Observational longitudinal association between waking movement behaviors and psychological distress among adolescents using isotemporal analysis: DADOS study.

Original article

Pablo Monteagudo[1]; Maria Reyes Beltran-Valls[1]; Mireia Adelantado-Renau[1]; Diego Moliner-Urdiales[1*].

[1] LIFE Research Group, Faculty of Humanities and Social Sciences, Department of Education and Specific Didactics,Universitat Jaume I, Av. Vicent Sos Baynat, S/N,12071 Castellon, Spain.

Corresponding author:

D. Moliner-Urdiales

Jaume I University

Department of Education and Specific Didactics

Av. Vicent Sos Baynat, S/N,12071 Castellon, Spain.

Email: dmoliner@uji.es

Title:

Observational longitudinal association between waking movement behaviors and psychological distress among adolescents using isotemporal analyses: DADOS study.

This study aimed to examine the impact of reallocating time spent in waking movement behaviors at baseline on indicators of psychological distress at 24-month follow-up using isotemporal substitution regression models among a sample of Spanish adolescents.

The DADOS (Deporte, ADOlescencia y Salud) study is a 3-year longitudinal observational research project carried out between years 2015–2017. The analyses included 197 adolescents (91 girls) aged 13.9±0.3 years at baseline. Waking movement behaviors were assessed by a wrist-worn GENEActiv triaxial accelerometer and expressed as minutes/day of light physical activity (LPA), moderate-vigorous physical activity (MVPA) and time spent in sedentary behavior (SB). The Behavior Assessment System for Children and Adolescents (level 3 for adolescents) was used to assess psychological distress indicators (i.e., anxiety, social stress, and risk of depression).

Results showed significant associations only for girls. The substitution of 10min/day of SB or LPA at baseline with 10min/day of MVPA was associated with lower levels of anxiety (both $p \leq 0.01$) and social stress (both $p<0.05$) at follow-up. The substitution of 10min/day of SB with 10min/day of LPA was associated with higher levels of anxiety at follow-up ($p=0.01$).

These findings highlight the need of specific physical activity recommendations for mental health paying special attention to sex-differences.

Keywords: risk of depression; anxiety; social stress; mental health; physical activity.

Introduction

Mental health disorders account for 16% of the global burden of disease and injury in the adolescence (World Health Organisation, 2018), a sensitive period in the lifespan characterized by biological, psychological, social, and cognitive changes (Proctor et al., 2009; Salmela-Aro &

Tuominen-Soini, 2010). Specifically, psychological distress, including anxiety, depression, and stress symptoms, could have a negative impact on adolescents' mental health (Miller, 2007; Wolfe & Mash, 2006). Previous research has suggested that health-promoting behavioral factors could protect against adolescents psychological distress (Firth et al., 2020; Kang & You, 2018).

In this line, whole-day guidelines for children and adolescents suggest that during waking periods youths should be physically active throughout the day due to its benefits in multiple domains of health (Bull et al., 2020). Device-based measures have shown that overall physical activity (PA) levels are inversely associated with high levels of sedentary behaviour (Saunders et al., 2020), which has detrimental effects for health. Thus, there is an increasing need to examine how different physical activity intensities and sedentary behaviour that integrate the waking movement behaviours relate to diverse health outcomes during childhood and adolescence.

In this regard, recent evidence has shown the important protective role of daily PA on psychological distress levels in an adolescent population (Rodriguez-Ayllon et al., 2019). For example, previous cross-sectional studies showed that self-reported levels of total PA or moderate and vigorous PA (MVPA) were negatively associated with levels of stress and anxiety in adolescents (Cowley et al., 2019; Dale et al., 2019). Similarly, Román-Mata (2020) found that students achieving the 60 minutes of MVPA recommended per day for children and adolescents showed lower levels of psychological distress than their counterparts. Particularly, self-reported data obtained from a recent longitudinal study suggested that achieving high levels of MVPA and reducing time spent in sedentary behaviors (SB) such as screen time, appears to provide protection against depressive symptoms (Brown et al., 2021). However, the few prospective studies examining the association between objectively measured PA by accelerometry and psychological distress in adolescents reported conflicting results. For instance, Booth et al. (2023) showed that higher time spent in MVPA in early adolescence was associated with decreased depressive-symptoms, while Toseeb et al. (2014) found no longitudinal association

between MVPA and the development of depressive symptoms. Moreover, the vast part of studies researching for associations between PA and psychological distress have used self-report measures to assess PA, and these methods rarely account for light PA (LPA), which in addition has the lowest reliability from self-report measures of all PA intensities (Kandola et al., 2020; Warren et al., 2010). Thus, the association between LPA and psychological distress has been understudied (Felez-Nobrega et al., 2021; Kandola et al., 2020). The review carried out by Felez-Nobrega et al. (2021) found that only 1 study had investigated the associations between LPA and perceived stress in college students using self-reported measures (Felez-Nobrega et al., 2020). This study identified beneficial associations between self-reported measures of LPA and perceived stress (Felez-Nobrega et al., 2020). To the best of our knowledge, only one prospective study has examined the associations between all PA intensities and psychological distress in adolescents using objective measures. In this study, Kandola et al. (2020) did not find evidence of a longitudinal association between MVPA and depression but they found that LPA was associated with a reduction in depressive symptoms. These findings point out the need to go deeper into this topic.

On the other hand, isotemporal substitution analysis for PA is a developed analytical model based on the finiteness of time in any given 24-hour period (Mekary et al., 2009). This statistical method could address how movement behaviors are associated with mental health levels (Gilchrist et al., 2021; Mekary et al., 2013), offering very useful information in order to design more specific intervention programs. In adolescents, only two recent studies have used isotemporal substitution analyses to investigate the prospective relationship between self-reported MVPA, SB, and psychological distress indicators. Using a cross-sectional design, Gilchrist et al. (2021) found that replacing 15 min/day of homework activities with MVPA was associated with lower levels of anxiety but increased depressive symptoms (Gilchrist et al., 2021). Similarly, in a longitudinal study, Sampasa-Kanyiga et al. (2021) reported that increasing 60 minutes/day of MVPA relative to the screen time and sleep duration was associated with

lower depressive symptoms in older adolescent girls at 12-month follow-up. Expanding the current scarce body of evidence about longitudinal relationships between waking movement behaviors and multiple psychological distress indicators during adolescence could help to design strategies to support mental health.

Furthermore, given the consistent sex differences observed in psychological distress, and PA (Altemus et al., 2014; Bann et al., 2019; Farooq et al., 2018; Gao et al., 2020; McLean et al., 2011; Salk et al., 2017), it is important to consider sex when examining the relationships between these health components. For instance, compared to men, women are more likely to exhibit anxiety and depressive symptoms (McLean et al., 2011; Salk et al., 2017), and more vulnerable to stress (Afifi, 2007; Chaplin et al., 2008). In fact, some studies have shown excessive psychological distress in females during early to mid-adolescence (Sweeting & West, 2003). Likewise, levels of PA decline dramatically during adolescence, being more marked in girls than in boys (Farooq et al., 2018). Altogether, these findings support the importance of examining sex-differences when assessing the associations between PA and psychological distress.

Thus, the first aim of this study was to examine the relationship of waking movement behaviors (SB, LPA and MVPA) with the main psychological distress indicators (i.e., anxiety, social stress, and risk of depression) among a sample of Spanish adolescents considering sex-differences. Furthermore, the second aim of this study was to examine how reallocations of time between waking movement behaviors at baseline are associated with changes in psychological distress indicators at 24-month follow-up using isotemporal substitution regression models.

Methods

Study design and sample selection

This observational study is part of the DADOS (Deporte, ADOlescencia y Salud) study, a 3-year longitudinal research project carried out between years 2015 and 2017, which aimed to investigate the influence of PA on health, cognition, and mental health during adolescence. A

convenience sampling technique was used to recruit participants. For that purpose, advertising leaflets including main information about the research project were sent to secondary schools and sport clubs located in the province of Castellon (Spain). The inclusion criteria were to be enrolled in the second grade of secondary school, and not to be previously diagnosed of any physical or mental impairment. Volunteers who met the inclusion criteria were selected for the study. A total of 197 adolescents (91 girls) aged 13.9 ± 0.3 years at baseline with valid data for movement behaviors at baseline and psychological distress indicators at baseline (2015) and at follow-up (2017) were included in the analyses. This sample size provided a post-hoc statistical power in girls of 0.996 for anxiety, 0.999 for social stress, and 0.999 for risk of depression, whereas in boys it was of 0.850 for anxiety, of 0.992 for social stress, and 0.539 for risk of depression.

Adolescents and their parents or guardians were informed of the nature and characteristics of the study, and all provided a written informed consent. The study was performed following the ethical guidelines of the Declaration of Helsinki 1964 (revision of Fortaleza 2013), and the study protocol was approved by the Research Ethics Committee of the XXXXXX University.

Waking movement behaviors

Waking movement behaviors were measured using the GENEActiv accelerometer (Activinsights Ltd, Kimbolton, UK), a waterproof device that contains a triaxial microelectromechanical accelerometer that records both motion-related and gravitational acceleration and has a linear and equal sensitivity along the three axes. Participants wore the accelerometer on their non-dominant wrist for at least four days with 24-hour valid data, including weekends and weekdays. GENEActiv accelerometer offers a body temperature sensor to help improve the confirmation of wear and non-wear time and has been found to be a reliable tool (Coefficient of Variation intra-instrument = 1.4%; Coefficient of Variation inter-instrument = 2.1%) (Eslinger et al., 2011) and a valid measure of PA in young people ($r = 0.925$, $P = 0.001$) (Phillips et al., 2013). Devices

were programmed with a sampling frequency of 100 Hz, and data were stored in gravity (g) units (1 g = 9.81 m/second^2). The raw acceleration output was converted to 1 s epochs using the GENEActiv Post-Processing PC Software (version 2.2, GENEActiv). According to Phillips et al. (2013), a GENEActiv cut off point for MVPA in adolescents was established for values ≥20 g, for LPA was established for values from 7 to 19 g, and for SB was established for values <7 g. By combining all registered days for each participant, waking movement behaviors were expressed as the average (min/day) of SB, LPA, and MVPA (moderate and vigorous PA were summed).

Psychological distress

The Spanish version of the Behavior Assessment System for Children and Adolescents (BASC; González, Fernández, Pérez, & Santamaría, 2004) level 3 for adolescents aged 12–18 years, was used to assess psychological distress indicators, including anxiety, social stress, and risk of depression. The BASC questionnaire has shown extensive psychometric properties in both non-referred and clinical populations with reliabilities for the subscales ranging from 0.80 to 0.87 (Reynolds & Kamphaus, 2004). BASC consists of statements rated as true or false. Specifically, the scale of risk of depression is composed by 14 statements that assess adolescents' feelings of loneliness, sadness, and their incapacity to enjoy life. The scale of anxiety involves 14 statements related to feelings of nervousness, worrying and fear, and social stress was calculated through 13 statements about feelings of stress and tension in personal relationships or feelings of being excluded from social activities. For each psychological distress indicator, standard T-scores with an average of 50 and standard deviations of 10 points were used in the analyses. Psychological distress indicators were dichotomized into "high" (<60) and "low" (≥60) according to the established cut off points (Reynolds & Kamphaus, 2004).

Covariates

Due to the relationship of PA and psychological distress indicators with body mass index (BMI) (Pabst et al., 2009; Wang et al., 2014), pubertal stage (Keenan et al., 2014), and socioeconomic

status (Barrett & Turner, 2005; Pino et al., 2018), these variables were included as covariates in the statistical analyses.

BMI was calculated as weight/height squared (kg/m^2). Body weight was measured to the nearest 0.1 kg using an electronic scale (SECA 861, Hamburg, Germany) with the participants lightly dressed and without shoes. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (SECA 213, Hamburg, Germany). Weight and height were assessed in duplicate and average measures were used for the analyses.

Pubertal stage was self-reported using standardized pictures according to the five stages described by Tanner and Whitehouse (1976), based on external primary and secondary sex characteristics. The stage of development was assessed through two components: pubic hair growth for boys and girls, plus genital development in boys, and breast development in girls. The highest rating of the two components was used for the data analyses.

Socioeconomic status was measured with the Family Affluence Scale developed by Currie et al. (2008). This questionnaire (ranging from 0 to 8 points) is based on material conditions in the family such as car ownership, bedroom occupancy, computer ownership, and home internet access (Currie et al., 2008).

Statistical analysis

Descriptive sample characteristics were summarized by sex and presented as mean ± standard deviation (SD) or frequency (percentages). After testing for normality using both, graphical (normal probability plots) and statistical (Kolmogorov-Smirnov test) procedures, comparisons between sexes at each time point were performed by independent T test or Mann-Whitney U test for continuous variables, and chi-squared test. Differences between descriptive data at baseline and at 24-month follow-up were assessed by paired T test, Wilcoxon test, or chi-squared test or McNemar test for nominal variables.

Network analysis was used to estimate and visualize relationship among psychological distress indicators (i.e., anxiety, social stress, and risk of depression), waking movement behaviors (i.e., SB, LPA, and MVPA) and covariates (i.e., BMI, pubertal stage, socioeconomic status, and the corresponding dependent variable value at baseline). In this analysis, connections between variables are not directly observed but are estimated. Network analysis is used to understand the relationship between variables in complex systems (Heino et al., 2019; Hevey, 2018). In the present study, the estimated partial correlation network was computed using the "Extended Bayesian Information Criterion Graphical Least Absolute Shrinkage and Selection Operator" (EBICglasso), which is a regularized estimation method. This method estimates parsimonious and interpretable network structure in the data, avoids spurious correlations, and handles relatively small datasets (Epskamp et al., 2018). The EBICglasso method was selected due to its applicability to non-normal variables via non-paranormal transformation and to ordinal variables via polychoric or polyserial correlations (Costantini et al., 2015; López-Roig et al., 2022). Continuous lines (i.e., edges) between variables (i.e., nodes) represent that they are related after controlling for all other variables, meanwhile the absence of lines means that variables are not related (Heino et al., 2019). All analyses were computed using the network analysis module of JASP software (JASP team, Amsterdam, The Netherlands) (2017), based on the bootnet package of the R environment (van Buuren & Groothuis-Oudshoorn, 2011). In order to confirm the estimated relationships, partial correlations were performed controlling for the aforementioned covariates.

Isotemporal substitution models were performed to assess the effect of reallocating 10 minutes of SB, LPA, or MVPA at baseline on psychological distress indicators at 24-month follow-up. A short time frame of 10 minutes was used because from a public health point of view this could generate an achievable objective and a very powerful message to promote PA between adolescent population (Corder et al., 2015). Thus, variables of waking movement behaviors were scaled to 10 min, and a "total activity time score" was calculated to represent the average daily

time spent in the different movement behavior (i.e., total activity time = SB + LPA + MVPA). Then, total activity time and covariates (i.e., BMI, pubertal stage, socioeconomic status, and the corresponding dependent variable value at baseline) were run into a regression model simultaneously with the exception of the movement behavior of interest. For example, to examine the impact of replacing 10 min of SB with LPA or MVPA on a specific psychological stress indicator (i.e. anxiety), the isotemporal substitution model is expresses as:

Anxiety = (β1) MVPA + (β2) LPA+ (β3) total time + (β4) covariates [BMI, pubertal stage, socioeconomic status and anxiety at baseline].

Because in this example SB would be omitted from the model, the remaining coefficients represent the change in anxiety achieved by engaging in 10 min of the respective movement behavior instead of engaging in 10 min of SB while holding the other activities constant (e.g., the coefficient β1 represents the impact of replacing 10 min of SB with 10 min of MVPA and the coefficient β2 represents the impact of replacing 10 min of SB with 10 min of LPA). Models substituting the three behaviors (i.e., SB, LPA, MVPA) were performed for all psychological distress indicators in separate models.

Post-hoc power analyses for multiple linear regression models were performed using G*Power (version 3.1, University Düsseldorf, DE), considering an α-error = 0.05 and introducing the adjusted R^2 to estimate effect sizes (adjusted R^2 are shown in supplementary tables 1,2, and 3). Due to the sex-specific differences in PA (Bann et al., 2019; Farooq et al., 2018), and psychological distress indicators reported in other studies (Altemus et al., 2014; Murray et al., 2011), the analyses were performed separately for boys and girls. Isotemporal substitution analyses were performed using the IBM SPSS Statistics for Windows version 26.0 (Armonk, NY: IBM Corp). The level of significance was set at $p < 0.05$.

Results

The characteristics of the participants at baseline and at 24-month follow-up by sex are shown in Table 1. BMI was higher at follow-up for both, boys and girls (all p <0.001). Boys achieved higher daily levels of MVPA than girls at baseline and at follow-up (all p < 0.001). Time spent in LPA and MVPA decreased at follow-up for boys and girls, while SB time significantly increased (all p <0.001). Psychological distress indicators did not show differences during the follow-up period for both, boys and girls. However, girls showed higher levels of anxiety than boys at baseline and at follow-up (p<0.001).

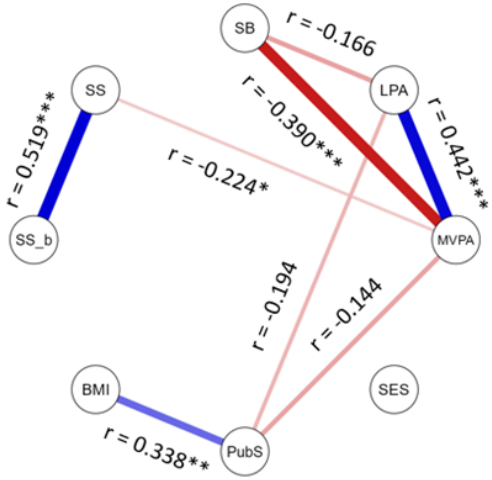
Table 1. Characteristics of participants at baseline and at 24-month follow-up by sex (Girls n=91; Boys n=106).

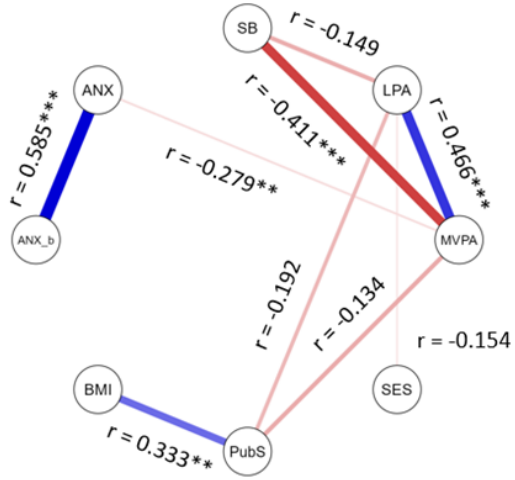
	Baseline		Follow-up		*p* values[a]	
	Girls	Boys	Girls	Boys	Girls	Boys
Age (years)	13.91 (0.29)	13.89 (0.29)	15.85 (0.31)	15.83 (0.29)	<0.001	<0.001
Weight (kg)	53.14 (9.07)	54.20 (9.43)	58.38 (9.05)[b]	64.14 (8.69)	<0.001	<0.001
Height (cm)	161.13 (6.67)[b]	164.91 (8.45)	163.20 (6.42)[b]	173.06 (6.51)	<0.001	<0.001
BMI (kg/m²)	20.41 (2.90)	19.83 (2.49)	21.91 (3.11)	21.41 (2.66)	<0.001	<0.001
Pubertal Stage (I-V) (%)	0/7/34/55/4[b]	0/9/32/43/16	0/0/18/66/16[b]	0/0/5/40/55	<0.001	<0.005
Waking movement behaviors						
SB (min/day)	703.40 (56.87)	697.91 (94.45)	740.34 (62.59)	744.47 (68.55)	<0.001	<0.001
LPA (min/day)	171.42 (25.02)	176.14 (66.37)	158.60 (28.30)	154.60 (30.09)	<0.001	<0.001
MVPA (min/day)	80.44 (23.96)[b]	96.65 (30.14)	70.90 (21.30)[b]	81.08 (28.53)	<0.001	<0.001
Psychological distress (T-score)						
Anxiety	48.84 (9.87)[b]	41.98 (9.16)	48.21 (9.68)[b]	40.93 (9.02)	0.558	0.107
Social Stress	46.58 (8.86)	44.71 (6.54)	45.71 (7.31)	43.63 (4.46)	0.439	0.145
Risk of depression	46.04 (6.86)	44.75 (5.86)	45.91 (7.37)	45.62 (6.06)	0.597	0.109
Psychological distress (Dichotomized)						
High anxiety, n (%)	13 (14.30)[b]	2 (1.90)	14 (15.40)[b]	5 (4.80)	0.796	0.375
High social stress, n (%)	6 (6.60)	2 (1.90)	6 (6.60)[b]	2 (1.90)	1.000	1.000
High risk of depression, n (%)	2 (2.20)	2 (1.90)	4 (4.40)	4 (3.80)	0.625	0.687

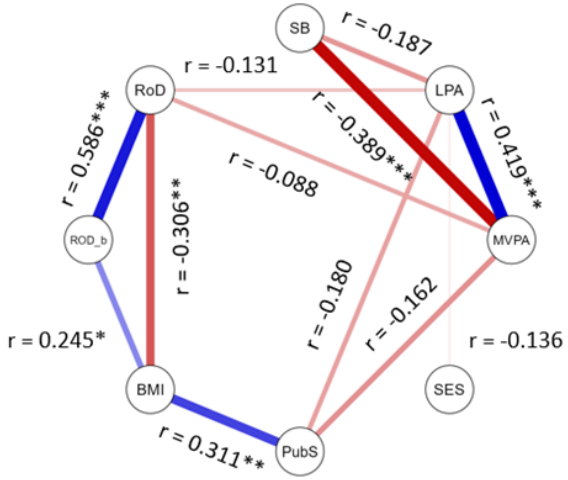
Data are presented as mean (SD) or frequency (percentages).
[a] Differences between baseline and follow-up tested by paired t-test, Wilcoxon test, chi- squared test or McNemar test.
[b] Differences between sexes tested at the specific time point by independent t-test, Mann-Whitney U test, or chi-squared test ($p < 0.05$).
BMI: Body Mass Index; SB: Sedentary Behavior; LPA: Light Physical Activity; MVPA: Moderate-Vigorous Physical Activity.

Figure 1 shows the relationships among waking movement behaviors (i.e., SB, LPA and MVPA), psychological distress indicators (i.e., anxiety, social stress, and risk of depression), and covariates (i.e., BMI, pubertal stage, and socioeconomic status, and the corresponding dependent variable value at baseline). In girls, social stress and anxiety were negatively correlated with MVPA (r=-0.224, p=0.039 and r=-0.279, p=0.010, respectively). Moreover, MVPA was negatively correlated with SB and positively correlated with LPA (all p<0.001). However, in boys, only MVPA was negatively related to SB (all p<0.001).

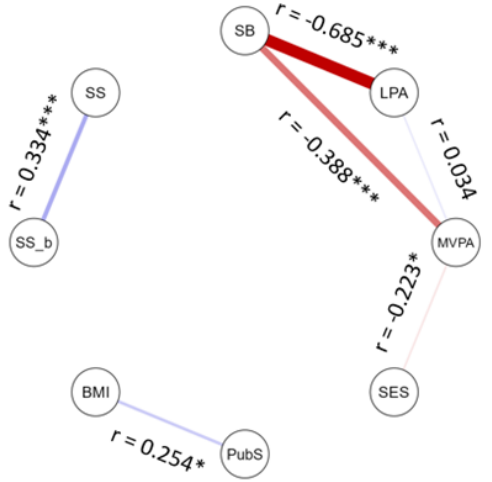
Girls

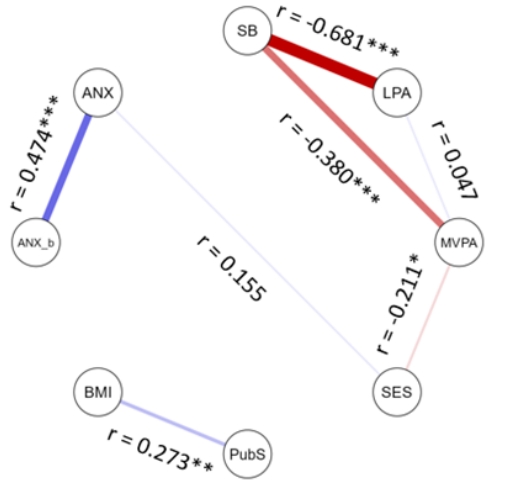

SB
SS
LPA
MVPA
SS_b
BMI
PubS
SES
r = -0.166
r = -0.390***
r = 0.442***
r = 0.519***
r = -0.224*
r = -0.194
r = -0.144
r = 0.338**


SB
ANX
LPA
MVPA
ANX_b
BMI
PubS
SES
r = -0.149
r = -0.411***
r = 0.466***
r = 0.585***
r = -0.279**
r = -0.192
r = -0.134
r = -0.154
r = 0.333**


SB
RoD
LPA
MVPA
ROD_b
BMI
PubS
SES
r = -0.187
r = -0.131
r = -0.389***
r = 0.419***
r = 0.586***
r = -0.088
r = -0.306**
r = -0.180
r = -0.162
r = -0.136
r = 0.245*
r = 0.311**

Boys


SB
SS
LPA
MVPA
SS_b
BMI
PubS
SES
r = -0.685***
r = -0.388***
r = 0.034
r = 0.334***
r = -0.223*
r = 0.254*


SB
ANX
LPA
MVPA
ANX_b
BMI
PubS
SES
r = -0.681***
r = -0.380***
r = 0.047
r = 0.474***
r = 0.155
r = -0.211*
r = 0.273**

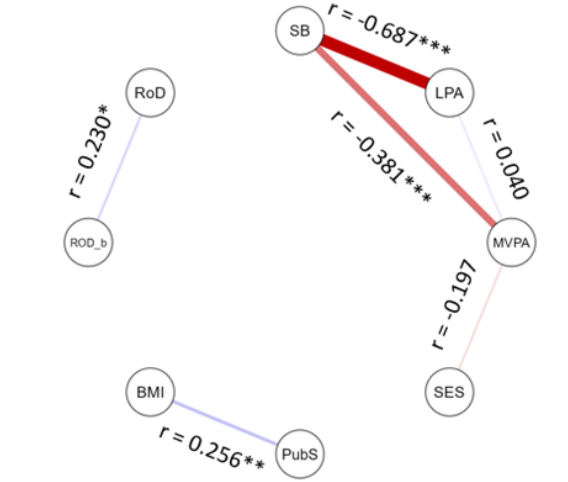

SB
RoD
LPA
MVPA
ROD_b
BMI
PubS
SES
r = -0.687***
r = -0.381***
r = 0.040
r = 0.230*
r = -0.197
r = 0.256**

Figure 1. Modelled network of the studied variables. Blue lines (edges) between the studied variables (nodes) represent positive relationships, whereas red edges represent negative relationships. The size and colour density of the edges vary to reflect the strength of the relationships, with thicker and deeper blue/red coloured edges representing the stronger relationships. Variables which are not graphically connected among each other are not related when controlling for other variables in the model. r = Pearson partial correlation coefficient (***$p \leq 0.001$, **$p < 0.01$, and *$p < 0.05$). SB: Sedentary Behavior; LPA: Light Physical Activity; MVPA: Moderate-Vigorous Physical Activity; SS: Social Stress at follow-up; ANX: Anxiety at follow-up; RoD: Risk of Depression at follow-up; BMI: Body Mass Index; PubS: Pubertal stage; SES: Socioeconomic status.

Isotemporal substitution analyses are shown in Table 2. In girls, the substitution of 10 min/day of SB or LPA at baseline with 10 min/day of MVPA was associated with lower levels of anxiety (both $p \leq 0.01$) and social stress (both $p < 0.05$). In addition, the substitution of 10 min/day of SB with 10 min/day of LPA at baseline was associated with higher anxiety at follow-up ($p = 0.01$). On the contrary, results did not show significant associations between movement behaviors and risk of depression for boys and girls, neither between movement behaviors and anxiety or social stress for boys. Additional analyses showing the covariates effects in the isotemporal substitution models are reported in supplementary tables 1, 2 and 3.

Table 2.

Isotemporal substitution models of baseline waking movement behaviors predicting psychological distress indicators at 24-month follow-up stratified by sex.

	Girls (n=91)			Boys (n=106)		
	Replaced movement behavior			**Replaced movement behavior**		
	MVPA	**LPA**	**SB**	**MVPA**	**LPA**	**SB**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**	**β (95% CI)**
Anxiety						
MVPA	-	**-0.559 (-3.804, -0.718)**	**-0.287 (-2.043, -0.279)**	-	0.195 (-0.149, 1.315)	0.124 (-0.211, 0.954)
LPA	**0.584 (0.718, 3.804)**	-	**0.284 (0.228, 1.972)**	-0.429 (-1.315, 0.149)	-	-0.156 (-0.471, 0.048)
SB	**0.682 (0.279, 2.043)**	**-0.646 (-1.972, -0.228)**	-	-0.389 (-0.954, 0.211)	0.221 (-0.048, 0.471)	-
Social Stress						
MVPA	-	**-0.409 (-2.457, -0.041)**	**-0.254 (-1.469, -0.078)**	-	0.180 (-0.122, 0.654)	0.153 (-0.082, 0.535)
LPA	**0.427 (0.041, 2.457)**	-	0.163 (-0.208, 1.159)	-0.396 (-0.654, 0.122)	-	-0.058 (-0.177, 0.098)
SB	**0.602 (0.078, 1.469)**	-0.370 (-1.159, 0.208)	-	-0.481 (-0.535, 0.082)	0.083 (-0.098, 0.177)	-
Risk of depression						
MVPA	-	0.032 (-1.067, 1.265)	-0.079 (-0.914, 0.428)	-	0.223 (-0.099, 0.996)	0.187 (-0.059, 0.812)
LPA	-0.034 (-1.265, 1.067)	-	-0.116 (-0.996, 0.312)	-0.491 (-0.996, 0.099)	-	-0.079 (-0.266, 0.122)
SB	0.187 (-0.428, 0.914)	0.264 (-0.312, 0.996)	-	-0.586 (-0.812, 0.059)	0.113 (-0.122, 0.266)	-

Isotemporal substitution models were adjusted for body mass index, pubertal stage, socioeconomic status, and the corresponding dependent variable value at baseline.

Significant findings are bolded ($p < 0.050$).

β: Standardized beta; CI: Confidence interval; SB: Sedentary Behavior; LPA: Light Physical Activity; MVPA: Moderate-Vigorous Physical Activity.

Discussion

The present study examines the relationship between movement behaviours during waking hours and psychological distress indicators in a sample of Spanish adolescents and explores how reallocating time spent in different behaviors is associated with psychological distress indicators at 24-month follow-up. Our results revealed sex-specific differences not only regarding the relationship between waking movement behaviors and psychological distress indicators, but also regarding isotemporal substitution analysis. These findings contribute to the scarce current scientific literature about the longitudinal association between movement behaviors and mental health indicators in adolescent population, adding new knowledge about the effect of replacing time spent in different PA intensities or sedentary behavior on psychological distress indicators. Additionally, these findings have important public health implications, revealing the detrimental effect on mental health derived from low daily levels of MVPA during adolescence.

On the one hand, our network analysis results showed that MVPA was negatively linked with all psychological distress indicators in girls, confirming previously reported results (Fromel et al., 2020; Hrafnkelsdottir et al., 2018; McDowell et al., 2017). For instance, Hrafnkelsdottir et al. (2018) found that more frequent vigorous PA were associated with fewer symptoms of depression and anxiety, and Fromel et al. (2020) found that girls with higher depressive symptoms performed significantly less vigorous PA than girls with low depressive symptoms. There were not relationships between psychological distress indicators and movement behaviours during waking hours in boys. Conversely, Kandola et al. (2020) showed a positive association between SB and depression and an inverse association between LPA and depression in a sample of 4257 adolescents. However, in comparison to that sample, our participants presented lower levels of LPA and higher levels of MVPA and in the present study a different data analyses approach is used, which may explain these divergent results. In this way, our results might indicate that intensity of PA matters, as previously suggested (Goldfield et al.,

2011). Indeed, Goldfield et al. (2011) reported that vigorous PA was inversely associated with anxiety in females. Therefore, participation in PA programs at high intensities seem to have the potential to improve adolescents' psychological distress.

On the other hand, reallocations of time using isotemporal substitution regression models between waking movement behaviors at baseline and psychological distress indicators at 24-month follow-up suggested that replacing 10 min per day of SB or LPA with MVPA was associated with lower levels of anxiety and social stress 24 months later in girls, but not in boys. Conversely, replacing SB with LPA, was associated with higher anxiety levels only in girls. Unexpectedly, substituting 10 min per day of MVPA with LPA or SB was not associated with risk of depression neither in boys nor in girls. The lack of similar studies in adolescents have made difficult the comparison and interpretation of our results. However, concerning anxiety, our results partially agree with previous studies carried out in adults and older adults, which found that reallocations of PA intensities or SB domains objectively measured by accelerometry were not associated with changes in anxiety symptoms (Curtis et al., 2020; Hofman et al., 2022). Regarding the positive unexpected association found in girls when replacing SB with LPA on anxiety, this result could be related to the fact that girls from our sample showed higher MVPA levels than those from other studies (Farooq et al., 2020), since 81% of them achieved MVPA recommendations. These results would suggest that when a minimal dose of MVPA has been reached, spending a minimum time in SB, as for example relaxing, could also be important to improve mental health in adolescents. Nevertheless, when PA levels are low, as in older populations, replacing SB with LPA has been shown to be effective to improve anxiety (Dillon et al., 2018).

Concerning social stress, up to our knowledge this is the first study investigating the impact of replacing time spent in SB with PA in adolescents on this variable. We found that the substitution of 10 min/day of SB or LPA at baseline with 10 min/day of MVPA was negatively associated with social stress (both $p \leq 0.01$) in girls but not in boys. Our results do not concur with those obtained

in previous studies with older populations, which did not show an association between any activity reallocation and general stress (Curtis et al., 2020; Park et al., 2020). However, our findings could also be supported by interventional studies aimed to improve psychological distress indicators, which have shown that high intensity physical exercise could provide acute and chronic effects on anxiety and stress in children and adolescents (Leahy et al., 2020; Martland et al., 2019). These results could be related to the fact that high intensity of exercise produces autonomic activation that mimics anxiety in a nonthreatening context, in which individuals increase capacity to tolerate interoceptive sensations while inhibiting escape responses (Blasco-Lafarga et al., 2022; Smith & Merwin, 2021).

Particularly, our data highlight sex-differences when different movement behaviors are replaced by each other. The sex-differences observed in our sample could be partially explained by the significant lower time spent in daily MVPA in girls compared to boys at baseline. In fact, although most of the girls in our study achieved current recommendations of MVPA (>60 min/day), these guidelines also state that increasing time in MVPA daily provide additional health benefits in teenagers (Bull et al., 2020). Indeed, it is likely that girls need to accumulate higher doses of MVPA than those minimally established at the current guidelines to prevent anxiety and social stress symptoms in the long term. Possibly, PA levels of our sample were enough to maintain low levels of risk of depression at 24-month follow-up, but not enough to prevent anxiety and social stress in girls. In fact, according to Cushing et al. (2018) different negative emotions may have different associations with MVPA (Cushing et al., 2018), as we show in the network analysis. Even so, from an integrative point of view, long-term mental health benefits appear contingent upon sustained PA engagement due to synergistic influences of neurobiological and behavioral learning mechanisms (Smith & Merwin, 2021). Consequently, our results could contribute to the design of prevention programs targeting mental health in adolescents by introducing little changes in waking movement behaviors. Specifically, substitution of sedentary time by MVPA should be mainly promoted, supporting the idea that youths should aim to interrupt sedentary

time and be physically active throughout the day (Bull et al., 2020). In addition, findings from our study highlight the need of specific PA recommendations for mental health.

The strengths of this study include its longitudinal design, and adequate sample size, and the use of accelerometry to objectively measure waking movement behaviors. Thereby, although self-reported measures provide rich contextual information on activity mode (i.e., sport practice, transportation, or play) or domain (i.e., family-based or school-based), they typically overestimate youth PA levels compared to objective measures and are generally unable to accurately classify PA intensity (Fairclough & Noonan, 2020). However, this study has some limitations that should be mentioned. Despite the inclusion of several confounders in the statistical analyses, other potential confounders such as genetic, environmental, or social factors remained unmeasured. A detailed assessment of SB activities (e.g., homework, screen time, etc.) as well as PA behaviors (e.g., individual vs. collective, etc.) could offer additional information in order to understand the sex-specific differences observed (Gilchrist et al., 2021). In fact, previous research suggested that the context in which PA is undertaken matters (Teychenne et al., 2020), like PA exposure to greenspace, which was associated with lower levels of depression, anxiety, and stress (Cohen-Cline et al., 2015). Hence, future studies should control the modality and the context in which free-living PA is spent. Moreover, our sample presented higher levels of SB compared to the previous data from the Spanish population (Ruiz et al., 2011), which could have affected mental health measurements to a larger extent (Hoare et al., 2016; Rodriguez-Ayllon et al., 2019).

In conclusion, our results support that replacing free-living SB or LPA with MVPA is associated with lower levels of anxiety and social stress in adolescent girls 24 months later. These findings highlight the need of reconsidering specifically PA guidelines for adolescents taking into account psychological distress indicators and putting special attention on sex-differences. We are still in the beginning of understanding how PA influences psychological distress and how modifying

waking movement behaviors might benefit mental health in the long term. Succeeding to fill this knowledge gap can contribute to promote mental health of adolescents globally and thus achieve some Sustainable Development Goals (SDGs) as good health and well-being (SDG 3), or gender equality (SDG 5).

References

Afifi, M. (2007). Gender differences in mental health. *Singapore Medical Journal*, *48*(5), 385–391.

Altemus, M., Sarvaiya, N., & Neill Epperson, C. (2014). Sex differences in anxiety and depression clinical perspectives. *Frontiers in Neuroendocrinology*, *35*(3), 320–330. https://doi.org/10.1016/J.YFRNE.2014.05.004

Bann, D., Scholes, S., Fluharty, M., & Shure, N. (2019). Adolescents' physical activity: Cross-national comparisons of levels, distributions and disparities across 52 countries. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 1–11. https://doi.org/10.1186/S12966-019-0897-Z/FIGURES/6

Barrett, A. E., & Turner, R. J. (2005). Family structure and mental health: The mediating effects of socioeconomic status, family process, and social stress. *Journal of Health and Social Behavior*, *46*(2), 156–169. https://doi.org/10.1177/002214650504600203

Blasco-Lafarga, C., Roldán, A., Cordellat, A., & Monteagudo, P. (2022). Acute High-Intensity Exercise Reduces Performance Anxiety: A Pilot Study in Wind Musicians. *Annals of Applied Sport Science*, *10*(4), 0–0. https://doi.org/10.52547/AASSJOURNAL.1094

Booth, J., Ness, A., Joinson, C., Tomporowski, P., Boyle, J., Leary, S., & Reilly, J. (2023). Associations between physical activity and mental health and behaviour in early adolescence. *Mental Health and Physical Activity*, *24*. https://doi.org/10.1016/j.mhpa.2022.100497

Brown, D. M. Y., Kwan, M. Y., Arbour-Nicitopoulos, K. P., & Cairney, J. (2021). Identifying patterns of movement behaviours in relation to depressive symptoms during adolescence: A latent profile analysis approach. *Preventive Medicine*, *143*. https://doi.org/10.1016/J.YPMED.2020.106352

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., Lambert, E., Leitzmann, M., Milton, K., Ortega, F. B., … Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, *54*, 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Chaplin, T. M., Hong, K., Bergquist, K., & Sinha, R. (2008). Gender Differences in Response to Emotional Stress: An Assessment Across Subjective, Behavioral, and Physiological Domains and Relations to Alcohol Craving. *Alcoholism: Clinical and Experimental Research*, *32*(7), 1242–1250. https://doi.org/10.1111/j.1530-0277.2008.00679.x

Cohen-Cline, H., Turkheimer, E., & Duncan, G. E. (2015). Access to green space, physical activity and mental health: a twin study. *Journal of Epidemiology and Community Health*. https://doi.org/10.1136/jech-2014-204667

Corder, K., Sharp, S. J., Atkin, A. J., Griffin, S. J., Jones, A. P., Ekelund, U., & van Sluijs, E. M. F. (2015). Change in objectively measured physical activity during the transition to adolescence. *British Journal of Sports Medicine*, *49*(11), 730–736. https://doi.org/10.1136/bjsports-2013-093190

Costantini, G., Epskamp, S., Borsboom, D., Perugini, M., Mõttus, R., Waldorp, L. J., & Cramer, A. O. J. (2015). State of the aRt personality research: A tutorial on network analysis of personality data in R. *Journal of Research in Personality*, *54*, 13–29. https://doi.org/10.1016/J.JRP.2014.07.003

Cowley, J., Kiely, J., & Collins, D. (2019). Is there a link between self-perceived stress and physical activity levels in Scottish adolescents? *International Journal of Adolescent Medicine and Health*, *31*(1). https://doi.org/10.1515/IJAMH-2016-0104/MACHINEREADABLECITATION/RIS

Currie, C., Molcho, M., Boyce, W., Holstein, B., Torsheim, T., & Richter, M. (2008). Researching health inequalities in adolescents: The development of the Health Behaviour in School-Aged Children (HBSC) Family Affluence Scale. *Social Science and Medicine*, *66*(6), 1429–1436. https://doi.org/10.1016/J.SOCSCIMED.2007.11.024

Curtis, R. G., Dumuid, D., Olds, T., Plotnikoff, R., Vandelanotte, C., Ryan, J., Edney, S., & Maher, C. (2020). The Association Between Time-Use Behaviors and Physical and Mental Well-Being in Adults: A Compositional Isotemporal Substitution Analysis. *Journal of Physical Activity and Health*, *17*(2), 197–203. https://doi.org/10.1123/JPAH.2018-0687

Cushing, C. C., Bejarano, C. M., Mitchell, T. B., Noser, A. E., & Crick, C. J. (2018). Individual Differences in Negative Affectivity and Physical Activity in Adolescents: An Ecological Momentary Assessment Study. *Journal of Child and Family Studies*, *27*, 2772–2779. https://doi.org/10.1007/s10826-018-1128-y

Dale, L. P., Vanderloo, L., Moore, S., & Faulkner, G. (2019). Physical activity and depression, anxiety, and self-esteem in children and youth: An umbrella systematic review. *Mental Health and Physical Activity*, *16*, 66–79. https://doi.org/10.1016/J.MHPA.2018.12.001

Dillon, C. B., McMahon, E., O'Regan, G., & Perry, I. J. (2018). Associations between physical behaviour patterns and levels of depressive symptoms, anxiety and well-being in middle-aged adults: a cross-sectional study using isotemporal substitution models. *BMJ Open*, *8*(1), e018978. https://doi.org/10.1136/BMJOPEN-2017-018978

Epskamp, S., Borsboom, D., & Fried, E. I. (2018). Estimating psychological networks and their accuracy: A tutorial paper. *Behavior Research Methods*, *50*(1), 195–212. https://doi.org/10.3758/S13428-017-0862-1/FIGURES/9

Eslinger, D., Rowlands, A., Hurst, T., Catt, M., & Murray, P. (2011). *Validation of the GENEA Accelerometer*. https://doi.org/10.1249/MSS.0b013e31820513be

Fairclough, S. J., & Noonan, R. J. (2020). Introduction to physical activity measurement. In T. A. Brusseau, S. J. Fairclough, & D. R. Lubans (Eds.), *The Routledge Handbook of Youth Physical Activity* (pp. 251–260). Routledge.

Farooq, A., Martin, A., Janssen, X., Wilson, M. G., Gibson, A. M., Hughes, A., & Reilly, J. J. (2020). Longitudinal changes in moderate-to-vigorous-intensity physical activity in children and adolescents: A systematic review and meta-analysis. *Obesity Reviews*, *21*(1). https://doi.org/10.1111/OBR.12953

Farooq, A., Parkinson, K. N., Adamson, A. J., Pearce, M. S., Reilly, J. K., Hughes, A. R., Janssen, X., Basterfield, L., & Reilly, J. J. (2018). Timing of the decline in physical activity in childhood and adolescence: Gateshead Millennium Cohort Study. *British Journal of Sports Medicine*, *52*(15), 1002–1006. https://doi.org/10.1136/BJSPORTS-2016-096933

Felez-Nobrega, M., Bort-Roig, J., Briones, L., Sanchez-Niubo, A., Koyanagi, A., Puigoriol, E., & Puig-Ribera, A. (2020). Self-reported and activPALTM monitored physical activity and sedentary behaviour in college students: Not all sitting behaviours are linked to perceived stress and anxiety. *Journal of Sports Sciences*, *38*(13), 1566–1574. https://doi.org/10.1080/02640414.2020.1748359

Felez-Nobrega, M., Bort-Roig, J., Ma, R., Romano, E., Faires, M., Stubbs, B., Stamatakis, E., Olaya, B., Haro, J. M., Smith, L., Shin, J. Il, Kim, M. S., & Koyanagi, A. (2021). Light-intensity physical activity and mental ill health: a systematic review of observational studies in the general population. *International Journal of Behavioral Nutrition and Physical Activity*, *18*(1), 123. https://doi.org/10.1186/s12966-021-01196-7

Firth, J., Solmi, M., Wootton, R. E., Vancampfort, D., Schuch, F. B., Hoare, E., Gilbody, S., Torous, J., Teasdale, S. B., Jackson, S. E., Smith, L., Eaton, M., Jacka, F. N., Veronese, N., Marx, W., Ashdown-Franks, G., Siskind, D., Sarris, J., Rosenbaum, S., … Stubbs, B. (2020). A meta-review of "lifestyle psychiatry": the role of exercise, smoking, diet and sleep in the prevention and treatment of mental disorders. *World Psychiatry*, *19*(3), 360–380. https://doi.org/10.1002/WPS.20773

Fromel, K., Jakubec, L., Groffik, D., Chmelík, F., Svozil, Z., & Safar, M. (2020). Physical Activity of Secondary School Adolescents at Risk of Depressive Symptoms. *Journal of School Health*, *90*(8), 641–650. https://doi.org/10.1111/JOSH.12911

Gao, W., Ping, S., & Liu, X. (2020). Gender differences in depression, anxiety, and stress among college students: A longitudinal study from China. *Journal of Affective Disorders*, *263*, 292–300. https://doi.org/10.1016/j.jad.2019.11.121

Gilchrist, J. D., Battista, K., Patte, K. A., Faulkner, G., Carson, V., & Leatherdale, S. T. (2021). Effects of reallocating physical activity, sedentary behaviors, and sleep on mental health in adolescents. *Mental Health and Physical Activity*, *20*. https://doi.org/10.1016/J.MHPA.2020.100380

Goldfield, G. S., Henderson, K., Buchholz, A., Obeid, N., Nguyen, H., & Flament, M. F. (2011). Physical Activity and Psychological Adjustment in Adolescents. *Journal of Physical Activity and Health*, *8*(2), 157–163. https://doi.org/10.1123/JPAH.8.2.157

Heino, M. T. J., Knittle, K., Fried, E., Sund, R., Haukkala, A., Borodulin, K., Uutela, A., Araujo-Soares, V., Vasankari, T., & Hankonen, N. (2019). Visualisation and network analysis of physical activity and its determinants: Demonstrating opportunities in analysing baseline associations in the Let's Move It trial. *Http://Mc.Manuscriptcentral.Com/HPBM*, *7*(1), 269–289. https://doi.org/10.1080/21642850.2019.1646136

Hevey, D. (2018). Network analysis: a brief overview and tutorial. *Health Psychology and Behavioral Medicine*, *6*(1), 301–328. https://doi.org/10.1080/21642850.2018.1521283

Hoare, E., Milton, K., Foster, C., & Allender, S. (2016). The associations between sedentary behaviour and mental health among adolescents: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *13*(1), 108. https://doi.org/10.1186/s12966-016-0432-4

Hofman, A., Voortman, T., Ikram, M. A., & Luik, A. I. (2022). Substitutions of physical activity, sedentary behaviour and sleep: associations with mental health in middle-aged and elderly persons. *Journal of Epidemiology and Community Health*, *76*(2), 175–181. https://doi.org/10.1136/JECH-2020-215883

Hrafnkelsdottir, S. M., Brychta, R. J., Rognvaldsdottir, V., Gestsdottir, S., Chen, K. Y., Johannsson, E., Guðmundsdottir, S. L., & Arngrimsson, S. A. (2018). Less screen time and more frequent vigorous physical activity is associated with lower risk of reporting negative mental health symptoms among Icelandic adolescents. *PLoS ONE*, *13*(4). https://doi.org/10.1371/journal.pone.0196286

Jasp, T. (2017). *Jasp* (Version 0.8.6.0). JASP Team.

Kandola, A., Lewis, G., Osborn, D. P. J., Stubbs, B., & Hayes, J. F. (2020). Depressive symptoms and objectively measured physical activity and sedentary behaviour throughout adolescence: a prospective cohort study. *The Lancet Psychiatry*, *7*(3), 262–271. https://doi.org/10.1016/S2215-0366(20)30034-1

Kang, N. G., & You, M. A. (2018). Association of perceived stress and self-control with health-promoting behaviors in adolescents: A cross-sectional study. *Medicine*, *97*(34). https://doi.org/10.1097/MD.0000000000011880

Keenan, K., Culbert, K. M., Grimm, K. J., Hipwell, A. E., & Stepp, S. D. (2014). Timing and tempo: Exploring the complex association between pubertal development and depression in African American and European American girls. *Journal of Abnormal Psychology*, *123*(4), 725. https://doi.org/10.1037/A0038003

Leahy, A. A., Mavilidi, M. F., Smith, J. J., Hillman, C. H., Eather, N., Barker, D., Lubans, D. R., Leahy, A. A., Mavilidi, M. F., Smith, J. J., Hillman, C. H., Eather, N., Barker, D., & Review, D. R. L. (2020). Review of High-Intensity Interval Training for Cognitive and Mental Health in Youth. *Medicine & Science in Sports & Exercise*, *52*(10), 2224–2234. https://doi.org/10.1249/MSS.0000000000002359

López-Roig, S., Ecija, C., Peñacoba, C., Ivorra, S., Nardi-Rodríguez, A., Lecuona, O., & Pastor-Mira, M. A. (2022). Assessing Walking Programs in Fibromyalgia: A Concordance Study between Measures. *International Journal of Environmental Research and Public Health 2022, Vol. 19, Page 2995*, *19*(5), 2995. https://doi.org/10.3390/IJERPH19052995

Martland, R., Mondelli, V., Gaughran, F., & Stubbs, B. (2019). Can high-intensity interval training improve physical and mental health outcomes? A meta-review of 33 systematic reviews across the lifespan. *Journal of Sports Sciences*, *38*(4), 430–469. https://doi.org/10.1080/02640414.2019.1706829

McDowell, C. P., MacDonncha, C., & Herring, M. P. (2017). Brief report: Associations of physical activity with anxiety and depression symptoms and status among adolescents. *Journal of Adolescence*, *55*, 1–4. https://doi.org/10.1016/J.ADOLESCENCE.2016.12.004

McLean, C. P., Asnaani, A., Litz, B. T., & Hofmann, S. G. (2011). Gender differences in anxiety disorders: Prevalence, course of illness, comorbidity and burden of illness. *Journal of Psychiatric Research*, *45*(8), 1027–1035. https://doi.org/10.1016/j.jpsychires.2011.03.006

Mekary, R. A., Lucas, M., Pan, A., Okereke, O. I., Willett, W. C., Hu, F. B., & Ding, E. L. (2013). Isotemporal Substitution Analysis for Physical Activity, Television Watching, and Risk of Depression. *American Journal of Epidemiology*, *178*(3), 474–483.

Mekary, R. A., Willett, W. C., Hu, F. B., & Ding, E. L. (2009). Isotemporal Substitution Paradigm for Physical Activity Epidemiology and Weight Change. *American Journal of Epidemiology*, *170*(4), 519–527. https://doi.org/10.1093/AJE/KWP163

Miller, A. (2007). Social neuroscience of child and adolescent depression. *Brain and Cognition*, *65*(1), 47–68. https://doi.org/10.1016/J.BANDC.2006.02.008

Murray, K. M., Byrne, D. G., & Rieger, E. (2011). Investigating adolescent stress and body image. *Journal of Adolescence*, *34*(2), 269–278. https://doi.org/10.1016/J.ADOLESCENCE.2010.05.004

Pabst, S. R., Negriff, S., Dorn, L. D., Susman, E. J., & Huang, B. (2009). Depression and Anxiety in Adolescent Females: The Impact of Sleep Preference and Body Mass Index. *Journal of Adolescent Health*, *44*(6), 554–560. https://doi.org/10.1016/J.JADOHEALTH.2008.11.012

Park, S., Park, S. Y., Oh, G., Yoon, E. J., & Oh, I. H. (2020). Association between Reallocation Behaviors and Subjective Health and Stress in South Korean Adults: An Isotemporal Substitution Model. *International Journal of Environmental Research and Public Health 2020, Vol. 17, Page 2488*, *17*(7), 2488. https://doi.org/10.3390/IJERPH17072488

Phillips, L. R. S., Parfitt, G., & Rowlands, A. v. (2013). Calibration of the GENEA accelerometer for assessment of physical activity intensity in children. *Journal of Science and Medicine in Sport*, *16*(2), 124–128. https://doi.org/10.1016/J.JSAMS.2012.05.013

Pino, E. C., Damus, K., Jack, B., Henderson, D., Milanovic, S., & Kalesan, B. (2018). Adolescent socioeconomic status and depressive symptoms in later life: Evidence from structural equation models. *Journal of Affective Disorders*, *225*, 702–708. https://doi.org/10.1016/J.JAD.2017.09.005

Proctor, C. L., Linley, P. A., & Maltby, J. (2009). Youth life satisfaction: A review of the literature. *Journal of Happiness Studies*, *10*(5), 583–630. https://doi.org/10.1007/S10902-008-9110-9

Reynolds, C. R., & Kamphaus, R. W. (2004). *Behavior assessment system for children,(BASC-2) handout* (2nd edition, Vols. 55014–1796). AGS publishing: Circle Pines.

Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., Muñoz, N. E., Mora-Gonzalez, J., Migueles, J. H., Molina-García, P., Henriksson, H., Mena-Molina, A., Martínez-Vizcaíno, V., Catena, A., Löf, M., Erickson, K. I., Lubans, D. R., Ortega, F. B., & Esteban-Cornejo, I. (2019). Role of Physical Activity and Sedentary Behavior in the Mental Health of

592 Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports*
593 *Medicine 2019 49:9*, *49*(9), 1383–1410. https://doi.org/10.1007/S40279-019-01099-5

594 Román-Mata, S. S., Puertas-Molero, P., Ubago-Jiménez, J. L., & González-Valero, G. (2020).
595 Benefits of Physical Activity and Its Associations with Resilience, Emotional Intelligence,
596 and Psychological Distress in University Students from Southern Spain. *International*
597 *Journal of Environmental Research and Public Health 2020, Vol. 17, Page 4474*, *17*(12),
598 4474. https://doi.org/10.3390/IJERPH17124474

599 Ruiz, J. R., Ortega, F. B., Martinez-Gomez, D., Labayen, I., Moreno, L. A., De Bourdeaudhuij, I.,
600 Manios, Y., Gonzalez-Gross, M., Mauro, B., Molnar, D., Widhalm, K., Marcos, A., Beghin,
601 L., Castillo, M. J., & Sjostrom, M. (2011). Objectively Measured Physical Activity and
602 Sedentary Time in European Adolescents: The HELENA Study. *American Journal of*
603 *Epidemiology*, *174*(2), 173–184. https://doi.org/10.1093/aje/kwr068

604 Salk, R. H., Hyde, J. S., & Abramson, L. Y. (2017). Gender differences in depression in
605 representative national samples: Meta-analyses of diagnoses and symptoms.
606 *Psychological Bulletin*, *143*(8), 783–822. https://doi.org/10.1037/bul0000102

607 Salmela-Aro, K., & Tuominen-Soini, H. (2010). Adolescents' Life Satisfaction During the
608 Transition to Post-Comprehensive Education: Antecedents and Consequences. *Journal of*
609 *Happiness Studies*, *11*(6), 683–701. https://doi.org/10.1007/S10902-009-9156-3

610 Sampasa-Kanyinga, H., Colman, I., Dumuid, D., Janssen, I., Goldfield, G. S., Wang, J. L., Patte, K.
611 A., Leatherdale, S. T., & Chaput, J. P. (2021). Longitudinal association between movement
612 behaviours and depressive symptoms among adolescents using compositional data
613 analysis. *PLOS ONE*, *16*(9), e0256867. https://doi.org/10.1371/JOURNAL.PONE.0256867

614 Smith, P. J., & Merwin, R. M. (2021). The Role of Exercise in Management of Mental Health
615 Disorders: An Integrative Review. *Annual Review of Medicine*, *72*, 45.
616 https://doi.org/10.1146/ANNUREV-MED-060619-022943

617 Sweeting, H., & West, P. (2003). Sex differences in health at ages 11, 13 and 15. *Social Science*
618 *& Medicine*, *56*(1), 31–39. https://doi.org/10.1016/S0277-9536(02)00010-2

619 Tanner, J. M., & Whitehouse, R. H. (1976). Clinical longitudinal standards for height, weight,
620 height velocity, weight velocity, and stages of puberty. *Archives of Disease in Childhood*,
621 *51*(3), 170–179. https://doi.org/10.1136/ADC.51.3.170

622 Teychenne, M., White, R. L., Richards, J., Schuch, F. B., Rosenbaum, S., & Bennie, J. A. (2020).
623 Do we need physical activity guidelines for mental health: What does the evidence tell
624 us? *Mental Health and Physical Activity*, *18*.
625 https://doi.org/10.1016/J.MHPA.2019.100315

626 Toseeb, U., Brage, S., Corder, K., Dunn, V. J., Jones, P. B., Owens, M., St Clair, M. C., van Sluijs,
627 E. M. F., & Goodyer, I. M. (2014). Exercise and Depressive Symptoms in Adolescents: A
628 Longitudinal Cohort Study. *JAMA Pediatrics*, *168*(12), 1093–1100.
629 https://doi.org/10.1001/JAMAPEDIATRICS.2014.1794

630 van Buuren, S., & Groothuis-Oudshoorn, K. (2011). mice: Multivariate Imputation by Chained
631 Equations in R. *Journal of Statistical Software*, *45*(3), 1–67.
632 https://doi.org/10.18637/JSS.V045.I03

633 Wang, H., Fu, J., Lu, Q., Tao, F., & Hao, J. (2014). Physical activity, body mass index and mental
634 health in Chinese adolescents: a population based study. *The Journal of Sports Medicine*
635 *and Physical Fitness*, *54*(4), 518–525. https://europepmc.org/article/med/25034554

636 Warren, J. M., Ekelund, U., Besson, H., Mezzani, A., Geladas, N., & Vanhees, L. (2010).
637 Assessment of physical activity-a review of methodologies with reference to
638 epidemiological research: a report of the exercise physiology section of the European
639 Association of Cardiovascular Prevention and Rehabilitation. *European Journal of*
640 *Cardiovascular Prevention and Rehabilitation*, *17*, 127–139.
641 https://doi.org/10.1097/HJR.0b013e32832ed875

642 Wolfe, D. A., & Mash, E. J. (2006). Behavioral and Emotional Disorders in Adolescents: Nature,
643 Assessment, and Treatment. In D. A. Wolfe & E. J. Mash (Eds.), *Behavioral and emotional*
644 *disorders in adolescents: Nature, assessment, and treatment*. The Guilford Press.
645 https://books.google.es/books?hl=ca&lr=&id=nRzMWqpj-
646 pcC&oi=fnd&pg=PA3&dq=psychological+distress+interfere+mental+health+children&ots
647 =5u7bKihzvP&sig=8ZPgJHtGRmDRgcUJi-y6Z-
648 xLtiM&redir_esc=y#v=onepage&q=psychological%20distress%20interfere%20mental%20
649 health%20children&f=false

650 World Health Organisation. (2018). *Adolescent mental health*. Https://Www.Who.Int/News-
651 Room/Fact-Sheets/Detail/Adolescent-Mental-Health.

652