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ORIGINAL CONTRIBUTION

Physical activity in European adolescents and associations with anxiety, depression and well-being

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Abstract In this cross-sectional study, physical activity, sport participation and associations with well-being, anxiety and depressive symptoms were examined in a large representative sample of European adolescents. A school-based survey was completed by 11,110 adolescents from ten European countries who took part in the SEYLE (Saving and Empowering Young Lives in Europe) study. The questionnaire included items assessing physical activity, sport participation and validated instruments assessing well-being (WHO-5), depressive symptoms (BDI-II) and anxiety (SAS). Multi-level mixed effects linear regression was used to examine associations between physical activity/sport participation and mental health measures. A minority of the sample (17.9 % of boys and 10.7 % of girls; $p < 0.0005$) reported sufficient activity based on WHO guidelines (60 min + daily). The mean number of days

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of at least 60 min of moderate-to-vigorous activity in the past 2 weeks was 7.5 ± 4.4 among boys and 5.9 days ± 4.3 among girls. Frequency of activity was positively correlated with well-being and negatively correlated with both anxiety and depressive symptoms, up to a threshold of moderate frequency of activity. In a multi-level mixed effects model more frequent physical activity and participation in sport were both found to independently contribute to greater well-being and lower levels of anxiety and depressive symptoms in both sexes. Increasing activity levels and sports participation among the least active young people should be a target of community and school-based interventions to promote well-being. There does not appear to be an additional benefit to mental health associated with meeting the WHO-recommended levels of activity.

Keywords Adolescent · Anxiety · Depression · Mental health · Exercise

Background

There is conclusive evidence that the physical health of adolescents is enhanced by frequent physical activity [1, 2]. It is recommended that children and adolescents aged 5–17 years should accumulate at least 60 min of moderate-to-vigorous activity each day [1, 3]. However, it has been reported that 80 % of 13–15 year-olds worldwide do not achieve this amount of activity per day [4]. Internationally, levels of physical activity have been found to decrease with age in adolescence, with girls engaging in significantly less activity than boys in most countries and regions worldwide [5]. Possible explanations for these sex disparities include the suggestion that competitive activities may appeal more to boys, while girls may focus more on health and fitness [6].

An association between physical activity and mental health in children and adolescents has also been reported, but research designs are often weak and effects small to moderate [7, 8]. A systematic review of randomised controlled trials of exercise interventions for anxiety and depression in children and adolescents reported a small effect in favour of physical activity in reducing depression and anxiety levels in the general population [9], while sedentary behaviour has been reported to be associated with anxiety disorder [10]. A recent longitudinal study has reported that adolescents who engage in higher frequencies of physical activity are more resilient to developing depressive symptoms [11]. Participation in sports has also been found to be associated with reduced levels of depression and suicidal ideation [12, 13] and adolescents who participate in team sports have been found to report higher levels of happiness than those who play individual sports [14].

Mental health problems are common in European adolescents. The multi-centre Saving and Empowering Young Lives in Europe (SEYLE) study reported that 5.8 % of participants met criteria for an anxiety disorder, 10.5 % met criteria for depressive disorder [15], while 32.3 % reported suicidal thoughts [16]. In this study, we examined physical activity and its associations with mental health indicators in the SEYLE sample. Our objectives were to describe the frequency of physical activity and participation in sport among girls and boys and to examine associations between physical activity and sports participation and anxiety, depressive symptoms and well-being. We hypothesised that the majority of adolescents were insufficiently active according to current public health guidelines, that girls were more inactive than boys and that higher frequency of physical activity would be associated with greater well-being and lower levels of anxiety and depressive symptoms among adolescents.

Method

Cross-sectional data were drawn from the Saving and Empowering Young Lives in Europe (SEYLE) study [16]. The SEYLE trial is registered at the German Clinical Trials Registry, number DRKS00000214. Participants were recruited from 168 schools in ten European countries (Austria, Estonia, France, Germany, Hungary, Ireland, Italy, Romania, Slovenia and Spain) and the trial evaluated school-based interventions for prevention of suicidal behaviour. Schools in the study regions were included if they were public, a minimum of 40 students aged 15 were enrolled, more than two teachers were employed to teach 15-year-old students, and no more than 60 % of students were of the same sex. All students in participating classes, including those who were aged 14 and 16, were included to avoid discrimination. Ethical approval was obtained at each study site from the appropriate local ethics committees. Full details of trial methodology, consent procedures, response rates and representativeness of the sample have been reported elsewhere [17]. Of 232 schools approached, 168 schools (72 %) agreed to participate. Of the 27,099 pupils approached, 14,267 were not enrolled because parental or student consent was not given, and 1722 pupils were absent on the day. In the current study, baseline data were used and only adolescents for whom sex was recorded were included (n = 11,072). Of these, 6566 (59 %) were girls and 4506 were boys. The mean age of the sample was 14.8 [SD 0.84].

Data collection

Students were administered a self-report questionnaire in their classroom, which included well-established

instruments and several items developed for the SEYLE study [17]. Local teams were uniformly trained in the study procedure. Adherence to study procedures and quality control was monitored through site visits and questionnaires. Data were entered at each site following double data entry procedures. Quality control of each local data set was carried out centrally before data were pooled.

Physical activity

Physical activity was assessed using a modified version of the PACE + (Patient-Centred Assessment and Counselling for Exercise Plus Nutrition) adolescent physical activity measure [19]. When compared with accelerometry, this measure has been reported to have acceptable validity in assessing non-compliance with physical activity recommendations [20]. The survey item assessing physical activity was as follows: "During the past 2 weeks, on how many days were you physically active for a total of at least 60 min? For each day, add up all the time you spent in physical activity like walking, riding a bicycle etc. Do not include your physical education or gym class. Count up the days with at least 60 min of physical activity in the past 2 weeks." Responses ranged from 0 to 14 days.

Sports participation

A further survey item asked participants whether they had regularly (at least once a week) played one or more sports in the past 6 months, with possible responses "Yes" or "No". Participants were also asked to name the sports in which they participated, with space for up to three sports to be entered. The named sports were later coded by the study team as a team sport or an individual sport/fitness activity. Team sports were classified as those that typically involved three or more players on each side who compete concurrently [14]. If participants named at least one team sport they were classified as engaging in team sports. Participants who did not report playing any team sport but named an individual sport or other fitness activity were coded as individual sport/fitness activity. A third sub-group comprised of those who reported no participation in sport or other fitness activity. For some analyses all sports (team and individual/fitness) were treated as one category.

Mental health

Depressive symptoms: Severity of depressive symptoms was measured using the Beck Depression Inventory II (BDI-II) [21]. Items of this instrument assess specific symptoms of depression experienced over the preceding 2 weeks. The BDI-II includes an item measuring loss of libido which was excluded from the SEYLE questionnaire as it is considered inappropriate for adolescents in some cultural settings [22]. Each question was scored from 0 to 3, indicating the severity of the symptom, with total scores ranging from 0 to 60. Cronbach's alpha in our sample was 0.86, indicating good internal reliability [18]. The reliability and validity of the BDI-II have been confirmed in clinical and community samples of adolescents [23, 24].

Anxiety symptoms: Symptoms of anxiety were assessed using the Zung Self-Rating Anxiety Scale (SAS) [25], a 20-item self-report questionnaire. Responses to each item range from 1 to 4 with scores ranging from 20 to 80 with higher scores indicating increased levels of anxiety. Cronbach's alpha in our sample was 0.81, indicating good internal reliability [18]. The SAS has been shown to have good reliability and validity in samples of undergraduate students [26].

Well-being: Well-being was assessed using the WHO-5 Well-being Index (WHO-5) [27], which measures positive psychological well-being. Responses to each item range from 0 to 5. These scores are summed and converted to obtain a percentage score ranging from 0 to 100, where 100 represents best possible level of well-being. Cronbach's alpha in our sample was 0.80, indicating good internal reliability. The psychometric properties of the WHO-5 have been confirmed in a large adult sample [28] and it has been confirmed as a valid scale for use in an adolescent sample [29].

Socio-economic status (SES) may be a confounding factor in associations between physical activity and mental health, as family affluence has been found to be associated with physical activity levels in most countries [30]. Although SES was not measured using a validated instrument in this study, we have used responses to the following question as a proxy measure of SES: "Do your parents have trouble making ends meet?" with responses categorised as "Yes" or "No".

Chronic illness and sexual intercourse were included as covariates in our multivariate analyses due to their associations with physical activity levels and mental health in our sample. The survey items included were: "Do you suffer from a chronic illness?" and "Have you ever had sexual intercourse?" with responses "Yes" or "No".

Cigarette smoking and alcohol use were also examined and included as covariates. These lifestyle factors have been reported to have associations with both physical activity and mental health [31]. Smoking was assessed by the following question: "How many cigarettes did you smoke per day, in the past 6 months?" and "Have you quit smoking cigarettes in the last 6 months?". Those who reported smoking at least one cigarette per day and not having quit smoking in the previous 6 months were coded as daily smokers. All other participants were coded as non-smokers. Drinking alcohol was assessed using the following survey

items: "How often do you have a drink containing alcohol such as a half pint or 330 ml bottle of beer, cider or alcopop, a glass of wine or a shot of strong alcohol?". Those who answered "Never" or "Once a month or less" were coded as non-drinkers, while those who responded "2–4 times a month", "2–3 times a week", "4 or more times a week", "Every day" or "Several times a day" were coded as alcohol drinkers.

Age was also recorded and has been included as a covariate due to known associations between increasing age and decreasing frequency of physical activity [5].

Statistical analyses

Based on their reported frequency of physical activity, participants were categorised as Least Active (60 min + activity on 0–3 days in the past 14 days), Somewhat Active (60 min + activity on 4–7 days in past 14 days), or Most Active (60 min + activity on 8–14 days). Within the most active group, a sub-group who reported daily physical activity was identified (Sufficiently Active according to WHO guidelines).

Mean frequency of physical activity of boys and girls were compared using *t*-tests. Proportions of boys and girls in the Least/Somewhat/Most Active categories and of those reporting smoking, alcohol use, chronic illness, sexual intercourse and family financial problems were compared using Chi-squared tests.

ANOVA was used to compare mean scores on the psychological variables (BDI II, SAS, WHO-5) between Least, Somewhat and Most Active groups of girls and boys. Bootstrapping was used to account for the non-normal distribution. Post hoc between-groups comparisons were carried out using Tukey's HSD to account for multiple testing. Effect size was measured using η^2 and the effect size was considered very small if $\eta^2 < 0.01$, small if <0.06, medium if <0.14 and large if 0.14+ [32].

To examine associations between frequency of physical activity and mental health variables (BDI, SAS and WHO-5) multi-level mixed effects linear regression was carried out with random effects to account for clustering of pupils within schools and countries. The coefficients from this model were used to estimate curves illustrating associations between frequency of activity and each of the mental health measures.

A further multi-level model was fitted for associations between physical activity, sport participation and each mental health measure with fixed effects for age, socio-economic status, smoking, alcohol use, sexual intercourse and chronic illness. Random effects were fitted to account for clustering of pupils within schools and countries.

As boys and girls differ significantly in terms of prevalence of mental health problems and in terms of physical activity levels, analyses were carried out separately for boys and girls. Cases with missing data on the relevant items were excluded from the analysis. Levels of missing data ranged from 3 to 4 % on the mental health measures and 12.3 % on the physical activity measure.

Analyses were carried out using SPSS version 20 and Stata version 13.

Results

Frequency of physical activity and sports participation

In our 10-country sample, 727 (17.9 %) boys and 628 (10.7 %) girls reported engaging in at least 60 min of physical activity every day (Table 1). Overall 13.6 % of the sample was sufficiently active. The mean number of days of activity in the past 14 days was significantly higher for boys (7.5 ± 4.4) than girls (5.9 ± 4.3; $p < 0.0005$). There were significant sex differences in the proportion of young people in each of the activity subgroups; with more girls than boys in the least active (34.3 % of girls, 21.1 % of boys; $p < 0.0005$) and somewhat active groups (34.3 % of girls, 31.2 % of boys; $p < 0.0005$), and more boys than girls in the most active group (47.7 % of boys, 31.4 % of girls; $p < 0.0005$).

In the total sample, 3345 adolescents (30.2 %) reported participation in at least one team sport, with large sex differences (19.0 % of girls, 46.6 % of boys; p < 0.0005). Just under one-third of the sample (32.8 %) reported no participation in sport or other fitness activity, while 37.0 % reported participation in an individual sport or fitness activity but no team sport.

There was no significant difference between the percentage of girls and boys reporting having a chronic illness (15.1 % of the total sample). Daily cigarette smoking was reported by more girls (29.8 %) than boys (24.3 %; $p < 0.0005$), while alcohol use was reported more frequently by boys (35.7 %) than girls (28.0 %; $p < 0.0005$). Girls more frequently reported that their parents have financial problems (14.8 %) compared to boys (9.9 %; $p < 0.0005$). Just under one-fifth (19.3 %) of the sample reported ever having had sexual intercourse, with this being more frequently reported by boys than girls (20.9 % of boys, 18.1 % of girls; $p < 0.0005$).

The most frequently reported number of days of activity in the past 14 days for boys was 14 ($n = 727$, 17.9 %) followed by 10 days ($n = 448$, 11.0 %). For girls, the most frequently reported number of days of activity were 4 days ($n = 638$, 10.8 %), followed by 2 days ($n = 631$, 10.7 %) and 14 days ($n = 628$, 10.7 %) (Fig. 1).

There were large differences between countries in terms of frequency of activity (Table 2). The highest proportion

Table 1 Socio-demographic characteristics, lifestyle and physical activity in boys and girls

Socio-demographic and lifestyle characteristics	Total sample ($n = 11,072$) Mean [SD]	Boys ($n = 4506$) Mean [SD]	Girls ($n = 6566$) Mean [SD]	p value
Age	14.8 [0.84]	14.7 [0.86]	14.8 [0.82]	<0.0005
	Yes n (%)	Yes n (%)	Yes n (%)	
Chronic illness	1653 (15.1 %)	666 (15.0 %)	987 (15.2 %)	0.72
Daily smoker	3040 (27.6 %)	1088 (24.3 %)	1952 (29.8 %)	<0.0005
Alcohol more than once monthly	3449 (31.2 %)	1610 (35.7 %)	1839 (28.0 %)	<0.0005
Parents have financial problems	1368 (12.8 %)	426 (9.9 %)	942 (14.8 %)	<0.0005
Sexual Intercourse	2078 (19.3 %)	913 (20.9 %)	1165 (18.1 %)	<0.0005
Physical Activity				
Mean no. of days activity 60 min + in past 14 days (SD)	6.6 (4.4)	7.5 (4.4)	5.9 (4.3)	<0.0005
Activity Frequency	n (%)	n (%)	n (%)	
Least active (0–3 days)	2875 (28.9 %)	857 (21.1 %)	2018 (34.3 %)	<0.0005
Somewhat active (4–7 days)	3284 (33.3 %)	1265 (31.2 %)	2019 (34.3 %)	<0.0005
Most active (8–14 days)	3786 (38.1 %)	1937 (47.7 %)	1849 (31.4 %)	<0.0005
(Sufficiently active:14 days)[a]	1355 (13.6 %)	727 (17.9 %)	628 (10.7 %)	<0.0005
Sport Participation				
No sport participation	3630 (32.8 %)	1051 (23.3 %)	2579 (39.3 %)	<0.0005
Individual sport/fitness activity	4097 (37.0 %)	1356 (30.1 %)	2741 (41.7 %)	<0.0005
Team sport	3345 (30.2 %)	2099 (46.6 %)	1246 (19.0 %)	<0.0005

[a] Sufficiently active according to WHO guidelines are included in Most Active group

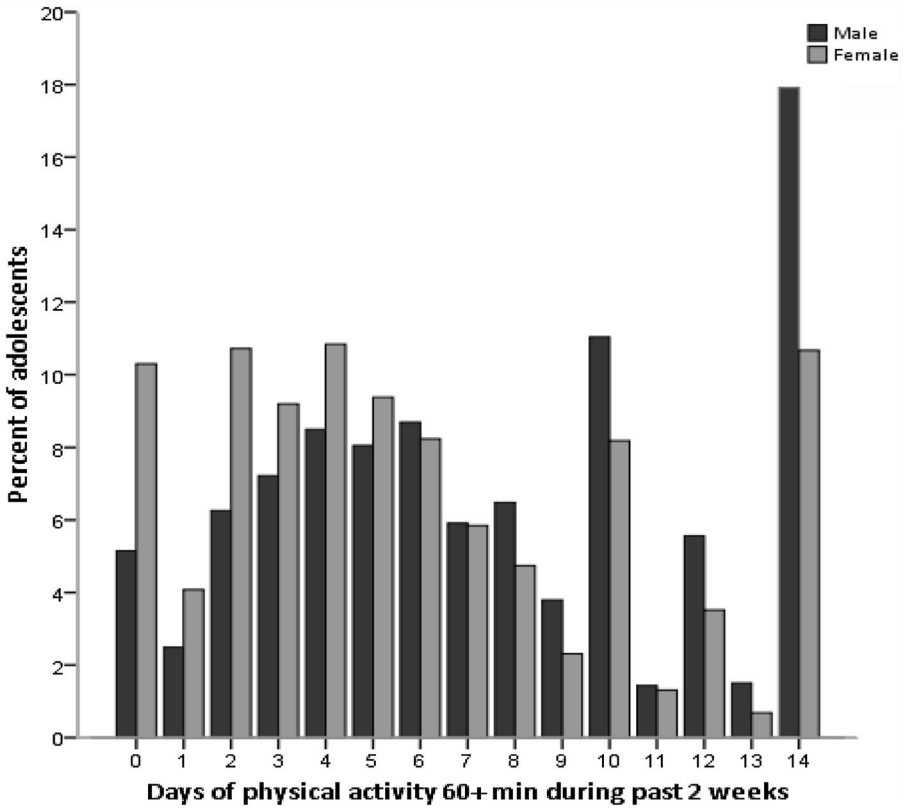

Fig. 1 Days of 60 min or more of activity in the past 2 weeks reported by girls and boys

Table 2 Frequency of physical activity among girls and boys by country

	Activity Frequency							
	Least Active (0–3 days) *n* (% within sex)		Somewhat Active (4–7 days) *n* (% within sex)		Most Active (8–14 days) *n* (% within sex)		[Sufficiently Active (14 days)][a] *n* (% within sex)	
	Male	Female	Male	Female	Male	Female	Male	Female
Austria	87 (25.4 %)	202 (34.6 %)	126 (36.7 %)	226 (38.8 %)	130 (37.9 %)	155 (26.6 %)	31 (9.0 %)	28 (4.8 %)
Estonia	71 (16.1 %)	100 (19.1 %)	132 (30.0 %)	204 (38.9 %)	237 (53.9 %)	220 (42.0 %)	114 (25.9 %)	92 (17.6 %)
France	103 (34.2 %)	332 (51.9 %)	117 (38.9 %)	181 (28.3 %)	81 (26.9 %)	127 (19.8 %)	31 (10.3 %)	45 (7.0 %)
Germany	120 (18.0 %)	223 (30.7 %)	224 (33.6 %)	288 (39.7 %)	322 (48.3 %)	215 (29.6 %)	105 (15.8 %)	47 (6.5 %)
Hungary	83 (22.9 %)	161 (31.3 %)	109 (30.0 %)	201 (39.0 %)	171 (47.1 %)	153 (29.7 %)	53 (14.6 %)	44 (8.5 %)
Ireland	94 (18.1 %)	81 (18.0 %)	173 (33.3 %)	193 (43.0 %)	253 (48.7 %)	175 (39.0 %)	62 (11.9 %)	25 (5.6 %)
Italy	128 (36.4 %)	441 (59.7 %)	126 (35.8 %)	227 (30.7 %)	98 (27.8 %)	71 (9.6 %)	27 (7.7 %)	11 (1.5 %)
Romania	38 (13.6 %)	150 (26.7 %)	61 (21.9 %)	183 (32.6 %)	180 (64.5 %)	228 (40.6 %)	86 (30.8 %)	98 (17.5 %)
Slovenia	33 (11.0 %)	148 (21.6 %)	66 (22.1 %)	197 (28.7 %)	200 (66.9 %)	341 (49.7 %)	104 (34.8 %)	162 (23.6 %)
Spain	100 (20.2 %)	180 (38.9 %)	131 (26.4 %)	119 (25.7 %)	265 (53.4 %)	164 (35.4 %)	114 (23.0 %)	76 (16.4 %)

[a] Sufficiently active according to WHO guidelines are included in Most Active group

of adolescents in the Most Active (8–14 days) group was in Slovenia (49.7 % of girls and 66.9 % of boys), with high levels of activity also in Estonia (42.0 % of girls and 53.9 % of boys) and Romania (40.6 % of girls and 64.5 % of boys in the Most Active group). Italy had the highest proportion of both boys and girls in the Least Active (0–3 days activity) group (59.7 % of girls and 36.4 % of boys).

Associations between frequency of physical activity, sport participation and mental health measures

There were significant differences between physical activity sub-groups in terms of scores on all of the mental health measures examined ($p < 0.0005$ for both sexes on BDI II, SAS, WHO-5) (Table 3). Higher frequency of activity was associated with lower levels of depression and anxiety and greater well-being.

Posthoc sub-group comparisons showed significant differences between the Least Active and Somewhat Active subgroups in terms of scores on all examined measures for both boys and girls, with the Somewhat Active group having lower depression and anxiety levels and higher well-being than the Least Active group. Comparisons between the Somewhat Active and Most Active subgroups showed significant differences among boys for depression and anxiety (Most Active group having lower scores) and also for well-being (Most Active group having higher scores), while for girls only well-being scores differed significantly, with the Most Active group having better well-being.

Participation in sport (team or individual/fitness) was associated with significantly lower levels of anxiety and depressive symptoms and higher levels of well-being ($p < 0.0005$ for both girls and boys on BDI II, SAS and WHO-5) (Table 2).

Posthoc analyses showed that the individual sport/fitness activity sub-group had lower depression and anxiety levels and higher well-being than the group with no sport participation for boys and girls. Comparisons between boys involved in individual sport/fitness activity and boys involved in team sports showed no significant differences on the mental health measures, while for girls there were significant differences on the depression, anxiety and well-being scores between those involved in individual sport/fitness activity and those involved in team sports, with team sport associated with higher well-being and lower anxiety and depressive symptoms.

To further examine associations between frequency of activity and mental health measures, multi-level mixed effects linear regression was carried out with random effects to account for clustering of pupils within schools and within countries. The coefficients from this model were used to estimate the curves represented in Figs. 2, 3 and 4.

Well-being: WHO-5

There was a positive correlation between frequency of activity and well-being for both boys and girls (Fig. 2). At lower levels of activity, small increases in number of days of activity were associated with greater well-being, with peak levels of well-being for boys at 11 days activity and for girls at 13 days. Further increases in activity above this level had limited impact on well-being for boys. Among girls, the association was curvilinear, with those with 14 days activity having reduced levels of well-being.

Table 3 Associations between frequency of physical activity, sport participation and well-being, anxiety and depressive symptoms for boys and girls

		Boys			Girls		
		WHO-5 well-being index*	Beck depression inventory (BDI II)*	Zung self-rating anxiety scale (SAS)*	WHO-5 well-being index*	Beck depression inventory (BDI II)*	Zung self-rating anxiety scale (SAS)*
Frequency of activity							
Least active (0–3 days)	Mean (95 % CI)[a]	62.0 (60.0–62.2)	7.3 (6.8–7.8)	31.8 (31.3–32.2)	57.0 (56.2–57.9)	9.9 (9.5–10.2)	34.9 (34.6–35.2)
Somewhat active (4–7 days)	Mean (95 % CI)[a]	66.3 (65.3–67.3)	6.1 (5.8–6.4)	30.3 (30.0–30.7)	61.0 (60.3–61.8)	8.7 (8.3–9.0)	33.9 (33.6–34.3)
Most active (8–14 days)	Mean (95 % CI)[a]	68.8 (68.1–70.0)	5.2 (5.0–5.5)	29.6 (29.3–30.0)	63.3 (62.5–64.2)	8.5 (8.1–8.8)	33.6 (33.2–33.9)
	η^2	0.03	0.02	0.02	0.02	0.008	0.006
Sport participation							
No sport	Mean (95 % CI)[a]	61.4 (60.2–62.6)	7.2 (6.7–7.6)	32.7 (31.2–32.1)	57.6 (56.8–58.3)	9.7 (9.4–10.0)	34.9 (34.6–35.2)
Individual sport/fitness activity	Mean (95 % CI)[a]	67.1 (66.2–68.1)	5.8 (5.5–6.1)	30.1 (29.8–30.4)	61.7 (61.0–62.4)	8.8 (8.5–9.2)	34.0 (33.7–34.3)
Team sport	Mean (95 % CI)[a]	68.4 (67.6–69.1)	5.5 (5.3–5.7)	30.1 (29.8–30.4)	63.7 (62.6–64.8)	8.0 (7.6–8.5)	33.1 (32.7–33.6)
	η^2	0.02	0.008	0.01	0.02	0.009	0.007

All post hoc comparisons (Tukey's HSD) between Least and Somewhat Active groups $p < 0.05$ for boys and girls

All post hoc comparisons between Somewhat and Most Active groups $p < 0.05$ for boys; for girls WHO $p < 0.05$, BDI $p = 0.68$, SAS $p = 0.35$

Post hoc group comparisons between No Sport and Individual sport: all $p < 0.05$; Individual Sports and Team Sports: Boys all NS (WHO $p = 0.12$, BDI $p = 0.39$, SAS $p = 0.98$); girls all $p < 0.05$

* All overall group comparisons $p < 0.0005$

[a] 95 % CIs based on Bootstrapping

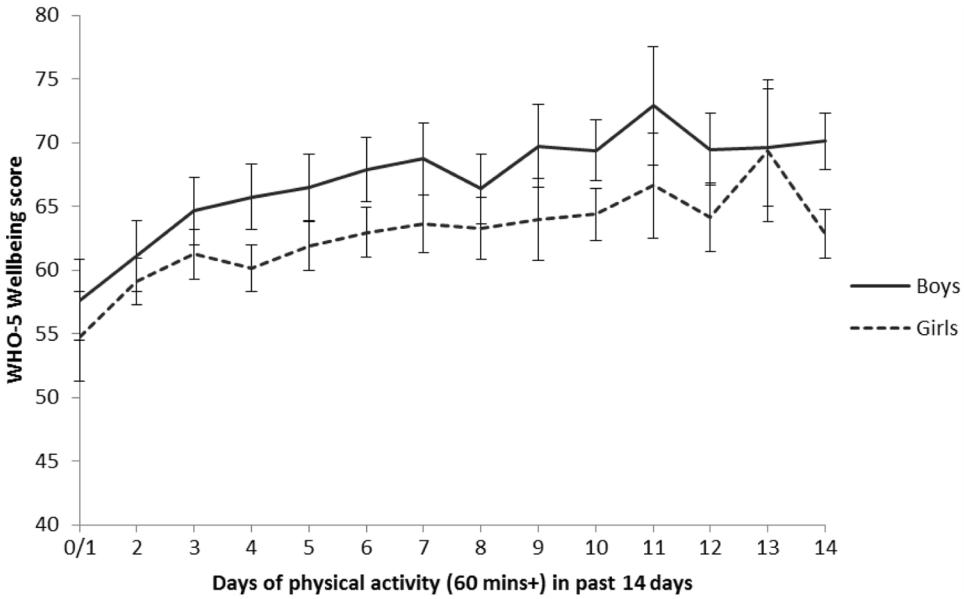

Fig. 2 Associations between frequency of physical activity and WHO-5 Well-being score (adjusted for clustering within school and country)

Depressive symptoms: BDI II

A negative correlation was found between frequency of activity and depressive symptoms for both sexes after adjustment for clustering by school and country (Fig. 3). For both boys and girls, those reporting 11 days activity had the lowest level of depression. Among boys, activity on more than 11 days was not associated with lower levels

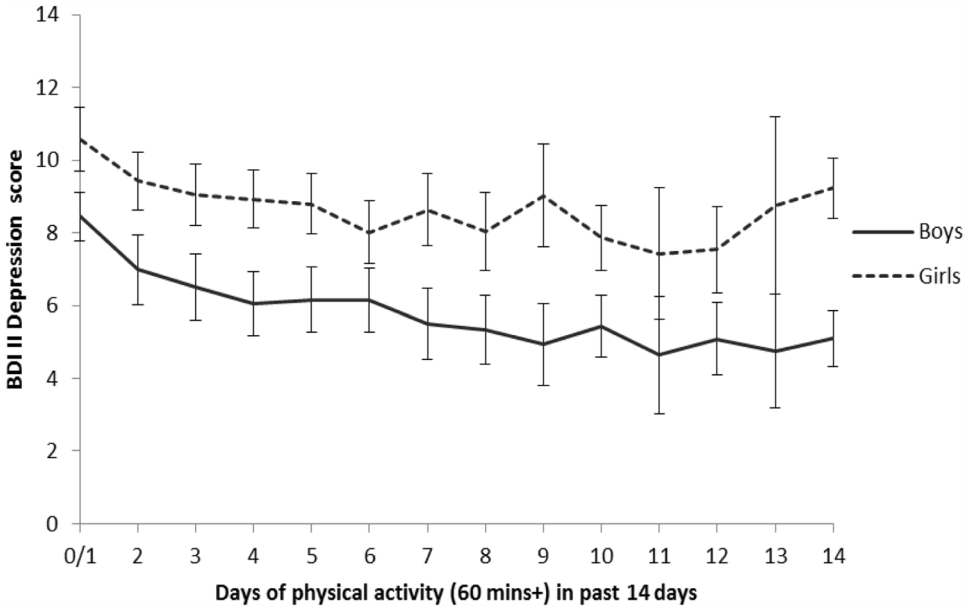

Fig. 3 Associations between frequency of physical activity and BDI-II depression score (adjusted for clustering within school and country)

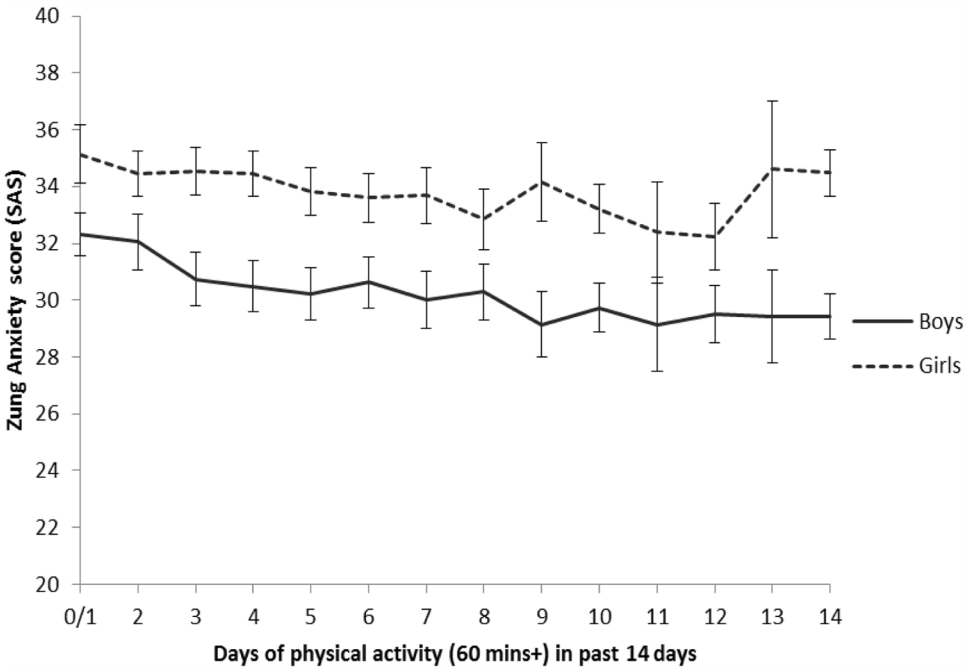

Fig. 4 Associations between frequency of physical activity and Zung Anxiety (SAS) score (adjusted for clustering within school and country)

of depressive symptoms. More frequent activity above this level was associated with higher levels of depressive symptoms among girls.

Anxiety symptoms: Zung self-rating anxiety scale (SAS)

A negative correlation was also found between frequency of activity and anxiety symptoms for both sexes (Fig. 4), with lowest levels of anxiety symptoms among girls reporting 12 days of activity and among boys reporting 9 days activity. For girls the association was curvilinear, with higher levels of anxiety associated with greater frequency of activity at the highest levels of activity.

A further multi-level model was fitted for associations between physical activity and sport participation and each mental health measure with fixed effects for age, socio-economic status, chronic illness, sexual intercourse, cigarette smoking and alcohol use, and random effects for clustering of pupils within schools and countries (Table 4). For both sexes, higher frequency of activity was associated with greater well-being. Among boys, the Somewhat Active and Most Active subgroups had WHO-5 well-being scores

Table 4 Associations between physical activity, participation in sport and well-being, depression and anxiety, based on linear mixed models

	WHO-5 well-being score		BDI II Depression score		Zung Anxiety Scale (SAS) score	
	Boys	Girls	Boys	Girls	Boys	Girls
Intercept	Coefficient (95 % CI)	Coefficient (95 % CI)	Coefficient (95 % CI)	Coefficient (95 % CI)	Coefficient (95 % CI)	Coefficient (95 % CI)
Reference group (Least Active (0–3 days activity), No sport participation)	61.9 (59.0 to 64.8)***	61.9 (58.7 to 65.0)***	6.3 (5.7 to 6.8)***	7.2 (6.4 to 8.0)***	30.6 (29.9 to 31.2)***	32.0 (31.1 to 33.0)***
Frequency of at least 60 min physical activity in past 14 days						
Somewhat Active (4–7 days)	4.5 (2.9 to 6.0)***	2.4 (1.3 to 3.6)***	−1.0 (−1.5 to −0.4)***	−0.5 (−1.0 to −0.01)*	−1.0 (−1.6 to −0.5)***	−0.3 (−0.8 to 0.2) ($p = 0.24$)
Most Active (8–14 days)	6.4 (4.9 to 7.9)***	4.4 (3.2 to 5.6)***	−1.7 (−2.2 to −1.2)***	−0.7 (−1.2 to −0.2)**	−1.7 (−2.2 to −1.2)***	−0.7 (−1.2 to −0.2)**
Participation in individual or team sport						
Yes	3.9 (2.5 to 5.2)***	2.8 (1.7 to 3.8)***	−0.6 (−1.1 to −0.2)**	−0.7 (−1.2 to −0.3)***	−0.5 (−1.0 to −0.04)*	−0.5 (−1.0 to −0.1)*

Multi-level mixed effects linear regression coefficients and their 95 % confidence intervals adjusted for the fixed effects of age, socio-economic status, cigarette smoking, alcohol use, sexual intercourse and chronic illness, and for clustering of pupils within schools and within countries

Reference group is the Least Active sub-group (0–3 days of at least 60 min physical activity), not currently participating in individual or team sport

Level of statistical significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.0005$

4.5 and 6.4 points higher, respectively, than the reference (Least Active) group ($p < 0.0005$ in both cases). For girls, the Somewhat Active and Most Active groups had well-being scores 2.4 and 4.4 points higher than the reference group ($p < 0.0005$ in both cases). Participation in sport also contributed to well-being score independently of frequency of activity for both sexes and was associated with an increment of 3.9 points for boys and of 2.8 points for girls ($p < 0.0005$ for boys and girls).

Smaller significant differences were found between the sub-groups in terms of BDI II depression score for both boys and girls. The Somewhat Active and Most Active subgroups of boys had BDI II depression scores 1.0 points ($p < 0.005$) and 1.7 points ($p < 0.0005$) lower on the BDI II depression scale than the reference group, while for girls the Somewhat Active and Most Active sub-groups had depressive symptoms 0.5 points ($p < 0.05$) and 0.7 points lower ($p < 0.01$). Participation in sport also conferred a benefit independent of frequency of activity.

Scores on the SAS anxiety scale were significantly lower among the Somewhat Active than the reference group for boys only, with a difference of -1.0 ($p < 0.01$), while for girls there was no significant difference ($p = 0.24$). However, among both boys and girls the Most Active group had lower anxiety scores than the reference group (-1.7 for boys ($p < 0.0005$) and -0.7 for girls ($p < 0.01$)).Participation in sport was also independently associated with significantly lower scores on the SAS for both sexes in multivariate analysis.

Discussion

A small minority (13.6 %) of the SEYLE adolescent sample reported meeting the level of physical activity recommended for good physical health (at least 60 min of moderate-to-vigorous activity daily) [3]. More frequent physical activity was associated with lower levels of depression and anxiety and greater well-being in our sample, after adjustment for possible confounding factors. The greatest differences in terms of all of the mental health measures examined was between the Least Active and Somewhat Active subgroups, while additional benefits of daily activity were not evident. Participation in sport (team or individual) conferred an additional mental health benefit independently of frequency of activity.

As hypothesised, girls were significantly more likely to be inactive than boys, with only 10.7 % of girls and 17.9 % of boys sufficiently active, based on WHO guidelines. This finding is in keeping with other international studies of activity levels in European adolescents aged 15 [5]. We also found significantly higher levels of participation in sport among boys than among girls. Over half of girls (60.7 %) and over three quarters (76.7 %) of boys reported engaging in team or individual sports or fitness activities. It has been suggested that opportunities to participate in sport and other physical activities may be biased in favour of boys [5].

Our findings of small but significant associations between physical activity and mental health are consistent with previous findings [7]. Although statistically significant, differences we have reported between more and less active adolescents in terms of anxiety and depressive symptoms may not be clinically meaningful. However, in terms of well-being, we can suggest based on our findings that moderately increasing activity in inactive adolescents could result in a meaningful improvement in well-being, as an increment of 10 % on an individual's WHO-5 score may be clinically meaningful [33]. These findings are in keeping with longitudinal research on the association between physical activity and changes in well-being [34].

It has been suggested that small effect sizes found for associations between physical activity and mental health measures may be due in part to measures of activity which do not take into account the nature of the activity [2]. We examined participation in individual and team sports to identify the types of activity which may be particularly beneficial to mental health. Lowest levels of anxiety and depression and highest level of well-being were found among those participating in team sports. Among girls, those participating in team sports differed significantly from those participating in individual sport or other physical activity in terms of all of the mental health factors examined, suggesting that team sports may confer particular mental health benefits for girls. For boys, those participating in team sports had significantly higher levels of well-being than those engaging in other sports, but there were no significant differences in terms of depression or anxiety in univariate analyses. In multivariate analysis, participating in any sport (individual or team) was associated with more positive mental health on all three of the examined measures, independent of frequency of activity, for both sexes.

We have reported an association between higher frequency of physical activity and better mental health, with lower and higher thresholds of activity associated with poorer mental health, particularly among girls. This is in keeping with previous findings on an adult population [35]. It may be the case that the sub-group reporting very frequent or daily physical activity includes some adolescents who over-exercise and suffer from eating disorders or other psychopathology [36, 37].

Several hypotheses have been proposed to explain the inverse association between physical activity and depression and other mental health problems [38]. Regular engagement in a challenging activity may lead to an increase in a person's confidence and subsequently to a

decrease in their depressive symptoms [39], or the social relationships developed from regular participation in physical activity may impact positively upon mental health [40]. Inversely, depression may negatively influence patterns of activity through symptoms such as low energy levels, apathy, or social isolation [41] or physical inactivity and depression and anxiety may also share other risk factors [38]. Our findings relating to the benefits of sport participation provide some support for the hypothesis that the mental health benefits of physical activity may be partly accounted for by the social interaction involved in team sports in particular, and confirm the importance of the psychological and social aspects of physical activity.

The greatest differences in terms of mental health measures were between the least active and the somewhat active adolescents. This is in keeping with other recent findings on adult physical activity and associations with mortality [42]. Our findings suggest that minor increments in physical activity may have substantial benefits to mental health and provide support for the suggestion that key policy aim for improving mental health should be to specifically target those who are fully inactive [42].

The limitations of this study include the use of a self-report instrument measuring physical activity, which may be prone to recall bias and varying interpretations of physical activity in different cultures, sexes and age groups [4]. The instrument used explicitly excluded activities carried out in physical education class, which may lead to an underestimate of activity levels. The level of missing data on this physical activity measure was also relatively high which may potentially have been a source of bias. As the study was cross-sectional, it was not possible to investigate any potential causal or temporal relationships between physical activity and mental health. Although we identified large cross-national differences in activity levels, we did not have scope to examine differing patterns of association between physical activity and mental health in the ten participating centres of this study. Further research could include in-depth cross-national comparisons and could also longitudinally examine the impact of physical activity on later mental health. The strengths of this study include the very large and representative sample of European adolescents and the use of multi-level mixed effects regression models which account for the clustered nature of the data [43].

Conclusions

Regular physical activity is associated with better mental health and well-being in adolescents. Our findings underline the importance of increasing activity levels among the least active young people. However, while at least one hour of physical activity daily is recommended for optimal physical health and development in children and adolescents, we did not find evidence for the benefit of daily activity in terms of mental health. Participation in sport confers an additional benefit over and above that provided by activity alone. It would be beneficial if recommendations for physical activity and sport participation in children and adolescents were formulated based on mental as well as physical health outcomes. Sex differences in activity levels and in sport participation persist, and making activities accessible to all through school physical education curricula and community organisations should be a priority. Community and school-based interventions to promote well-being and positive mental health in adolescents should incorporate a focus on frequent physical activity and engagement in individual or team sports.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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