Volume 22 Issue 9 September 2022 ISSN 1746-1391

European Journal of Sport Science

The Official Journal of the European College of Sport Science

European Journal of Sport Science

Routledge Taylor & Francis Group

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tejs20

Physical activity measured by accelerometry among adolescents participating in sports clubs and non-participating peers

K. Toivo, H. Vähä-Ypyä, P. Kannus, K. Tokola, L. Alanko, O. J. Heinonen, R. Korpelainen, J. Parkkari, K. Savonen, H. Selänne, S. Kokko, U. M. Kujala, J. Villberg & T. Vasankari

To cite this article: K. Toivo, H. Vähä-Ypyä, P. Kannus, K. Tokola, L. Alanko, O. J. Heinonen, R. Korpelainen, J. Parkkari, K. Savonen, H. Selänne, S. Kokko, U. M. Kujala, J. Villberg & T. Vasankari (2022): Physical activity measured by accelerometry among adolescents participating in sports clubs and non-participating peers, European Journal of Sport Science, DOI: 10.1080/17461391.2022.2103740

To link to this article: https://doi.org/10.1080/17461391.2022.2103740

EUROPEAN JOURNAL OF SPORT SCIENCE
https://doi.org/10.1080/17461391.2022.2103740

Physical activity measured by accelerometry among adolescents participating in sports clubs and non-participating peers

K. Toivo [a,b], H. Vähä-Ypyä [b], P. Kannus [b], K. Tokola [b], L. Alanko [c,d], O. J. Heinonen [e], R. Korpelainen [f,g,h], J. Parkkari [a,b,i], K. Savonen [j,k], H. Selänne [l], S. Kokko [i], U. M. Kujala [i], J. Villberg [i] and T. Vasankari [b,m]

[a]Tampere Research Center of Sports Medicine, UKK Institute for Health Promotion Research, Tampere, Finland; [b]UKK Institute for Health Promotion Research, Tampere, Finland; [c]Clinic for Sports and Exercise Medicine, Helsinki, Finland; [d]Central Finland Hospital, Jyväskylä, Finland; [e]Paavo Nurmi Centre & Unit of Health and Physical Activity, University of Turku, Turku, Finland; [f]Department of Sports and Exercise Medicine, Oulu Deaconess Institute Foundation sr., Oulu, Finland; [g]Center for Life Course Health Research, University of Oulu, Oulu, Finland; [h]Medical Research Center, University of Oulu and University Hospital of Oulu, Oulu, Finland; [i]Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland; [j]Kuopio Research Institute of Exercise Medicine, Kuopio, Finland; [k]Department of Clinical Physiology and Nuclear Medicine, Kuopio University Hospital, Kuopio, Finland; [l]Department of Psychology, University of Jyväskylä, Jyväskylä, Finland; [m]Faculty of Medicine and Health Technology, Tampere University, Tampere, Finland

ABSTRACT

The purpose of this descriptive cross-sectional study is to describe the amount and intensity of physical activity (PA) measured by accelerometry among adolescents participating in organized sports (SCP) and age-matched non-participating peers (NP). SCPs (332) and NPs (139) wore an accelerometer on the hip for seven days. PA was reported using the 1-min exponential moving average. The current moderate-to-vigorous physical activity (MVPA) recommendation of at least an average of 60 min of MVPA daily was reached by 85% of SCPs and 45% of NPs ($p < .001$). During training days, the MVPA times among SCPs ranged from 153 ± 39 min in males and 109 ± 35 min in females participating in basketball to 113 ± 33 min in males participating in floorball and 83 ± 32 min in females participating in gymnastics. Sports participation contributes rather strongly to the accumulation of the recommended amount of MVPA. During training days, SCPs, except for females participating in gymnastics, accumulated more MVPA than NPs. During non-training days, only males participating in cross-country skiing and females participating in track and field accumulated more MVPA than NPs.

KEYWORDS

accelerometer; organized sports participation; physical activity; adolescence

HIGHLIGHTS

- PA of Finnish adolescents participating in nine different organized sports and age-matched non-participating peers was measured by accelerometry for one week and the results are reported using the 1-min exponential moving average.
- Adolescents participating in many organized sports accumulated more PA than non-participants; this was observed in meeting the PA recommendations, total amount of PA at different intensities, and step count.
- The current PA recommendation of at least an average of 60 min of MVPA per day was reached by 85% of SCPs and 45% of non-participating peers. Vigorous physical activity at least three times per week was incorporated by 96% of SCPs and 81% of NPs.
- During training days, males participating in soccer, basketball, and cross-country skiing spent more time in MVPA than females participating in the same sports. During non-training days, the time spent in MVPA was similar between males and females participating in sports clubs.

Background

The health benefits of regular physical activity (PA) are well known for children and adolescents (Janssen & Leblanc, 2010). The World Health Organization's (WHO) physical activity guidelines, updated in 2020, as well as the Finnish PA guidelines, state that children and adolescents should do at least an average of 60 min per day of moderate-to-vigorous intensity physical activity (MVPA) and that vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone, should be incorporated at least three days a week (Bull et al., 2020; Ministry of Education and Culture, 2021). In contrast, The WHO guidelines from 2010 state that 60 min of MVPA should be accumulated each day (World Health

CONTACT K. Toivo kerttu.toivo@ukkinstituutti.fi Tampere Research Center of Sports Medicine, UKK Institute for Health Promotion Research, Kaupinpuistokatu 1, 33500 Tampere, Finland

Supplemental data for this article can be accessed at https://doi.org/10.1080/17461391.2022.2103740.

Organization, 2010). The Canadian 24-hour movement guideline, released in 2016, also stated that at least 60 min per day, on average, is recommended for surveillance of PA (Tremblay et al., 2016). This allows for some normal day-to-day variability, and the daily average is used predominantly in the studies upon which the guidelines are based (Tremblay et al., 2016). The influence of the fractionalization of MVPA throughout the week has been studied, and better cardiometabolic health in children and youth seems to be associated with meeting the 60-min PA target on at least five out of seven days (Janssen, Wong, Colley, & Tremblay, 2013).

Accelerometry offers an objective way to measure PA, and the reliability of self-report measures for PA varies between studies, usually being low-moderate compared to objective measurements (Ekelund, Tomkinson, & Armstrong, 2011; Prince et al., 2008; Sprengeler, Wirsik, Hebestreit, Herrmann, & Ahrens, 2017). There is also considerable variability between studies in how the MVPA recommendations are met even when using device-based/accelerometry measurements. This is due to the different intensity thresholds used across studies (Ekelund et al., 2011). To address this problem, the mean amplitude deviation (MAD) of the raw acceleration signal can be used to produce comparable results among different studies (Aittasalo et al., 2015). To reach the minimum PA recommendation of 60 min of accelerometer-measured daily MVPA, 11,500–14,000 accelerometer-measured steps are needed in adolescents (Adams, Johnson, & Tudor-Locke, 2013).

The aim of this study was to determine how MVPA and VPA recommendations are met among adolescents participating in organized sports (SCP) and adolescents who are not participating in organized sports (NP). As a secondary aim, we determined male-female differences in daily MVPA times during all days, training days and non-training days. We also compared the length of PA bouts during training and non-training days and investigated the number of daily steps among adolescents in both groups. The differences in the amount and intensity of PA between athletes and non-athletes have previously been studied in university students (Clemente, Nikolaidis, Martins, & Mendes, 2016); however, to our knowledge, not in adolescents participating in different sports disciplines and their non-participating counterparts.

Methods

This cross-sectional study was a part of the Finnish Health Promoting Sports Club (FHPSC) study conducted by the University of Jyväskylä in collaboration with six national Centres of Excellence in Sports and Exercise Medicine and the UKK Institute (Kokko et al., 2015), located in different regions of Finland: Tampere, Turku, Helsinki, Jyväskylä, Kuopio, and Oulu. A total of 240 sports clubs from 10 of the most popular sports disciplines were targeted to produce a representative sample of the most popular team and individual sports for youth in Finland; both summer and winter sports were included (Kokko et al., 2015). The sports included were soccer, floorball, basketball, ice hockey, skating, gymnastics, track and field, swimming, cross-country skiing, and orienteering. The number of sports clubs that successfully participated in the study and was included in the final analysis was 154.

All sports clubs participated in the study voluntarily, and permission for participation was requested at the beginning of the study. All respondents were notified that they had a right to refuse to participate and withdraw from the study at any time. The study was carried out in conformance with the Declaration of Helsinki. A positive statement from the Ethics Committee of Health Care in the District of Central Finland was received (record number 23U/2012).

Altogether, 471 adolescents between 14 and 17 years old (SCP: 332 participants, 52% female; NP: 139 participants, 64% female) wore an accelerometer on the hip for at least 10 h per day on at least four days of the seven measurement days. SCPs were recruited via sports clubs and NPs were recruited via schools. The data were collected within 14 months, mainly during the competition season for SCPs. The same number of subjects was aimed for in each centre. Owing to differing timing for data collection, different age cohorts were targeted: for winter sports, youth born in 1997 (9th graders in Spring 2013), and for summer sports youth born in 1998 (9th graders in Autumn 2013). Plus-minus one year was accepted at sampling stage. Comparison data for non-sports club participants were collected via schools (9th grades) similarly in two stages and approximately within the same timeframe. The schools were selected from the same districts as the sports clubs (Kokko et al., 2015).

PA was measured with a hip-worn tri-axial Hookie AM 20-accelerometer (Hookie Technologies Ltd., Helsinki, Finland), which has been shown to be valid among adults (Vähä-Ypyä et al., 2015) and adolescents (Aittasalo et al., 2015). The accelerometer collected and stored tri-axial data (in raw mode) in g-units. The intensity of PA was calculated for 6 s epoch data from the accelerometer as the MAD of the resultant acceleration; this is a validated measure to allow comparison between different studies (Vähä-Ypyä et al., 2015). MAD values were converted to METs (metabolic equivalent, 1 MET = 3.5 ml (O_2)/kg/min) and intensity was calculated as

the 1-min exponential moving average of epoch-wise MET values. The 1 min epoch is the most commonly used epoch in other studies (Clemente et al., 2016), but 6 s epochs are also used (Husu, Vähä-Ypyä, & Vasankari, 2016). Moderate physical activity was defined as activity corresponding as 3–5.9 MET, vigorous activity more than 6 MET, and very vigorous activity (vVPA) more than 9 MET.

Upon the first study visit, the accelerometer was fitted, and guidance was given to attach the elastic belt at the level of the iliac crest. The accelerometers were returned one week later on a study visit or later by mail. In addition, PA was recorded in a structured diary, in which the adolescents were asked to record the time of waking up and going to bed, as well as the types and intensities of all PA performed during the day. For the SCP group, we classified days with competitions, organized training, training during school, and independent training as training days. Days not including any of these were classified as non-training days. Those adolescents who had not recorded PA in the diary were excluded from the analysis.

The accelerometry measurement was studied in relation to energy expenditure while walking and running (Freedson, Melanson, & Sirard, 1998). Thus, MET values are not directly applicable during tasks performed on skates, skis, or bicycles. Swimmers were excluded from the analysis, as they did not wear the accelerometer during training. Sports disciplines with eight or more same-sex participants were included in the analysis of meeting the PA recommendations and step count. Sports with fewer than eight participants of the same sex were included in the bout length analysis, in which both sexes were analysed together. Ten SCPs reported participating in another sport than originally reported. They may have switched sports during the study and therefore were excluded from the analyses. Additionally, two SCPs did not report participating in any sports and were excluded from the analysis.

Multilevel data-structure was constructed to allow for the clustering of values within the centre the accelerometer was given in and the sports discipline of the subject. Generalized linear mixed model (GLMM) was used to analyse differences in PA times and meeting the PA recommendations between SCPs and NPs. Linear mixed model (LMM) was used to analyse differences in PA bout lengths between training and non-training days within SCPs participating in the same sport as well as in NPs. A probability value (p) of less than .05 was considered significant. IBM SPSS (v.26.0) was used to carry out all analyses.

The percentage of SCPs and NPs who reached the PA recommendations was reported in three ways: reaching an average of 60 min of MVPA on each measuring day, reaching the 60 min recommendation on each measuring day, and reaching the 60 min recommendation on all but one measuring day (Table 1).

Results

The mean age of SCPs and NPs was similar (15.6 ± 0.5 years), and statistically significant differences were not found in the height between SCPs and NPs among males (176 ± 6.7 cm vs 174 ± 7.0 cm, respectively, p = .08) or females (166 ± 6.2 cm vs 166 ± 6.0 cm, respectively, p = .93). SCP females' mean weight was slightly lower than that of NP females' (58.2 ± 7.8 kg vs 60.8 ± 9.7 kg, respectively; p = .03). Among males, the difference in weight between SCPs and NPs was not statistically significant (64.8 ± 9.6 kg vs 62.8 ± 12 kg, respectively, p = .24).

The daily mean time of 60 min of MVPA was reached by 85% of SCP and 45% of NP (p < .001). Sixty minutes of MVPA each day was reached by 20% of SCP and 5% of NP (p < .001). When one resting day was accepted, the percentage of SCPs accumulating 60 min on MVPA each day was 49%. Vigorous PA (>6 MET) on at least three days was incorporated by 96% of SCP and 81% of NP (p < .001)

The daily time spent in MVPA in SCPs when looking at all days together in males ranged from 123 ± 35 min in basketball players to 97 ± 21 min in floorball players, and in females from 84 ± 22 min in cross-country skiers to 67 ± 24 min in gymnasts. When looking at training days only, MVPA time among SCPs ranged from 153 ± 39 min in males and 109 ± 35 min in females participating in basketball to 113 ± 33 min in males participating in floorball and 83 ± 32 min in females participating in gymnastics (Table 2). The median number and interquartile range of measuring days and training days for each sports discipline are shown in the supplementary material.

During training days, males participating in soccer, basketball, and cross-country skiing spent more time in MVPA than females participating in the same sports (Table 2). During non-training days, no statistically significant differences in time spent in MVPA were observed between SCP males and females. During non-training days, SCP males participating in floorball and cross-country skiing and females participating in track and field spent more time in MVPA than NP. See Table 2.

The time spent in moderate PA (3-6 MET) during training days among males ranged from 117 ± 30 min in basketball players to 83 ± 20 min in floorball players and among females from 85 ± 15 min in floorball players to

Table 1. Reaching the physical activity recommendations and daily time of physical activity on all days in sports participants and non-participants.

		60 min MVPA per day, mean, (%)	*p*-value[1]	60 min MVPA each day (%)	*p*-value[1]	60 min MVPA, 1 rest day, (%)	*p*-value[1]	>6 MET at least 3×/ week, (%)	*p*-value[1]	Daily MVPA (min)	*p*-value[1]	*p*-value[2]
Soccer	Males (*n* = 25)	96	<.001*	8	.82	48	.02*	100	.02*	110 ± 29	<.001*	.01*
	Females (*n* = 18)	83	<.001*	11	.47	33	.13	100	.003*	84 ± 34	.001*	
Floorball	Males (*n* = 25)	96	<.001*	8	.82	72	<.001*	100	.02*	97 ± 21	.001*	.18
	Females (*n* = 8)	88	<.001*	13	.56	38	.21	88	.55	83 ± 31	.02*	
Basketball	Males (*n* = 19)	90	.001*	37	.01*	68	<.001*	95	.12	123 ± 35	<.001*	.005*
	Females (*n* = 8)	88	<.001*	13	.56	25	.55	100	.02*	81 ± 31	.03*	
Ice hockey†	Males (*n* = 31)	94	<.001*	36	.002*	52	.004*	97	.04*	103 ± 34	<.001*	
Skating†	Females (*n* = 26)	92	<.001*	15	.19	58	<.001*	96	.02*	83 ± 23	<.001*	
Gymnastics	Females (*n* = 29)	48	.57	7	.73	31	.10	90	.18	67 ± 24	.22	
Track and field	Males (*n* = 20)	90	.001*	15	.36	55	.01*	100	.02*	100 ± 37	<.001*	.26
	Females (*n* = 21)	76	.002*	29	.02*	57	<.001*	95	.03*	86 ± 40	<.001*	
Orienteering	Females (*n* = 26)	85	<.001*	23	.01*	35	.06	100	.01*	83 ± 25	<.001*	
Cross country skiing†	Males (*n* = 13)	92	.001*	39	.03*	54	.03*	85	.79	114 ± 32	<.001*	.005*
	Females (*n* = 15)	80	.001*	33	.03*	40	.07	93	.11	84 ± 22	.001*	
Non-participants	Males (*n* = 49)	51		6		20		81		65 ± 27		.04*
	Females (*n* = 90)	42		4		16		80		60 ± 24		

Note: n = sample size, MVPA = moderate to vigorous physical activity, VPA = vigorous physical activity, vVPA = very vigorous physical activity, MET = metabolic equivalent, min = minutes. *indicates statistical significance. †indicates a sport that is not performed on foot, which underestimates the amount of VPA and vVPA. [1]indicates the *p*-value for statistical significance between sports participants and non-participants. [2]indicates the *p*-value for statistical significance between females and males.

64 ± 25 min in orienteerers. The time spent in vigorous PA (MET 6–9) in SCP males ranged from 31 ± 14 min in soccer players to 6 ± 5 min in ice hockey players and among females from 21 ± 16 min in soccer players to 6 ± 5 min in skaters. Time spent in vVPA (>9 MET) among males ranged from 12 ± 6 min in cross-country skiers to 4 ± 5 in ice hockey players and among females from 20 ± 12 min in orienteerers to 3 ± 5 min in gymnasts. See Table 2.

Basketball players attained significantly longer MVPA times during training days than during non-training days in all bout lengths (Figure 1). Among orienteerers, the difference between training- and non-training days was significant in bouts of 10 min or longer, and among cross-country skiers and soccer players, the difference was significant in bouts of three minutes or longer. Among gymnasts and floorball players, the difference between training and non-training days was significant in bouts shorter than 10 min. Among ice hockey players, the difference in MVPA time between training and non-training days was significant in bouts of 30 s to 2.9 min and among non-participants in bouts of 10–19.9 min (Figure S1 and supplementary material).

The hour-by-hour figure of the daily accumulation of steps is shown in Figure 2. During non-training days, the accumulation of steps was similar between SCPs and NPs. The *p*-values showing the statistical significance between SCPs and NPs are presented in the supplementary material. The total average step count for SCPs and NPs together was 9220 (SD 3000) for males and 8740 (SD 2950) for females ($p = .03$).

Discussion

As expected, adolescents participating in many organized sports accumulated more PA than NPs; this was observed in meeting the PA recommendations, total amount of PA at different intensities, and step count. Eighty-five per cent of SCPs and 45% of NPs reached the current WHO PA recommendation of at least an average of 60 min per day of MVPA. Only 20% of SCPs

Table 2. The daily time and intensity of physical activity on training days and non-training days in sports participants and non-participants.

		Training days									Non-training days		
		3–6 MET (min)	*p*-value[1]	6–9 MET (min)	*p*-value[1]	>9MET (min)	*p*-value[1]	MVPA (min)	*p*-value[1]	*p*-value[2]	MVPA (min)	*p*-value[1]	*p*-value[2]
Soccer	Males (*n* = 25)	101 ± 28	.002*	31 ± 14	<.001*	9 ± 6	.01*	141 ± 35	<.001*	.002*	63 ± 43	.90	.75
	Females (*n* = 18)	72 ± 28	.25	21 ± 16	<.001*	7 ± 7	.44	100 ± 40	.009*		59 ± 28	.74	
Floorball	Males (*n* = 25)	83 ± 20	.25	20 ± 12	<.001*	10 ± 8	.002*	113 ± 33	.006*	.51	78 ± 36	.07	.27
	Females (*n* = 8)	85 ± 15	.05*	12 ± 9	.06	7 ± 8	.44	104 ± 29	.02*		61 ± 26	.67	
Basketball	Males (*n* = 19)	117 ± 30	<.001*	29 ± 17	<.001*	6 ± 4	.19	153 ± 39	<.001*	.01*	60 ± 32	.93	.59
	Females (*n* = 8)	84 ± 27	.04*	15 ± 10	.002*	10 ± 11	.10	109 ± 35	.003*		53 ± 21	.74	
Ice hockey†	Males (*n* = 31)	102 ± 32	.002	6 ± 5	.86	4 ± 5	.52	113 ± 36	.003*		77 ± 36	.09	
Skating†	Females (*n* = 26)	78 ± 22	.03*	6 ± 5	.69	4 ± 4	.65	88 ± 25	.05		66 ± 29	.14	
Gymnastics	Females (*n* = 29)	71 ± 27	.20	8 ± 8	.11	3 ± 5	.60	83 ± 32	.11		46 ± 20	.08	
Track and field	Males (*n* = 20)	94 ± 31	.02*	13 ± 7	.02*	9 ± 8	.01*	116 ± 40	.002*	.08	58 ± 28	.81	.24
	Females (*n* = 21)	72 ± 36	.16	9 ± 7	.06	10 ± 8	.02*	92 ± 46	.02*		73 ± 37	.01*	
Orienteering	Females (*n* = 26)	64 ± 25	.78	15 ± 9	<.001*	20 ± 12	<.001*	99 ± 27	.002*		57 ± 30	.93	
Cross country skiing†	Males (*n* = 13)	107 ± 43	.001*	11 ± 8	.20	12 ± 6	.002*	129 ± 38	<.001*	.02*	88 ± 44	.02*	.06
	Females (*n* = 15)	80 ± 22	.03*	14 ± 13	<.001*	5 ± 6	.81	100 ± 21	.005*		59 ± 26	.77	
Non-participants	Males (*n* = 49)	68 ± 31		6 ± 7		3 ± 7		77 ± 32		.06	61 ± 29		.05*
	Females (*n* = 90)	61 ± 27		5 ± 6		5 ± 6		71 ± 31			57 ± 24		

Note: n = sample size, MVPA = moderate to vigorous physical activity, VPA = vigorous physical activity, vVPA = very vigorous physical activity, MET = metabolic equivalent, min = minutes. *indicates statistical significance. †indicates a sport that is not performed on foot, which underestimates the amount of VPA and vVPA. [1]indicates the *p*-value for statistical significance between sports participants and non-participants. [2]indicates the *p*-value for statistical significance between females and males.

accumulated at least 60 min of MVPA each day. However, it is recommended that athletes have at least one resting day from training or competition every week. When one resting day was accepted, the percentage of SCPs accumulating 60 min of MVPA each day increased to 49%.

Participation in organized sports is popular among Finnish adolescents, with 69% of 7- to 14-year-olds reportedly taking part in sports-club activities. However, participation declines with increasing age (Husu et al., 2016). In a recent accelerometer-based study of Finnish adolescents, 13- to 15-year-old boys took an average of 9270 steps per day and girls took 8836 steps; the number of daily steps was found to decrease with increasing age (National Sports Council, 2020). Based on accelerometer measurements carried out in Canada in 2014–2015, 33.2% of young people aged 6–17 attained, on average, 60 min of MVPA per day, and 5.5% attained this every day (Colley et al., 2017). Similar results were found in our study. In a recent survey of Finnish 9th-grade adolescents, 18% reported 60 min of daily MVPA and 30% reported 60 min of MVPA on five to six days per week; boys were more likely than girls to report MVPA every day (Mehtälä et al., 2020). The changes in physical activity patterns from adolescence to young adulthood have recently been studied, SC participation was associated with a sustained or increased PA pattern and SC withdrawal with a PA decrease from a high level (Aira et al., 2021).

In many studies, boys have been found to be more physically active than girls (Colley et al., 2017; Husu et al., 2016; National Sports Council, 2020). This was also found in our study when combining all days and on training days in adolescents participating in soccer, basketball, and cross-country skiing. During non-training days, there was no difference between males and females in the average daily time spent in MVPA. The difference in MVPA accumulation between males and females was observable in soccer, basketball, and cross-country skiing. For example, males participating in basketball spent, on average, 42 min more in MVPA

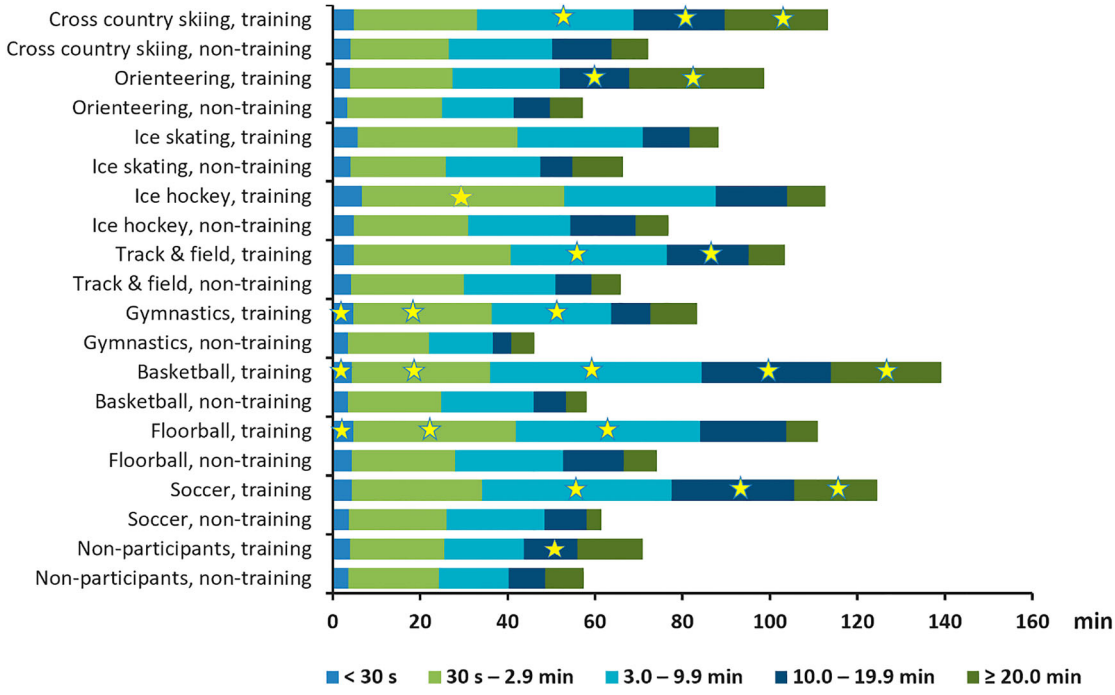

Figure 1. Comparison of the length of moderate to vigorous physical activity bouts between training and non-training days among adolescents participating in different organized sports and non-participants using the 1-min exponential moving average. Significant differences between training and non-training days are indicated with a star. s = seconds.

daily than females, which would result in 5 h 45 min per week or about 255 h/year. Participation in organized sports contributes to achieving the daily PA recommendations, especially among boys (Marques, Ekelund, & Sardinha, 2016).

Organized sport participation has been found to be associated with better cardiovascular endurance in 10- to 16-year-old adolescents (Carlisle, Weaver, Stodden, & Cattuzzo, 2019). The differences in PA behaviour between different individuals are explained largely by biological and genetic factors, in addition to social and environmental determinants, such as participation in organized sports (Lightfoot et al., 2018). In our study, more than 80% of all adolescents accumulated vigorous PA on at least three days during the measuring period.

The length of the analysis period used when measuring PA with accelerometry deserves attention due to the different kinetics of the cardiorespiratory, endocrine, and metabolic responses to PA (Caspersen, Powell, & Christenson, 1985; De Feo et al., 2003; Phillips, Green, MacDonald, & Hughson, 1995). We chose to look at the 1 min exponential moving average throughout the study, which is the mostly commonly used method to present PA measured by accelerometer (Clemente et al., 2016). If a shorter analysis period would have been used, the total length of accumulated PA time would be somewhat longer, because shorter bouts of physical activity subsequently become more detectable (Orme et al., 2014; Vähä-Ypyä et al., 2015).

There was variety in the sport in which SCPs reached the highest levels of PA depending on the intensity of PA that was examined. The amount of PA recorded in a specific sport also depends on the characteristics of the sport, the size of the area it is performed on, and the time of the training season. When comparing PA levels between athletes participating in different sports, the varying demands of the sport also need to be considered. The length of PA bouts found in this study reflects the type of training carried out in each sport during the measurement period.

A strength of this study was that the adolescents participating in this study formed a representative sample from different regions of Finland, and the SCPs participated in the ten most popular sports in the country. Both individual and team sports and summer and winter sports were equally represented (Kokko et al., 2015). The age at which one typically specializes and reaches their highest competitive level varies across the different sports included in this study; therefore, we did not divide the SCPs into subgroups according to training volume or competition level. The difference in the maturity status between SCPs and NPs does not explain the differences between sex and sports. As reported earlier (Toivo et al., 2018), almost all of the participants at this

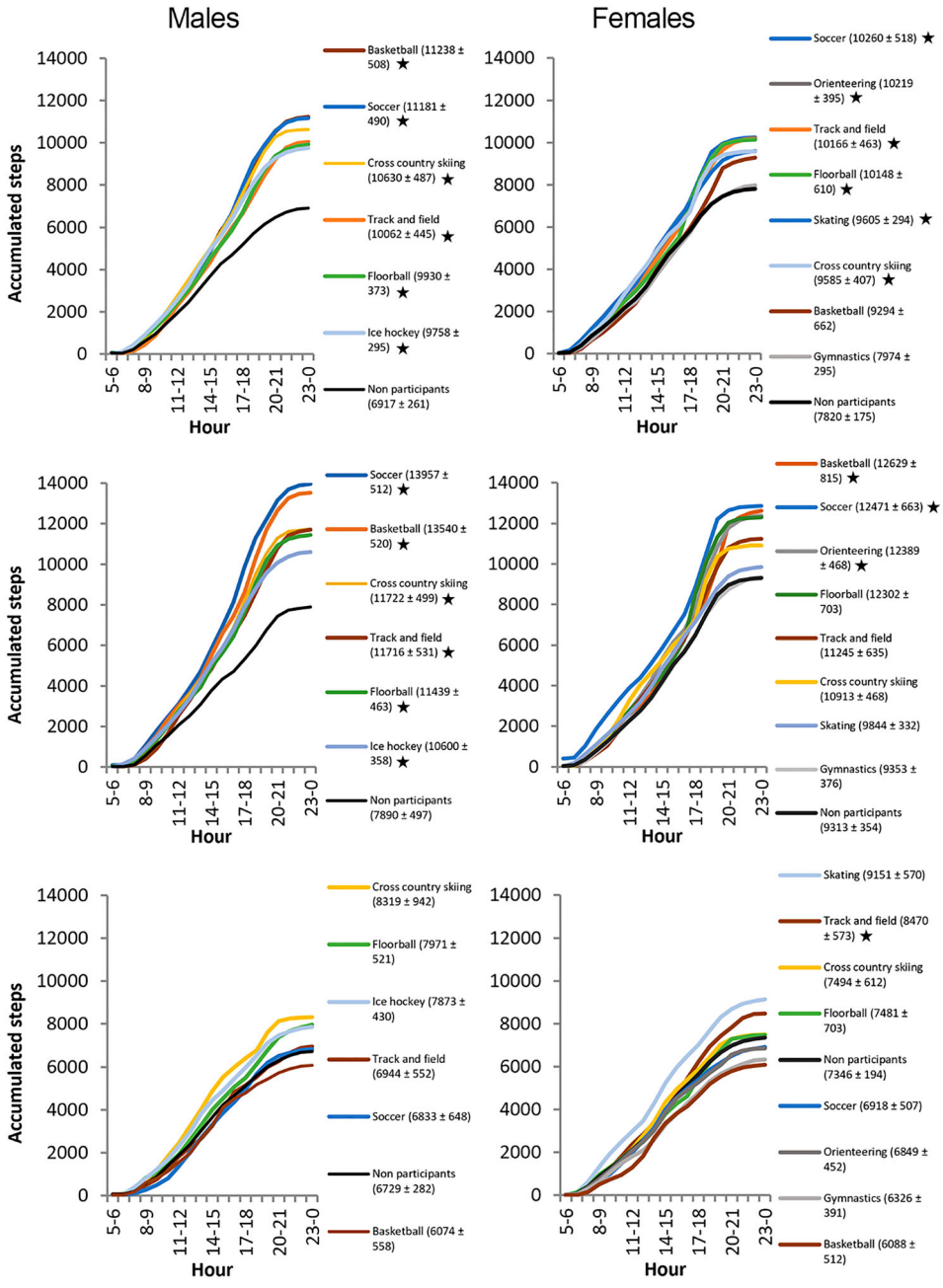

Figure 2. Daily accumulation of steps on all days (top row), training days (middle row), and non-training days (bottom row). Males are shown on the left side and females on the right side. Statistical significance between sports club participants and non-participants is shown with a star.

age have reached puberty and no differences were observed between SCPs and NPs by sex.

Our study also had some limitations. It is well known that use of absolute thresholds for physical activity level underestimates the amount of intense physical activity in lower-fit individuals and overestimates the amount in high-fit individuals, when compared to relative intensity thresholds that are based on physical fitness (Vähä-Ypyä, Sievänen, Husu, Tokola, & Vasankari, 2021). That might also be the case in the current study where levels of physical fitness were not measured. Further, it is possible that the most sedentary individuals did not participate in the study. Swimmers did not wear the accelerometer during training in the water, therefore we excluded swimmers from the analysis. However, based on training diaries, swimmers trained 79–88 min per day. Additionally, VPA performed on skates or skis is underestimated when using an accelerometer. Conversely, a significant amount of training in this type of sports is performed on foot too.

In a study comparing PA across different domains in children, it was found that school hours contributed to 46% of the objectively measured MVPA, whereas sporting activities contributed to only 24% (Sprengeler et al., 2017). In the future, PA patterns in adolescents should be analysed separately during sport-specific training and the time outside practice. Also, PA monitoring can be used at the team or individual level to aid in ensuring appropriate training loads. As such, training loads are known to have an effect on the risk for injury and illness (Bergeron et al., 2015; Drew & Finch, 2016; Ristolainen, Kettunen, Waller, Heinonen, & Kujala, 2014; Schwellnus et al., 2016; Soligard, Schwellnus, & Alonso, 2016).

Conclusions

Sports participation seems to strongly contribute to the accumulation of the recommended amount of PA for health. Nearly half of the NPs and 85% of SCPs reached the WHO recommendation of an average of at least 60 min of MVPA per day, and only 20% of SCPs and 5% of NPs accumulated 60 min of MVPA each day.

Acknowledgements

The authors wish to thank all the participating sports clubs and their officials and coaches. The authors also thank the participating schools for their assistance in the surveys. Without all the adolescents who participated in the study, especially those who took part in the PA measurement, this research would not have been possible. The authors want to express their gratitude to these youths.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study was financially supported by the Finnish Ministry of Education and Culture (major, [Grant number: 6/091/2011]) and the Ministry of Social Affairs and Health (minor, [Grant number: 152/THL/TE/2012]).

Ethics approval and consent to participate

The study was carried out in conformance with the Declaration of Helsinki. A positive statement from the Ethics Committee of Health Care District of Central Finland was received (record number 23U/2012). All sports clubs participated in the study of their own free will. This was secured by requesting club permission at the beginning of the study. Thereafter, all respondents were notified that they had a right to refuse to participate and withdraw from the study at any time.

Data availability statement

The data cannot be shared because permission was not asked from the participants or their parents.

ORCID

K. Toivo http://orcid.org/0000-0002-4573-1937
T. Vasankari http://orcid.org/0000-0001-7209-9351

References

Adams, M. A., Johnson, W. D., & Tudor-Locke, C. (2013). Steps/day translation of the moderate-to-vigorous physical activity guideline for children and adolescents. *The International Journal of Behavioral Nutrition and Physical Activity*, *10*(49). doi:10.1186/1479-5868-10-49

Aira, T., Vasankari, T., Heinonen, O., Korpelainen, R., Kotkajuuri, J., Parkkari, J., … Kokko, S. (2021). Physical activity from adolescence to young adulthood: Patterns of change, and their associations with activity domains and sedentary time. *International Journal of Behavioral Nutrition and Physical Activity*, *18*(1), 85. doi:10.1186/s12966-021-01130-x

Aittasalo, M., Vähä-Ypyä, H., Vasankari, T., Husu, P., Jussila, A.-M., & Sievänen, H. (2015). Mean amplitude deviation calculated from raw acceleration data: A novel method for classifying the intensity of adolescents' physical activity irrespective of accelerometer brand. *BMC Sports Science, Medicine and Rehabilitation*, *7*(18).

Bergeron, M. F., Mountjoy, M., Armstrong, N., Chia, M., Côté, J., Emery, C., … Engebretsen, L. (2015). International Olympic committee consensus statement on youth athletic development. *British Journal of Sports Medicine*, *49*(13), 843–851. doi:10.1136/bjsports-2015-094962

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., … Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, *54*(24), 1451–1462. doi:10.1136/bjsports-2020-102955

Carlisle, C. C., Weaver, R. G., Stodden, D. F., & Cattuzzo, M. T. (2019). Contribution of organized sport participation to health-related fitness in adolescents. *Global Pediatric Health*, *6*, 2333794X19884191. doi:10.1177/2333794X19884191

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports*, *100*(2), 126–131.

Clemente, F. M., Nikolaidis, P. T., Martins, F. M., & Mendes, R. S. (2016). Weekly physical activity patterns of university students: Are athletes more active than non-athletes? *Springerplus*, *5*(1), 1808. doi:10.1186/s40064-016-3508-3

Colley, R. C., Carson, V., Garriguet, D., Janssen, I., Roberts, K. C., & Tremblay, M. S. (2017). Physical activity of Canadian children and youth, 2007 to 2015. *Health Reports*, *28*(10), 8–16.

De Feo, P., Di Loreto, C., Lucidi, P., Murdolo, G., Parlanti, N., De Cicco, A., … Santeusanio, F (2003). Metabolic response to

exercise. *Journal of Endocrinological Investigation*, *26*(9), 851–854.

Drew, M. K., & Finch, C. F. (2016). The relationship between training load and injury, illness and soreness: A systematic and literature review. *Sports Medicine*. doi:10.1007/s40279-015-0459-8

Ekelund, U., Tomkinson, G., & Armstrong, N. (2011). What proportion of youth are physically active? Measurement issues, levels and recent time trends. *British Journal of Sports Medicine*, *45*(11), 859–865. doi:10.1136/bjsports-2011-090190

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. Accelerometer. *Medicine & Science in Sports & Exercise*, *30* (5), 777–781.

Husu, P., Vähä-Ypyä, H., & Vasankari, T. (2016). Objectively measured sedentary behavior and physical activity of Finnish 7- to 14-year-old children- associations with perceived health status: A cross-sectional study. *BMC Public Health*, *16*(338). doi:10.1186/s12889-016-3006-0

Janssen, I., & Leblanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *The international Journal of Behavioral Nutrition and Physical Activity*, *7*(40). doi:10.1186/1479-5868-7-40

Janssen, I., Wong, S. L., Colley, R., & Tremblay, M. S. (2013). The fractionalization of physical activity throughout the week is associated with the cardiometabolic health of children and youth. *BMC Public Health*, *13*(554). doi:10.1186/1471-2458-13-554

Kokko, S., Selänne, H., Alanko, L., Heinonen, O., Korpelainen, R., Savonen, K., … Parkkari, J. (2015). Health promotion activities of sports clubs and coaches, and health and health behaviours in youth participating in sports clubs: The Health Promoting Sports Club study. *BMJ Open Sport and Exercise Medicine*, *1*(1). 10.1136/bmjsem-2015-000034

Lightfoot, J. T., Geus EJC, D. E., Booth, F. W., Bray, M. S., DEN Hoed, M, Kaprio, J., … Bouchard, C. (2018). Biological/genetic regulation of physical activity level: Consensus from GenBioPAC. *Medicine & Science in Sports & Exercise*, *50* (4), 863–873. doi:10.1249/MSS.0000000000001499

Marques, A., Ekelund, U., & Sardinha, L. B. (2016). Associations between organized sports participation and objectively measured physical activity, sedentary time and weight status in youth. *Journal of Science and Medicine in Sport*, *19* (2), 154–157. doi:10.1016/j.jsams.2015.02.007

Mehtälä, A., Villberg, J., Blomqvist, M., Huotari, P., Jaakkola, T., Koski, P., … Kokko, S. (2020). Individual- and environmental-related correlates of moderate-to-vigorous physical activity in 11-, 13-, and 15-year-old Finnish children. *PLoS One*, *15*(6), e0234686. doi:10.1371/journal.pone.0234686

Ministry of Education and Culture. (2021). *Recommendation on physical activity for children and adolescents aged 7 to 17 years* (Report series of the Ministry of Education and Culture, Finland 2021:21).

National Sports Council. (2020). *Koronarajoitukset vaikuttivat rajusti lasten ja nuorten liikkumiseen, engl: COVID restrictions had a marked affect on the physical activity of children and adolescents* (Valtion liikuntaneuvosto, engl. National Sports Council) 13.

Orme, M., Wijndaele, K., Sharp, S. J., Westgate, K., Ekelund, U., & Brage, S. (2014). Combined influence of epoch length, cut-point and bout duration on accelerometry-derived physical activity. *The international Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 34. doi:10.1186/1479-5868-11-34

Phillips, S. M., Green, H. J., MacDonald, M. J., & Hughson, R. L. (1995). Progressive effect of endurance training on VO2 kinetics at the onset of submaximal exercise. *Journal of Applied Physiology*, *79*(6), 1914–1920. doi:10.1152/jappl.1995.79.6.1914

Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Connor Gorber, S., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: A systematic review. *The international Journal of Behavioral Nutrition and Physical Activity*, *5*(56). doi:10.1186/1479-5868-5-56

Ristolainen, L., Kettunen, J. A., Waller, B., Heinonen, A., & Kujala, U. M. (2014). Training-related risk factors in the etiology of overuse injuries in endurance sports. *Journal of Sports Medicine and Physical Fitness*, *54*(1), 78–87.

Schwellnus, M., Soligard, T., Alonso, J. M., Bahr, R., Dijkstra, H. P., Gabbett, T. J., … Engebretsen, L. (2016). How much is too much? (part 2) International Olympic Committee consensus statement on load in sport and risk of illness. *British Journal of Sports Medicine*, *50*(17), 1043–1052. doi:10.1136/bjsports-2016-096572

Soligard, T., Schwellnus, M., & Alonso, J. (2016). Infographic. International Olympic Committee consensus statement on load in sport and risk of injury: How much is too much? *British Journal of Sports Medicine*, *50*(17), 1042. doi:10.1136/bjsports-2016-096583

Sprengeler, O., Wirsik, N., Hebestreit, A., Herrmann, D., & Ahrens, W. (2017). Domain-specific self-reported and objectively measured physical activity in children. *International Journal of Environmental Research and Public Health*, *14*(3). doi:10.3390/ijerph14030242

Toivo, K., Kannus, P., Kokko, S., Alanko, L., Heinonen, O. J., Korpelainen, R., … Parkkari, J. (2018). Musculoskeletal examination in young athletes and non-athletes: The Finnish Health Promoting Sports Club (FHPSC) study. *BMJ Open Sport & Exercise Medicine*, *4*(1), e000376. doi:10.1136/bmjsem-2018-000376

Tremblay, M. S., Carson, V., Chaput, J. P., Connor Gorber, S., Dinh, T., Duggan, M., … Zehr, L. (2016). Canadian 24-hour movement guidelines for children and youth: An integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition and Metabolism*, *41*(6 Suppl 3), S311–S327. doi:10.1139/apnm-2016-0151

Vähä-Ypyä, H., Sievänen, H., Husu, P., Tokola, K., & Vasankari, T. (2021). Intensity paradox – Low-fit people Are physically most active in terms of their fitness. *Sensors*, *21*(6), 2063. doi:10.3390/s21062063

Vähä-Ypyä, H., Vasankari, T., Husu, P., Mänttäri, A., Vuorimaa, T., Suni, J., & Sievänen, H. (2015). Validation of cut-points for evaluating the intensity of physical activity with accelerometry-based mean amplitude deviation (MAD). *PLoS One*, *10*(8), e0134813. doi:10.1371/journal.pone.0134813

World Health Organization. (2010). Global recommendations on physical activity for health.