A.D., H.P. and V.P.; Resources, M.M.-D. and M.S.; Data Curation, M.S. and L.Š.; Writing-Original Draft Preparation, M.S. and L.Š.; Writing-Review & Editing, M.M.-D., M.S., L.Š., A.D., H.P. and V.P.; Visualization, M.S. and L.Š.; Supervision, M.S.; Project Administration, M.M.-D. and M.S.; Funding Acquisition, M.M.-D.

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

Abbreviations

BMI	Body-mass index
CRO-PALS	Croatian Physical Activity in Adolescence Longitudinal Study
GEE	Generalized estimating equations
MET	Metabolic equivalent
MPA	Moderate physical activity
MVPA	Moderate to vigorous physical activity
OR	Odd ratio
PA	Physical activity
PAEE	Physical activity energy expenditure
SB	Sedentary behavior
SHAPES	School Health Action, Planning and Evaluation System questionnaire
SP	Sport participation
SPSS	Statistical Package for Social Sciences
ST	Screen-time
S4SF	Sum of four skinfolds
TSB	Total sedentary behavior
TV	Television viewing
VPA	Vigorous physical activity
95% CI	95 percent confident interval

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Strengths and limitations

This research has several strengths. First, we used a multi-sensor PA monitor to objectively evaluate PA patterns. Second, we adjusted for numerous covariates (biological age, SES, S4SF, T_{max} and the amount of rainfall). Biological age was included rather than chronological, since it has proven to be a better predictor of participation in PA. Third, to account for seasonal variation of PA, not only that we confined PA assessment to 3 spring months, but we managed to account for weather conditions by adjusting for T_{max} and the amount of rainfall in the data analyses. Third, we analyzed PA and SB patterns during both the school day and the weekend day. Fourth, we examined different domains of SB: (1) ST, (2) homework and (3) other SB activities (i.e. listening to music, reading a book). Fifth, we included a fairly large number of participants (N = 844). Second, we randomly selected schools, thus minimizing sample bias. Sixth, we followed our participants for all four years of high school, which was longer than the follow-up period in most of the previous studies among adolescents, particularly the ones examining SB activities. Seventh, unlike prior studies, we extended SB beyond screen time by including several other domains of sedentary time. Eight, we succeeded in achieving a very low drop-out rate after four years of follow-up (N = 721/844; drop-out rate = 16%). Finally, we assessed both PA and SB simultaneously, which enabled us to directly compare the extent of tracking of these two behaviors.

However, this study has several limitations. First, although 5-day assessment period used in this study has been previously shown to yield reliable estimates of PA, by increasing the assessment period to the whole week more accurate estimates of PA patterns would be generated. Second, SES is a very complex concept which has been shown to influence PA levels of adolescents. In this study, as a proxy of SES, we used a one-item question, thus ignoring the complex nature of SES. Although we adjusted for it, we did not include more detailed information about the SES of students, such as parents' education, monthly income etc. Therefore, some residual confounding of the relationship between PA and school type by SES is possible. Third, the differences in PA cannot fully be attributed to school environment, since SenseWear Armband cannot analyze the domains of PA or the type of activity participants engaged in, but only intensity and duration. Thus, it is possible that out of school activities contributed the differences between the male and

female adolescents from different schools. Future studies should provide more detailed information about the SES of the participants. Fifth, we randomly selected schools and classes for the purpose of this study and achieved an acceptable response rate. Nevertheless, more physically active families are more prone to participating in the studies of such nature. Thus, potential selection bias cannot be excluded. Sixth, we used questionnaires to assess PA and SB, which typically leads to an overestimation of PA and underestimation of SB activities. Although this could have led to an underestimation of stability coefficients derived from GEE, it had a negligible effect on risk behavior tracking which is based on ranking individuals.

GENERAL CONCLUSION

The Croatian Physical Activity and Adolescence Longitudinal Study (CRO-PALS) was an observational, longitudinal study that investigated lifestyle behaviors of adolescents in the city of Zagreb (Croatia) during the four years between 1st and 4th grade of secondary school. The CRO-PALS also wanted to estimate the prevalence of these behaviors and we targeted the population of 900 secondary school students (assuming approximately 40,000 adolescents in the city of Zagreb and 70% of insufficient PA). At the first stage, we randomly selected 14 out of 86 schools based on the proportion of grammar and vocational schools. At the second stage, we randomly selected half of the first grade classes in each of the selected schools, minimizing the risk of potential selection bias. Finally, 1,408 students were recruited and 903 of them (with the response rate of 64%) agreed to participate and were enrolled in further analyses.

The aforementioned project consisted of three independent studies, which derived several important findings. Specifically, boys and girls from grammar schools exhibited higher TEE and AEE compared with their peers from vocational schools, although no significant differences regarding the duration of daily LPA, MPA and VPA between these two groups of adolescents were found. Also, both the duration and the energy expended in PA declined markedly between the 1st and 2nd grade of high school in both genders, while in the same period time spent in SBs did not change significantly. The decline in PA was more pronounced during school days compared with weekends in both boys and girls. Finally, PA showed moderate tracking across all intensities, while the tracking of SB was even slightly higher, and can be interpreted as moderate to high. Moreover, the least active adolescents and those who spent the most time in front of the screens at year 1 were 12 and 15 times more likely to remain inactive and of exhibiting high screen time over 4 years of follow-up, respectively and youth who participated in sport in school and outside of school at baseline were around 18 to 28 more likely to participate in sports throughout high school, independent of gender.

Previous studies have shown strong associations between health and education (Centers for Disease Control and Prevention, 2011). Thus, school could to be a potential strategic place for increasing the level of PA and decreasing the level of SBs. Also, healthy lifestyle behaviors developed early during the childhood usually persist later in life pointing out that, targeting children in primary and secondary schools should be of great importance. Based on our findings

policies and strategies aimed at increasing PA should focus vocational schools. Moreover, interventions should be extended beyond the school-week to cover weekends also. Also, the results of this research contibute in explaining the patterns of physical activity among adolescents. By exploring several factors of physical activity, this study helps to detect a group of adolescents with high risk. Based on that, special strategies and interventions could be created and implemented within the school system (more hours of physical education, more extra-curricular activities, organized leisure-time physical activity) for the targeted population of children with higher risk for physical inactivity. Second, by determing the stability of physical activity and participating in sport, this study helps in creating the interventions for increasing of maintaining the level of physical activity during the period of early adolescence.

Perspectives for future research

According to our limitations, future studies should use objective methods of PA assessment (actigraphy) over a longer period of follow-up and in a larger sample size to examine PA patterns across school-types more accurately. Based on our findings, special interventions and policies that aim at increasing PA during both school days and especially weekend days at the beginning of secondary school are warranted. Finally, strong tracking of high PA and low screen time points to the fact that an increase in PA induced by interventions timed at the beginning of high school could be maintained at least to the end of adolescence and school policies that promote organized sport participation both before and during high school should be implemented within the school system.

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