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Frequency of vigorous physical activity and depressive symptoms across adolescence: Disentangling the reciprocal associations between different groups and subtypes of symptoms

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ABSTRACT

Physical activity has a demonstrated positive effect on youth depressive symptoms. However, very few studies have explored the bi-directionality of the links between physical activity and depression. The present study aims at filling this gap and tests whether any associations are moderated by sex. Moreover, the role of subtype of depressive symptoms, vegetative (i.e., lack of energy, poor sleep) or non-vegetative (i.e., mood-related), is explored. Participants were 910 12–13 year-old Swedish adolescents (56% girls) who answered a three-wave survey at ages 12–13 (T1), 15–16 (T2), and 18–19 (T3). Using a cross-lagged structural model, depression predicted decreased frequency of vigorous physical activity (VPA) from T1 to T2 ($\beta = -0.09$, $p < .05$) and from T2 to T3 ($\beta = -0.10$, $p < .01$), while frequency of VPA at T2 decreased depression at T3 ($\beta = -0.12$, $p < .05$). Associations did not differ between boys and girls. Non-vegetative symptoms predicted decreased frequency of VPA from T1 to T2 ($\beta = -0.10$, $p < .05$), while frequency of VPA at T2 predicted decreased non-vegetative symptoms at T3 ($\beta = -0.15$, $p < .05$). Vegetative symptoms predicted decreased frequency of VPA from T1 to T2 ($\beta = -0.09$, $p < .05$), while have a reciprocal influence with VPA from T2 to T3. Overall, our results highlight an association across adolescence between VPA and depression. The association becomes stronger and reciprocal in middle adolescence, which suggests this period as an effective developmental time to plan physical-activity-based interventions to decrease youth depressive symptoms.

Depression is one of the most common disorders among adolescents. In some studies, the prevalence rate of major depression has been estimated at around 5.6% for 15–19 year-old adolescents (WHO, 2017), while the recent Global Burden of Disease study estimated a prevalence of depressive disorders of 908.56 per 100 000 adolescents, or roughly 1% (Piao et al., 2022). Moreover, recent studies have highlighted that depressive symptoms have increased in the new generations of youth compared with the previous ones (Bremberg, 2015; Twenge et al., 2019), with an increase of prevalence of 10.9% from 1990 to 2019 (Piao et al., 2022), especially in youth from low socio-economic groups (Buli et al., 2023). This rise is concerning since depressive symptoms in adolescence have been associated with higher rates of depression and suicide in adulthood (Johnson et al., 2009). Therefore, a better understanding of factors that can curb the negative trajectories of adolescents with depressive symptoms is warranted.

Physical activity has often been associated with mental health. The positive effects of physical activity on mental health problems, including depression, for adult populations have been highlighted by several reviews (see Rebar et al., 2015; Rosenbaum et al., 2014), which indicates that physical activity might decrease mental health problems in adults. Conversely, studies of adolescents are fewer and often of low quality, as suggested by Dale et al. (2019). Nevertheless, the field is evolving rapidly, and recent reviews on both the association between physical activity and youth depression (e.g. Biddle et al., 2019; Dale et al., 2019; Korczak et al., 2017), and on the effects of physical activity interventions on youth mental health (Spruit et al., 2016; Wang et al., 2022) consistently indicate a small-to-moderate positive association between physical activity and adolescents' depressive symptoms. In addition, in a

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review of reviews, Biddle et al. (2019) tested the causal effect of physical activity on depression, analyzing strength of association, dose-response association, and experimental evidence. They found enough evidence to support the idea that the association was partially causal (Biddle et al., 2019). In addition, although the small evidence, the first available studies on the matter seem to suggest no difference in the effects between low intensity and high intensity training (see Hu et al., 2020 for a review), while another review concluded that moderate-to-vigorous physical activity (MVPA) has better effects than low intensity exercise (Dale et al., 2019) in preventing depressive symptoms.

However, there is some evidence, suggesting that the relation between physical activity and mental health may be bidirectional. On the one hand, physical activity might improve both biological, i.e. better neuroplasticity and neuroendocrine response, reductions in inflammation, and oxidative stress, and psychosocial mechanisms, i.e. better self-esteem, self-efficacy and social support, which in turn are connected with decreased depressive symptoms (see Kandola et al., 2019 for a review). On the other hand, depressive symptoms can be associated with a lower willingness to be active (Pattern et al., 2009). Most of the studies have focused on and supported the first contention, i.e., that physical activity may have an effect on level of depression. There is some evidence, however, that points to depressed youth being less willing to take part in physical activities and being less active in general than youth with low depressive symptoms. For instance, using a population sample, Patten et al. (2009) suggested that receiving a diagnosis of depression increases the risk of transition from an active to an inactive pattern of behavior. Similar results were confirmed in another study (Roshanaei-Moghaddam et al., 2009). When it comes to youth, depressive symptoms have been longitudinally associated with lower cardiorespiratory fitness in girls (Olive et al., 2016). Therefore, before offering conclusive answers regarding the relation between depression and physical activity, the bidirectionality of the effects need to be investigated.

To the best of our knowledge, there are only three studies that have investigated the bidirectional nature of the relationship between depression and physical activity in adolescents, and the evidence is contradictory. Gunnell et al. (2016), using a Latent Growth Model and examining the change in depressive symptoms and physical activity over 11 years, with two years interval on average, starting when adolescents were 13 years-old, found an effect only for the initial level of depression on the decrease in physical activity, while physical activity did not predict depression. Conversely, Buchan et al. (2021), examining two points in time one year apart, found that moderate-to-strong physical activity (MVPA) predicted a decrease in depressive symptoms among adolescents attending grades 9 to 12, while the opposite relation was not significant. Finally, Stavrakakis et al.(2012), extending the investigatory period from early to late adolescence (11–17 years old) by three points in time, did find a bidirectional influence from early to late adolescence. To sum up, conclusive evidence about the direction of effect between physical activity and depression cannot be found in the existing studies.

In addition, the limited literature on the bidirectional association between physical activity and depression leaves two other questions unanswered. First, we do not know whether the nature of this association differs for girls and boys. A vast literature points out that girls are more at risk than boys for depressive disorders (see Zahn-Waxler et al., 2008, for a review). In addition, some studies highlight differences in boys and girls regarding the effects of physical activity on depression, with a negative association in boys (see Sagatum et al., 2007; Isaksson et al., 2020). Nevertheless, physical activity-based interventions seem to work better in reducing internalizing symptoms among girls than among boys (see Spruit et al., 2016 for a review). When it comes to bidirectionality of effects, to our knowledge, only Buchan et al. (2021) have looked into sex differences in the bidirectional association between depressive symptoms and physical activity, finding that physical activity predicts decreased depressive symptoms only for boys. However, the authors did stratify their sample without testing for whether the difference between boys and girls was significant. Second, there is a paucity of studies that investigate the effect of vigorous physical activity (VPA) on depressive symptoms among adolescents. While high intensity training has been proved effective in reducing depressive problems in adults (see Martland et al., 2019 for a review), little is known about adolescents. Some studies reported an effect of VPA in reducing burn out and depressive symptoms among youth (Elliot et al., 2015; Harbour et al., 2008), which was not confirmed in other studies (e.g. Allison et al., 2005). However, none of the above-mentioned studies have investigated bidirectional associations between VPA and depressive symptoms. It might be that a higher intensity of PA might have stronger effects on depressive symptoms. For instance, Mata et al. (2012), found that intensity of physical activity positively affected the level of positive affect in depressed adults. Therefore, there is a need for more studies that examine whether there is a similar bidirectional association between depressive symptoms and vigorous physical activity, and whether this association holds the same for boys and for girls.

Finally, another unexplored aspect is the role played by different subtypes of depressive symptoms in relation to physical activity. There is general consensus over the existence of two subtypes of symptoms of depressive disorder, namely vegetative and non-vegetative/anhedonic (see, e.g. Rice et al., 2019; Young et al., 1986). Vegetative symptoms include appetite and weight disturbance, fatigue, insomnia and loss of energy, which might be more responsible for a decrease in physical activity than non-vegetative (or anhedonic) symptoms, which include mood-related symptoms (e.g., depressed mood, anhedonia, guilt, loss of concentration and suicidality). Moreover, vegetative symptoms characterize adolescents' depression rather more than adults' ones (Rice et al., 2019), which might have implications for both screening (Rice et al., 2019) and treatment (Fournier et al., 2013). For the above-mentioned reasons, physical-activity-based intervention might also have a different impact on these subtypes. To our knowledge, only Stavrakakis et al. (2012) have investigated the roles of different subtypes of symptoms, and found that affective symptoms (that resemble in part non-vegetative symptoms) hold a reciprocal influence with physical activity, while somatic symptoms (similar to vegetative symptoms) do not. However, the authors reported a lack of reliability of the measure they used to assess the somatic (i.e., vegetative) symptoms and hypothesized that the lack of association could be due to that. Therefore, the roles of different types of depressive symptoms in relation to physical activity should be further investigated.

The present study is designed to overcome the above-mentioned limitations. Using a longitudinal design that spans from early adolescence to late adolescence (13-19 years-old), we aim to:

1) investigate the bidirectional effects of frequency of vigorous physical activity (VPA) and depression from early to late adolescence;
2) examine whether the effects are similar for boys and girls;
3) test whether the vegetative and non-vegetative subtypes of symptoms differ in their association with -VPA across adolescence.

1. Method

1.1. Participants and procedure

The study uses data from the "SALVe- Cohort" study, which aims to study the determinants of psychological and psychosocial development in two groups born in 1997 and 1999 and follow them from childhood to adulthood. All individuals born in 1997 and 1999 and living in the Swedish region of Västmanland in 2012 qualified for the study. However, some individuals (such as those living in Sweden for less than five years and those suffering from mental illness or serious diseases) were initially excluded due to inclusion criteria (see Vadlin et al., 2015 for details). Here, we include the individuals who were born in 1999, since they have complete data that cover all the adolescent period (from 13 to

18 years-old). The adolescents were contacted when they were 12–13 (T1), 15–16 (T2), and 18–19 (T3). At T1, they were contacted by regular mail and invited to participate in the longitudinal study. They were informed that their participation was voluntary and that they could interrupt it at any time. They returned a self-reported questionnaire at T1, T2 and T3. At T1 both parents and adolescents gave written consent for participation, while at T2 and T3 only the adolescents gave consent, in line with Swedish law. The study was approved by the Ethical Review Board in Uppsala (Dnr. 2012/187).

A questionnaire was sent out to 2289 responders at wave 1 (T1), of whom 935 (about 41%) responded. The final sample that participated at least to one wave consisted of 910 young people, of whom 56% (N = 511) were female; 21% (N = 191) had non-Scandinavian parents.

1.2. Measures

Depressive symptoms. The Depression Self-Rating Scale Adolescent version, DSRS-A (Sonnby et al., 2022; Svanborg & Ekselius, 2003) was used. The scale is composed of 15 items based on the DSM-IV criteria for a major depressive disorder. The adolescents were asked about their depressive feelings in the last two weeks, with a no (0) or yes (1) response alternative, with higher scores indicating higher number of symptoms. Cronbach's alphas were 0.81, 0.77 and 0.87, for T1, T2 and T3 respectively. The items were divided into two parcels that constituted the two observed factors of a latent construct of depression in the models, one representing the vegetative symptoms (sleep disturbances, weight loss or gain/appetite disturbances, psychomotor agitation or retardation, fatigue or loss of energy) and the other the non-vegetative symptoms (dysphoric mood/irritability, loss of interest or pleasure in most activities, feelings of worthlessness or guilt, concentration disturbances, and thoughts of suicide). The same procedure was followed for the vegetative model where three parcels were created, representing appetite related symptoms (i.e. weight loss or gain/appetite disturbances), sleep problems (i.e. sleep disturbances), and energy related problems (psychomotor agitation or retardation, fatigue or loss of energy), and for the non-vegetative model, with two parcels representing core symptoms (dysphoric mood/irritability, loss of interest or pleasure in most activities) and cognitive symptoms (feelings of worthlessness or guilt, concentration disturbances, and thoughts of suicide).

Frequency of vigorous physical activity. Physical activity was assessed with a slight modified item of the HSCB study: "How often do you exercise at least 30 min in your spare time so that you get tired/sweaty?". The original item was validated in international studies and showed good reliability and fair validity (Booth et al. , 2001; Rangul et al., 2008). To the original item, we added also the indication of duration of the activity (i.e. "at least 30 min") to increase the reliability of the measure. The response alternative ranged from never (1) to every day (7).

Covariate and Moderator. Sex (male, female), reported by adolescents, was used as moderators. Parents' country of birth was assessed with two questions to the adolescents asking where both parents (mother and father respectively) were born. The range of answers were: Sweden, Nordic countries, another country in Europe, outside Europe. The items were combined in one item and dichotomized with the following possible answer: Scandinavian parents vs at least one of the parents born outside Scandinavia, and used as covariate in the analyses.

1.3. Plan of analysis

We constructed cross-lagged structural models to address our research questions. We created a latent factor of depression, dividing the observed items into parcels. Parceling is a process where two or more items of a construct are aggregated (i.e., averaged in our case) before being used as the indicators of the latent constructs (Little, 2013; Little et al., 2022). This approach has several advantages when using SEM (structural equation model) especially with longitudinal data (see Little et al., 2022 for a comprehensive review of benefits and caveats) and it is recommended when the aim of the study is to model the relationships among latent variables (Little et al., 2002), which is the case of the present study. In order to create the parcels, we adopted a Facet-Representative Parceling method (Little et al., 2022), given the multidimensionality of the items (i.e. vegetative and non-vegetative symptoms). For the depression model, a parcel including all the vegetative items and one including all the non-vegetative items were created. Confirmatory factor models were run to test the loadings invariance across the different time points. A change in CFI of 0.01 or less was used to establish factors loadings invariance (Little, 2013). Vigorous Physical activity (VPA) was represented as an observed variable instead, since it was assessed with only one item.

To achieve the first aim, we compared four nested models. Following the approach used by Bryant et al. (2000), we tested four models. The first model tested the stability of VPA and depression at different time levels, without cross-lagged paths. The second model tested the effect of VPA on depressive symptoms over time. The third model investigated the effects of depressive symptoms on VPA. The fourth model tested the reciprocal effects of VPA and depressive symptoms over time with a cross-lagged structural equation model. We compared the models to see which one would obtain the best balance between parsimony and complexity.

We used a similar approach to test the roles of vegetative and non-vegetative symptoms. Following the distinction observed by Rice et al. (2019), in the vegetative model, the items were divided in three parcels, indicating appetite, sleep and energy related symptoms, respectively. Finally, in the non-vegetative model, the items were divided in two parcels, indicating core and cognitive symptoms.

In each model, we controlled for ethnicity, regressing the effects of ethnicity on VPA and depression at T2.

To test for the moderating effects of sex, we performed a multigroup analyses. First, we kept the cross-lagged paths free and then we constrained them to be identical for boys and girls. Then we compared the chi squares of the constrained model and each one of the non-constrained models. A non-significant difference in chi squares would mean that the two groups did not differ with regard to the association examined.

We imputed missing data using the Full Information Maximum Likelihood (FIML) method in Mplus (Muthén & Muthén, 1998-2012). This procedure gives better estimates than pair- and list-wise deletion, especially when data are missing at random (MAR) or missing completely at random (MCAR) (Little & Rubin, 2019) and are longitudinal (Little, 2013; Newman, 2003). The imputation was conducted after the parceling. Little's MCAR test was performed to determine the missing patterns of the data, which confirmed that the data were MCAR ($\chi^2 = 448.397$, df = 475, $p > .05$). With regard to indices of model fit, chi-square, the Root Mean Square Error of Approximation (RMSEA), and the Comparative Fit Index (CFI) are reported. The RMSEA value, which is a measure of approximate fit in the population, is good when it is $<$ 0.05, and acceptable when it is between 0.05 and 0.10 (Hu & Bentler, 1998). Finally, the CFI (Hu & Bentler, 1998) should be above 0.95.

2. Results

2.1. Descriptives

Correlations among all the variables, and their means and standard deviations are presented in Table 1 and 2a and 2b, which refer to Time 1 (T1), Time 2 (T2) and Time 3 (T3). All the correlations presented the expected direction, with negative correlations between VPA and depressive symptoms at all time points.

At T1, 6% (N = 51) of the adolescents were inactive, a percentage that rose to 7% (N = 53) at T2 and to 11% (N = 69) at T3.

Table 1
Correlations and descriptive statistics for VPA and depression parcels (vegetative and non-vegetative).

Variables	VPA T1	VPA T2	VPA T3	Vegetative T1	Non-vege T1	Vegetative T2	Non-vege T2	Vegetative T3	Non-vege. T3
VPA T2	.42[a]								
VPA T3	.29[a]	.48[a]							
Vegetative T1	−.15[a]	−.13[a]	−.10[a]						
Non-Vege. T1	−.13[a]	−.14[a]	−.12[a]	.58[a]					
Vegetative T2	−.08[b]	−.11[a]	−.14[a]	.31[a]	.25[a]				
Non-vege. T2	−.08[a]	−.15[a]	−.13[a]	.26[a]	.36[a]	.63[a]			
Vegetative T3	−.06[b]	−.13[a]	−.14[a]	.13[a]	.25[a]	.27[a]	.25[a]		
Non-vege. T3	−.09[b]	−.17[a]	−.17[a]	.20[a]	.28[a]	.28[a]	.35[a]	.71[a]	
M	3.87	3.89	3.01	.11	.11	.21	.22	.24	.24
SD	1.48	1.64	1.80	.14	.17	.20	.28	.24	.28

[a] <.001.
[b] <.05; +<.10.

Table 2a
Correlations and Descriptive Statistics for VPA, and Vegetative parcels (appetite, sleep and energy)

Variables	VPA T1	VPA T2	VPA T3	Appetite T1	Sleep T1	Energy T1	Appetite T2	Sleep T2	Energy T2	Appetite T3	Sleep T3	Energy T3
VPA T2	.42**											
VPA T3	.29**	.47**										
Appetite T1	−.11**	−.09**	−.08*									
Sleep T1	−.09**	−.09**	−.07*	.22**								
Energy T1	−.13**	−.11**	−.07*	.28**	.27**							
Appetite T2	−.00	−.02	−.07*	.16**	.17**	.15**						
Sleep T2	−.07*	−.05*	−.08*	.18**	.23**	.14**	.24**					
Energy T2	−.09**	−.14**	−.14**	.09**	.18**	.20**	.28**	.38**				
Appetite T3	−.03	−.08**	−.13**	.05*	.01	.03	.08*	.12**	.11**			
Sleep T3	−.00	−.13**	−.10**	.08**	.01	.11**	.12**	.21**	.17**	.37**		
Energy T3	−.08*	−.10**	−.12**	.09*	.03	.12**	.13**	.15**	.23**	.42**	.56**	
M	3.87	3.89	3.01	.06	.12	.15	.11	.21	.28	.14	.28	.30
SD	1.48	1.64	1.80	.18	.25	.26	.22	.29	.31	.24	.33	.33

Table 2b
Correlations and Descriptive Statistics for VPA, and Non-Vegetative parcels (core and cognitive)

Variables	VPA T1	VPA T2	VPA T3	Core T1	Cognitive T1	Core T2	Cognitive T2	Core T3	Cognitive T3
VPA T2	.42**								
VPA T3	.29**	.47**							
Core T1	−.13*	−.15**							
Cognitive T1	−.06*	−.05*	−.04*	.42**					
Core T2	−.07*	−.14**	−.13*	.34**	.23**				
Cognitive T2	−.15**	−.11**	−.05**	.19**	.23**	.51**			
Core T3	−.07*	−.15**	−.15**	.28**	.16**	.36**	.17**		
Cognitive T3	−.04	−.16**	−.12**	.15**	.21**	.20**	.14**	.53**	
M	3.87	3.89	3.01	.13	.05	.25	.11	.28	.13
SD	1.48	1.64	1.80	.22	.20	.30	.31	.33	.28

2.2. Depression and VPA

First, we tested for factor loadings invariance, which was confirmed (see Table 4). Second, we tested the four models depicted in Fig. 1. All the models achieved a good fit (Table 3). The difference in chi square suggested that the VPA driven model and the Depression driven model were both significantly better than the Stability model. Moreover, the Reciprocal model was significantly better than both VPA driven model and the Depression driven model, suggesting that the Reciprocal model represented the relationship between VPA and Depression over time relatively better than the alternative models. Fig. 1 shows the structural part of the model (for the measurement part, see Table 4). Frequency of VPA at T1 did not affect depressive symptoms at T2 ($\beta = -0.01$, $p > .05$), but depressive symptoms at T1 decreased frequency of VPA at T2 ($\beta = -0.09$, $p < .05$). The relation between T2 and T3 became reciprocal, however, as depressive symptoms at T2 reduced frequency of VPA at T3 ($\beta = -0.10$, $p < .01$), while frequency of VPA at T2 reduced depressive symptoms at T3 ($\beta = -0.12$, $p < .05$).

2.3. Moderation effects of sex

The constrained model where all the cross-lagged paths were constrained to be equal for girls and boys did not differ from the unconstrained model, indicating that the relation between depression and frequency of VPA did not differ between boys and girls (see Table 3).

2.4. Vegetative and non-vegetative symptoms

We re-ran the model dividing the depression symptoms with two latent variables, one that included vegetative symptoms and the other with non-vegetative symptoms. However, the covariance between the latent factors of vegetative and non-vegetative symptoms was not acceptable (higher than 0.90), indicating that these subfactors were part of the same latent factor. In order to test the effects of the two subtypes of symptoms and to avoid collinearity, we ran two separate models, one for vegetative symptoms and one for non-vegetative symptoms. Both models had a good fit (see Table 3). When it comes to vegetative symptoms, depressive symptoms decreased frequency of VPA from T1 to T2 ($\beta = -0.09$, $p < .05$), while depressive symptoms and frequency of

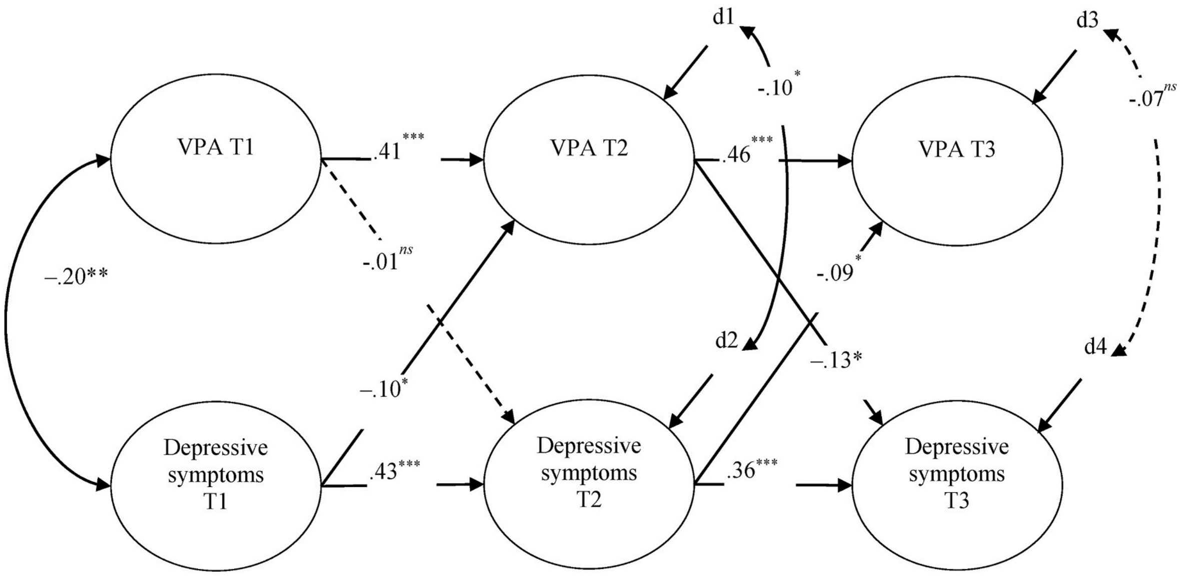

Fig. 1. Structural model of Depressive symptoms model, with standardized results (*p < .05, **p < .01, ***p < .001).

Table 3
Model fit for competitive models.

Model	χ^2	df	<	RMSEA	CFI	Model comparison	p
Depression model							
A. Stability model	81.69	24	.001	.54	.97		
B. VPA driven	73.56	22	.001	.053	.97	A	>.05
C. Depression driven	71.22	22	.001	.052	.97	A	>.05
D. Reciprocal model	63.29	20	.001	.051	.98	B–C	>.05
Vegetative symptoms model							
A. Stability model	108.311	51	.001	.037	.95		
B. VPA driven	103.589	49	.001	.037	.95	A	>.05
C. Depression driven	98.069	49	.001	.041	.93	A	>.05
D. Reciprocal model	93.601	47	.001	.035	.97	B–C	>.05
Non-vegetative symptoms model							
A. Stability model	66.113	24	.001	.046	.96		
B. VPA driven	57.667	22	.001	.044	.97	A	>.05
C. Depression driven	57.112	22	.001	.044	.97	A	>.05
D. Reciprocal model	44.898	20	.001	.042	.97	B–C	>.05
Multigroup analysis							
Gender							
A. Constrained model	123.821	53	.001	.057	.96		
B. Free model	120.577	49	.001	.060	.96	A	>.05

VPA had a reciprocal influence on each other between T2 and T3 ($\beta = -0.12$, $p < .05$ and $\beta = -0.10$, $p < .05$, respectively) (see Fig. 2). The results for the non-vegetative symptoms model differed from the original model, as depressive symptoms at T1 decreased VPA at T2 ($\beta = -0.10$, $p < .05$), while frequency of VPA at T2 predicted a decrease in depressive symptoms at T3 ($\beta = -0.15$, $p < .05$). The other paths were not significant (see Fig. 3).

3. Discussion

The aim of this study was to test the reciprocal association of frequency of vigorous physical activity (VPA) and depression from early to late adolescence. We found that depressive symptoms in early adolescence decreased frequency of VPA in middle adolescence, while depression and frequency of VPA were reciprocally associated from middle to late adolescence. This holds for boys and girls. However, when looking more specifically at subtypes of symptoms, it appears that different symptoms have different temporal relationships with vigorous physical activity. Adolescents with elevated non-vegetative symptoms (i.e., mood-related symptoms) in early adolescence are less likely to be involved in VPA in middle adolescence, while VPA decreased non-vegetative symptoms from middle to late adolescence. Vegetative symptoms (i.e., those more related to lack of energy and other physiology-related symptoms) seem to have a role in decreasing frequency of vigorous physical activity from early to middle adolescence, where-after the relation becomes reciprocal.

Our results further support the idea that the relationship between depression and physical activity is complex by nature. A reciprocal association between depression and physical activity has been confirmed in several studies with an adult population (da Silva et al., 2018; Hiles et al., 2017; Lindwall et al., 2014), but the evidence on adolescents is inconclusive. Our results only partly support the bidirectionality that was found in the study by Stavrakakis et al. (2012), and is partly consistent with Gunnell et al. (2016) study, as, even though we find a small effect from frequency of VPA to depressive symptoms from middle to late adolescence, the strength of the association is always stronger from depression to physical activity than vice-versa. Conversely, Buchan et al. (2021) did not find an effect of depressive symptoms on physical activity (PA). The difference might be due to that they focused on MVPA instead of VPA, as our study. One might hypothesize that depressive symptoms affect stronger VPA than MVPA, as committing in VPA might require more efforts and motivation that might be affected by depressive

Table 4
Standardized factor loadings and standard errors for the observed variables on latent factors of depression, vegetative and non-vegetative symptoms.

Observed indicators	Latent variables		
	Depression	Vegetative	Non-vegetative
T1			
Depression model			
Vegetative	.76/.06		
Non-vegetative	.76/.06		
Vegetative model			
Appetite parcel		.46/.04	
Sleep parcel		.49/.04	
Energy parcel		.58/.05	
Non-vegetative model			
Core parcel			.84/.10
Cognitive parcel			.50/.06
T2			
Depression model			
Vegetative parcel	.80/.06		
Non-vegetative parcel	.78/.06		
Vegetative model			
Appetite parcel		.42/.04	
Sleep parcel		.56/.04	
Energy parcel		.65/.04	
Non-vegetative model			
Core parcel			.91/.10
Cognitive parcel			.56/.07
T3			
Depression model			
Vegetative parcel	.78/.06		
Non-Vegetative parcel	.90/.06		
Vegetative model			
Appetite parcel		.54/.04	
Sleep parcel		.70/.03	
Energy parcel 3		.78/.03	
Non-vegetative model			
Core parcel			.80/.09
Cognitive parcel			.65/.08

Note. All the factor loadings were $p < .01$. Factor loadings were tested for invariance across time points (depression model: $\Delta CFI = 0.001$, vegetative model: $\Delta CFI = 0.004$, non-vegetative model: $\Delta CFI = 0.001$).

symptoms. Gunnell et al. (2016) and Stavrakakis et al. (2012) studies cannot contribute to test this hypothesis as they adopted a generic measure of PA, without distinguish between MVPA and VPA. Therefore, further studies are needed to understand the effect of depression on different intensity of PA.

The associations between depression and physical activity are robust across sex, which is in contrast with the available literature on the matter. Whereas correlation studies have found a stronger effect between physical activity and internalizing problems for boys than for girls (see Sagatum et al., 2007; Isakson et al., 2020), physical activity-based interventions have been found to work better with girls (Spruijtz et al., 2016). While the above-mentioned correlation studies did not test reciprocity of the effects and cannot be compared directly with the present study, the results related to the intervention studies might lead to the hypothesis that the relation between physical activity and depression is stronger for girls than boys. Nevertheless, the difference in the intervention effects might be also due to the initial levels of physical activity and biological and psychosocial mechanisms activated by the intervention, i.e. self-esteem or self-efficacy in boys and girls. For instance, girls reported to have lower physical activity levels (e.g., Kjellenberg et al., 2022) and self-efficacy related to physical activity than boys (e.g., Spence et al., 2010), which render them more likely to benefit from physical based intervention. This would explain the difference with the present study where the relation between vigorous physical activity and depression is independent from sex. However, this hypothesis needs to be confirmed in studies assessing the mediating mechanisms of physical-activity-based interventions for boys and girls.

Based on our results, we suggest that different types of symptoms might have different roles in decreasing physical activity during different developmental periods. Non-vegetative symptoms seem to play a role only in early adolescence. This difference may reside in the different biological and emotional mechanisms at work at different phases of adolescence. Early adolescence (10–14 year) is usually the period when puberty starts (Phillips, 2014), which corresponds to a reactivation of the hypothalamus-pituitary-gonadal (HPG) axis. This reactivation is responsible for a massive release of gonadotrophin-releasing hormone (GnRH), which in turn controls the sex hormones, such as testosterone and estradiol. Sex hormones have been connected with both social and affective development (see Peper & Dahl, 2013 for a review). Consistently, time of puberty has been associated with an increase in negative affect, and the relation has been found to be curvilinear with a peak one year after onset (DeRose & Brooks-Gunn, 2008). Because of this, it might be hypothesized that the increase in negative mood also due to pubertal processes might be particularly important in the choice of being physically active during

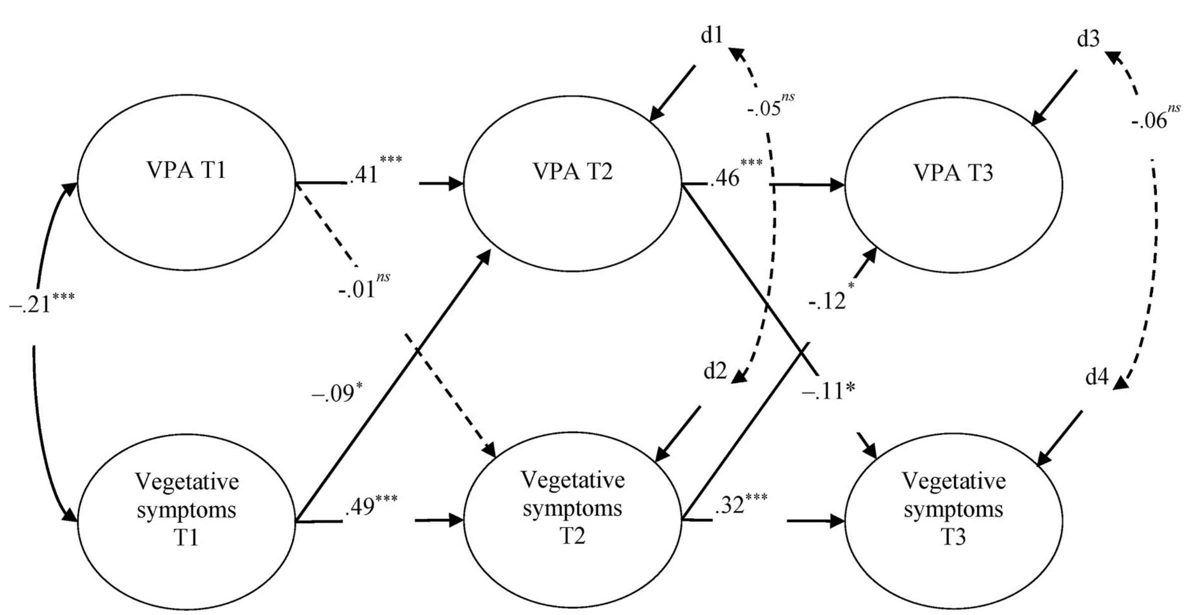

Fig. 2. Structural model of Vegetative symptoms model, with standardized results (*p < .05, **p < .01, ***p < .001).

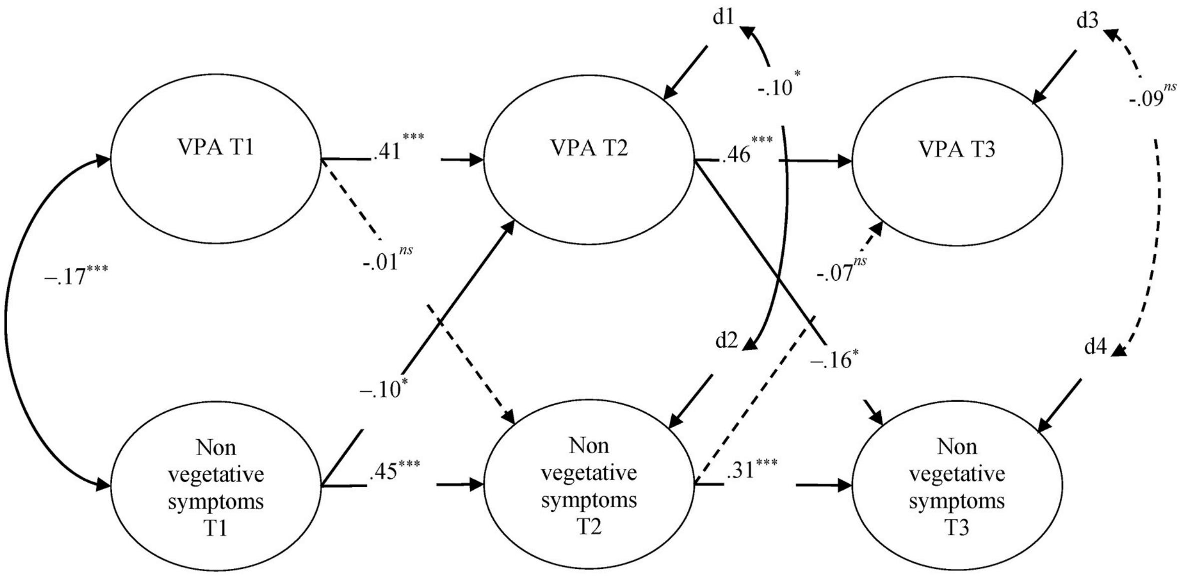

Fig. 3. Structural model of Non-vegetative symptoms model, with standardized results (*p < .05, **p < .01, ***p < .001).

this developmental period. However, further studies are needed to confirm this hypothesis.

Despite different effects of subtypes of symptoms, vigorous physical activity is likely to have a protective role in decreasing depressive symptoms from middle to late adolescence. Recent reviews (Andermo et al., 2020; Rodriguez-Ayllon et al., 2019) have found that the protective effects of physical activity are limited to adolescents and are not present among children. Moreover, recent studies have highlighted that depressive symptoms increase on average until the end of adolescence (Kwong et al., 2019) and that the peak of onset of mood disorders is about age 20 (Solmi et al., 2022). Our study suggests that physical-based activity intervention implemented just before the peak, i.e. middle adolescence, might have an impact in the reduction of depressive symptoms and mood disorders.

This study has some knowledge gaps. An important one lies on focusing only on a self-reported measure of vigorous physical activity. Nevertheless, the measure has been shown partial validity when compared with other objective measures (Booth et al., 2001), and has been distinguished from moderate-to-vigorous physical activity (MVPA) in a recent study (Tanaka et al., 2017). Moreover, the use of one-item measure limits knowledge of the roles of different types of physical activity, e.g., aerobic vs anaerobic or moderate, and context (i.e. alone, in group). For instance, moderate-to-vigorous physical activity (MVPA) has been seen to positively impact adolescents' mental health and it is recommended by WHO. Therefore, further studies would need to test reciprocal effects of MVPA and depression through adolescence. As already stated, different types of measurement may also be responsible for the different findings of two of the studies that explore reciprocity with the same age group. Moreover, it was not possible to investigate whether the effect of physical activity depended on the domain, as has been highlighted in a meta-analysis of studies of different physical-activity arenas (leisure-time physical, school sport, etc.), and mental health (White et al., 2017). Moreover, a limitation of the type of Cross-lagged model used (CLPM) is that such a model is not able to examine intra-individual changes, like the RI-CLPM model for instance, but only between-individual changes. However, given the nature of our research questions (which looks at group-level relations) and the timing and the frequency of the data collection (every three years, three data waves), there are good reasons to prefer CLPM to RI-CLPM (see Orth et al., 2021). Finally, the sample is somewhat representative of a Swedish region and generalizability of results to other populations should be taken with caution. Further studies should take into consideration all the above-mentioned aspects.

This study also has some strengths. To our knowledge, it is the first study to test longitudinally the bidirectionality of depressive symptoms and vigorous physical activity across boys and girls, finding that the relation did not differ between those groups. Moreover, it is also the first study to disentangle the independent roles of different subtypes of depressive symptoms during different developmental periods across adolescence.

To conclude, this study highlights that depressive symptoms in adolescence, both vegetative and non-vegetative, might contribute to a decrease in vigorous physical activity in boys and girls, regardless of developmental period. However, as vigorous physical activity seems to predict a decrease in depressive symptoms of both subtypes from middle to late adolescence, i.e., during a period when physical activity starts to decrease and depressive symptoms are almost at their peak. Preventive interventions focused on increasing physical activity during this developmental period may contribute to an amelioration of adolescents' mental ill-health, reducing both vegetative and non-vegetative depressive symptoms.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Allison, K. R., Adlaf, E. M., Irving, H. M., Hatch, J. L., Smith, T. F., Dwyer, J. J., & Goodman, J. (2005). Relationship of vigorous physical activity to psychologic distress among adolescents. *Journal of Adolescent Health : Official Publication of the Society for Adolescent Medicine, 37*(2), 164–166. https://doi.org/10.1016/j.jadohealth.2004.08.017

Andermo, S., Hallgren, M., Nguyen, T.-T.-D., Jonsson, S., Petersen, S., Friberg, M., Romqvist, A., Stubbs, B., & Elinder, L. S. (2020). School-related physical activity interventions and mental health among children: A systematic review and meta-analysis. *Sports medicine-open, 6*(1), 1–27. https://doi.org/10.1186/s40798-020-00254-x

Biddle, S. J., Ciaccioni, S., Thomas, G., & Vergeer, I. (2019). Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality. *Psychology of Sport and Exercise, 42*, 146–155. https://doi.org/10.1016/j.psychsport.2018.08.011

Booth, M. L., Okely, A. D., Chey, T., & Bauman, A. (2001). The reliability and validity of the physical activity questions in the WHO health behaviour in schoolchildren (HBSC) survey: A population study. *British Journal of Sports Medicine, 35*(4), 263–267. https://doi.org/10.1136/bjsm.35.4.263

Bremberg, S. (2015). Mental health problems are rising more in Swedish adolescents than in other Nordic countries and The Netherlands. *Acta Paediatrica, 104*(10), 997–1004. https://doi.org/10.1111/apa.13075

Bryant, A. L., Schulenberg, J., Bachman, J. G., O'Malley, P. M., & Johnston, L. D. (2000). Understanding the links among school misbehavior, academic achievement, and cigarette use: A national panel study of adolescents. *Prevention Science, 1*(2), 71–87. https://doi.org/10.1023/A:1010038130788

Buchan, M. C., Romano, I., Butler, A., Laxer, R. E., Patte, K. A., & Leatherdale, S. T. (2021). Bi-Directional relationships between physical activity and mental health among a large sample of Canadian youth: A sex-stratified analysis of students in the COMPASS study. *International Journal of Behavioral Nutrition and Physical Activity, 18*(1), 1–11. https://doi.org/10.1186/s12966-021-01201-z

Buli, B. G., Larm, P., Nilsson, K. W., & Giannotta, F. (2023). Trends in adolescent mental health problems 2004–2020: Do sex and socioeconomic status play any role? *Scandinavian Journal of Public Health*. https://doi.org/10.1177/14034948231165552

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

DeRose, L. M., & Brooks-Gunn, J. (2008). Pubertal development in early adolescence: Implications for affective processes. In L. B. Sheeber, & N. B. Allen (Eds.), *Adolescent emotional development and the emergence of depressive disorders* (pp. 56–73). Cambridge University Press. https://doi.org/10.1017/CBO9780511551963.004.

Elliot, C., Lang, C., Brand, S., Holsboer-Trachsler, E., Pühse, U., & Gerber, M. (2015). The relationship between meeting vigorous physical activity recommendations and burnout symptoms among adolescents: An exploratory study with vocational students. *Journal of Sport & Exercise Psychology, 37*(2), 180–192. https://doi.org/10.1123/jsep.2014-0199

Fournier, J. C., DeRubeis, R. J., Hollon, S. D., Gallop, R., Shelton, R. C., & Amsterdam, J. D. (2013). Differential change in specific depressive symptoms during antidepressant medication or cognitive therapy. *Behaviour Research and Therapy, 51*(7), 392–398. https://doi.org/10.1016/j.brat.2013.03.010

Gunnell, K. E., Flament, M. F., Buchholz, A., Henderson, K. A., Obeid, N., Schubert, N., & Goldfield, G. S. (2016). Examining the bidirectional relationship between physical activity, screen time, and symptoms of anxiety and depression over time during adolescence. *Preventive Medicine, 88*, 147–152. https://doi.org/10.1016/j.ypmed.2016.04.002

Harbour, V. J., Behrens, T. K., Kim, H. S., & Kitchens, C. L. (2008). Vigorous physical activity and depressive symptoms in college students. *Journal of Physical Activity and Health, 5*(4), 516–526. https://doi.org/10.1123/jpah.5.4.516

Hiles, S., Lamers, F., Milaneschi, Y., & Penninx, B. (2017). Sit, step, sweat: Longitudinal associations between physical activity patterns, anxiety and depression. *Psychological Medicine, 47*(8), 1466–1477. https://doi.org/10.1017/S0033291716003548

Hu, L.-t., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods, 3*(4), 424. https://doi.org/10.1037/1082-989X.3.4.424

Hu, M. X., Turner, D., Generaal, E., Bos, D., Ikram, M. K., Ikram, M. A., … Penninx, B. W. (2020). Exercise interventions for the prevention of depression: A systematic review of meta-analyses. *BMC Public Health, 20*(1), 1–11. https://doi.org/10.1186/s12889-020-09323-y

Isaksson, J., Selinus, E. N., Åslund, C., & Nilsson, K. W. (2020). Physical activity in early adolescence predicts depressive symptoms 3 years later: A community-based study. *Journal of Affective Disorders, 277*, 825–830. https://doi.org/10.1016/j.jad.2020.09.008

Johnson, J. G., Cohen, P., & Kasen, S. (2009). Minor depression during adolescence and mental health outcomes during adulthood. *The British Journal of Psychiatry, 195*(3), 264–265. https://doi.org/10.1192/bjp.bp.108.054239

Kandola, A., Ashdown-Franks, G., Hendrikse, J., Sabiston, C. M., & Stubbs, B. (2019). Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity. *Neuroscience & Biobehavioral Reviews, 107*, 525–539. https://doi.org/10.1016/j.neubiorev.2019.09.040

Kjellenberg, K., Ekblom, O., Ahlen, J., Helgadóttir, B., & Nyberg, G. (2022). Cross-sectional associations between physical activity pattern, sports participation, screen time and mental health in Swedish adolescents. *BMJ Open, 12*(8), Article e061929. https://doi.org/10.1136/bmjopen-2022-061929

Korczak, D. J., Madigan, S., & Colasanto, M. (2017). Children's physical activity and depression: A meta-analysis. *Pediatrics, 139*(4). https://doi.org/10.1542/peds.2016-2266

Kwong, A. S., Manley, D., Timpson, N. J., Pearson, R. M., Heron, J., Sallis, H., … Leckie, G. (2019). Identifying critical points of trajectories of depressive symptoms from childhood to young adulthood. *Journal of Youth and Adolescence, 48*, 815–827. https://doi.org/10.1007/s10964-018-0976-5

Lindwall, M., Gerber, M., Jonsdottir, I. H., Börjesson, M., & Ahlborg, G., Jr. (2014). The relationships of change in physical activity with change in depression, anxiety, and burnout: A longitudinal study of Swedish healthcare workers. *Health Psychology, 33*(11), 1309. https://doi.org/10.1037/a0034402

Little, T. D. (2013). *Longitudinal structural equation modeling*. Guilford press.

Little, T. D., Cunningham, W. A., Shahar, G., & Widaman, K. F. (2002). To parcel or not to parcel: Exploring the question, weighing the merits. *Structural Equation Modeling, 9*(2), 151–173. https://doi.org/10.1207/s15328007 sem0902

Little, T., Rioux, C., Odejimi, O., & Stickley, Z. (2022). *Parceling in structural equation modeling: A comprehensive introduction for developmental scientists (elements in research methods for developmental science)*. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781009211659

Little, R. J., & Rubin, D. B. (2019). *Statistical analysis with missing data* (Vol. 793). John Wiley & Sons.

Mata, J., Thompson, R. J., Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Gotlib, I. H. (2012). Walk on the bright side: Physical activity and affect in major depressive disorder. *Journal of Abnormal Psychology, 121*(2), 297. https://doi.org/10.1037/a0023533

Muthén, L. K., & Muthén, B. O. (1998-2012). *Mplus user's guide* (7th ed.). Muthén & Muthén.

Newman, D. A. (2003). Longitudinal modeling with randomly and systematically missing data: A simulation of ad hoc, maximum likelihood, and multiple imputation techniques. *Organizational Research Methods, 6*(3), 328–362. https://doi.org/10.1177/1094428103254673

Olive, L., Byrne, D., Telford, R. D., Abhayaratna, W., & Telford, R. M. (2016). Childhood stress, emotional distress, and cardiovascular function in adolescents. *Handbook of Psychocardiology*.

Orth, U., Clark, D. A., Donnellan, M. B., & Robins, R. W. (2021). Testing prospective effects in longitudinal research: Comparing seven competing cross-lagged models. *Journal of Personality and Social Psychology, 120*(4), 1013–1034. https://doi.org/10.1037/pspp0000358

Patten, S. B., Williams, J. V., Lavorato, D. H., & Eliasziw, M. (2009). A longitudinal community study of major depression and physical activity. *General Hospital Psychiatry, 31*(6), 571–575. https://doi.org/10.1016/j.genhosppsych.2009.08.001

Peper, J. S., & Dahl, R. E. (2013). Surging hormones: Brain-behavior interactions during puberty. *Current Directions in Psychological Science, 22*(2), 134–139. https://doi.org/10.1177/0963721412473755

Phillips, D. C. (2014). *Encyclopedia of educational theory and philosophy*. Sage Publications.

Piao, J., Huang, Y., Han, C., et al. (2022). Alarming changes in the global burden of mental disorders in children and adolescents from 1990 to 2019: A systematic analysis for the global burden of disease study. *European Child & Adolescent Psychiatry, 31*, 1827–1845. https://doi.org/10.1007/s00787-022-02040-4

Rangul, V., Holmen, T. L., Kurtze, N., Cuypers, K., & Midthjell, K. (2008). Reliability and validity of two frequently used self-administered physical activity questionnaires in adolescents. *BMC Medical Research Methodology, 8*, 1–10. https://doi.org/10.1186/1471-2288-8-47

Rebar, A. L., Stanton, R., Geard, D., Short, C., Duncan, M. J., & Vandelanotte, C. (2015). A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health Psychology Review, 9*(3), 366–378. https://doi.org/10.1080/17437199.2015.1022901

Rice, F., Riglin, L., Lomax, T., Souter, E., Potter, R., Smith, D., Thapar, A., & Thapar, A. (2019). Adolescent and adult differences in major depression symptom profiles. *Journal of Affective Disorders, 243*, 175–181. https://doi.org/10.1016/j.jad.2018.09.015

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. (2019). Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: A systematic review and meta-analysis. *Sports Medicine, 49*(9), 1383–1410. https://doi.org/10.1007/s40279-019-01099-5

Rosenbaum, S., Tiedemann, A., Sherrington, C., Curtis, J., & Ward, P. B. (2014). Physical activity interventions for people with mental illness: A systematic review and meta-analysis. *The Journal of Clinical Psychiatry, 75*(9), Article 14465. https://doi.org/10.4088/JCP.13r08765

Roshanaei-Moghaddam, B., Katon, W. J., & Russo, J. (2009). The longitudinal effects of depression on physical activity. *General Hospital Psychiatry, 31*(4), 306–315. https://doi.org/10.1016/j.genhosppsych.2009.04.002

Sagatun, A., Søgaard, A. J., Bjertness, E., Selmer, R., & Heyerdahl, S. (2007). The association between weekly hours of physical activity and mental health: A three-year follow-up study of 15–16-year-old students in the city of oslo, Norway. *BMC Public Health, 7*(1), 1–9. https://doi.org/10.1186/1471-2458-7-155

da Silva, F. C., Iop, R.d. R., de Oliveira, L. C., Boll, A. M., de Alvarenga, J. G. S., Gutierres Filho, P. J. B., de Melo, L. M. A. B., Xavier, A. J., & da Silva, R. (2018). Effects of physical exercise programs on cognitive function in Parkinson's disease patients: A systematic review of randomized controlled trials of the last 10 years. *PLoS One, 13*(2). https://doi.org/10.1371/journal.pone.0193113

Solmi, M., Radua, J., Olivola, M., Croce, E., Soardo, L., Salazar de Pablo, G., … Fusar-Poli, P. (2022). Age at onset of mental disorders worldwide: Large-scale meta-analysis of 192 epidemiological studies. *Molecular Psychiatry, 27*(1), 281–295. https://doi.org/10.1038/s41380-021-01161-7

Sonnby, K., Skordas, K., Vadlin, S., Olofsdotter, S., Nilsson, K. W., & Ramklint, M. (2022). Psychometric validation of two versions of the adolescent depression self-rating scale (DSRS-A and DSRS-A screener). *Nordic Journal of Psychiatry, 76*(3), 233–242. https://doi.org/10.1080/08039488.2021.1956583

Spence, J. C., Blanchard, C. M., Clark, M., Plotnikoff, R. C., Storey, K. E., & McCargar, L. (2010). The role of self-efficacy in explaining gender differences in physical activity among adolescents: A multilevel analysis. *Journal of Physical Activity and Health, 7*(2), 176–183. https://doi.org/10.1123/jpah.7.2.176

Spruit, A., Assink, M., van Vugt, E., van der Put, C., & Stams, G. J. (2016). The effects of physical activity interventions on psychosocial outcomes in adolescents: A meta-analytic review. *Clinical Psychology Review, 45*, 56–71. https://doi.org/10.1016/j.cpr.2016.03.006

Stavrakakis, N., de Jonge, P., Ormel, J., & Oldehinkel, A. J. (2012). Bidirectional prospective associations between physical activity and depressive symptoms. The TRAILS Study. *Journal of Adolescent Health, 50*(5), 503–508. https://doi.org/10.1016/j.jadohealth.2011.09.004

Svanborg, P., & Ekselius, L. (2003). Self-assessment of DSM-IV criteria for major depression in psychiatric out-and inpatients. *Nordic Journal of Psychiatry, 57*(4), 291–296. https://doi.org/10.1080/08039480307281

Tanaka, C., Kyan, A., Takakura, M., Olds, T., Schranz, N., Tanaka, M., & Tanaka, S. (2017). The validity of the Japanese version of physical activity questions in the WHO Health Behaviour in School-aged Children (HBSC) survey. *Research in Exercise Epidemiology, 19*(2), 93–101. https://doi.org/10.24804/ree.19.93

Twenge, J. M., Cooper, A. B., Joiner, T. E., Duffy, M. E., & Binau, S. G. (2019). Age, period, and cohort trends in mood disorder indicators and suicide-related outcomes in a nationally representative dataset, 2005–2017. *Journal of Abnormal Psychology, 128*(3), 185. https://doi.org/10.1037/abn0000410

Vadlin, S., Åslund, C., Rehn, M., & Nilsson, K. W. (2015). Psychometric evaluation of the adolescent and parent versions of the gaming addiction identification test (GAIT). *Scandinavian Journal of Psychology, 56*(6), 726–735. https://doi.org/10.1111/sjop.12250

Wang, X., Cai, Z.-d., Jiang, W.-t., Fang, Y.-y., Sun, W.-x., & Wang, X. (2022). Systematic review and meta-analysis of the effects of exercise on depression in adolescents. *Child and Adolescent Psychiatry and Mental Health, 16*(1), 1–19. https://doi.org/10.1186/s13034-022-00453-2

White, R. L., Babic, M. J., Parker, P. D., Lubans, D. R., Astell-Burt, T., & Lonsdale, C. (2017). Domain-specific physical activity and mental health: A meta-analysis. *American Journal of Preventive Medicine, 52*(5), 653–666. https://doi.org/10.1016/j.amepre.2016.12.008

Who. (2017). *Depression and other common mental health disorders*. Geneva: World Health Organization.

Young, M. A., Scheftner, W. A., Klerman, G. L., Andreasen, N. C., & Hirschfeld, R. M. (1986). The endogenous sub-type of depression: A study of its internal construct validity. *The British Journal of Psychiatry, 148*(3), 257–267. https://doi.org/10.1192/bjp.148.3.257

Zahn-Waxler, C., Shirtcliff, E. A., & Marceau, K. (2008). Disorders of childhood and adolescence: Gender and psychopathology. *Annual Review of Clinical Psychology, 4*, 275–303. https://doi.org/10.1146/annurev.clinpsy.3.022806.091358