Physical Activity, Sedentary Behavior, and Symptoms of Major Depression in Middle Childhood

Tonje Zahl, MSC,[a,b] Silje Steinsbekk, PhD,[b] Lars Wichstrøm, PhD[a,b]

abstract

OBJECTIVE: The prospective relation between physical activity and *Diagnostic and Statistical Manual of Mental Disorders*-defined major depression in middle childhood is unknown, as is the stability of depression. We therefore aimed to (1) determine whether there are reciprocal relations between moderate-to-vigorous physical activity (MVPA) and sedentary behavior, on one hand, and *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* defined symptoms of major depressive disorder, on the other and (2) assess the extent of stability in depressive symptoms from age 6 to 10 years.

METHODS: A community sample of children living in Trondheim, Norway, comprising a total of 795 6-year-old children was followed up at 8 (n = 699) and 10 (n = 702) years of age. Physical activity was recorded by accelerometry and symptoms of major depression were measured through semistructured clinical interviews of parents and children. Bidirectional relationships between MVPA, sedentary activity, and symptoms of depression were analyzed through autoregressive cross-lagged models, and adjusted for symptoms of comorbid psychiatric disorders and BMI.

RESULTS: At both age 6 and 8 years, higher MVPA predicted fewer symptoms of major depressive disorders 2 years later. Sedentary behavior did not predict depression, and depression predicted neither MVPA nor sedentary activity. The number of symptoms of major depression declined from ages 6 to 8 years and evidenced modest continuity.

CONCLUSIONS: MVPA predicts fewer symptoms of major depression in middle childhood, and increasing MVPA may serve as a complementary method to prevent and treat childhood depression.

[a]*NTNU Social Reseach, Trondheim, Norway; and* [b]*Department of Psychology, Norwegian University of Science and Technology, Trondheim, Norway*

Ms Zahl carried out initial analyses and drafted initial manuscript; Dr Steinsbekk conceptualized, designed, and supervised the study; Dr Wichstrøm obtained funding and conceptualized, designed, and supervised the study; and all authors approved the final manuscript as submitted.

DOI: 10.1542/peds.2016-1711

Accepted for publication Nov 8, 2016

Address correspondence to Tonje Zahl, MSC, NTNU Social Research, Dragvoll Allé 38B, 7048 Trondheim, Norway. E-mail: tonje.zahl@samfunn.ntnu.no

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: This research was supported by grants 228685 and 213793 from the Research Council of Norway and grant F05148 from the Norwegian Extra Foundation for Health and Rehabilitation.

WHAT'S KNOWN ON THIS SUBJECT: Moderate-to-vigorous physical activity (MVPA) reduces the likelihood of depression in adolescents and adults, and is cross-sectionally associated with depression in children. However, the prospective relation between MVPA, sedentary time, and depression in childhood is unknown.

WHAT THIS STUDY ADDS: Objectively measured MVPA at ages 6 and 8 predict fewer symptoms of depression in children 2 years later, whereas sedentary activity is prospectively unrelated to depression. Depression does not forecast reduced physical activity in children.

To cite: Zahl T, Steinsbekk S, Wichstrøm L. Physical Activity, Sedentary Behavior, and Symptoms of Major Depression in Middle Childhood. *Pediatrics.* 2017;139(2):e20161711

Both observational and treatment studies[1–3] indicate that physical activity (PA)—and moderate-to-vigorous PA (MVPA), in particular—may reduce the likelihood of major depressive disorder (MDD) and/or reduce the symptoms of MDD in adolescents[4] and adults.[5–7] It has recently become increasingly clear that depression can also be present in young children.[8,9] Preventive[10] and treatment efforts[11] for childhood depression are only modestly effective, which suggests that alternative or complementary interventions must be sought. MVPA might possibly serve as a strategy for preventing or reducing childhood depression. Indeed, a meta-analysis of randomized and quasiexperimental studies[12] among children in late childhood and early adolescence suggested a small short-term effect of PA interventions. Given the waxing and waning of depression,[13] it is important also to discern whether long-term effects are present. Toward this end, prospective community studies might prove valuable. Importantly, psychomotor retardation is 1 symptom of MDD,[14] and depressed children show higher levels of motor inactivity than controls,[6,15] which might explain the association reported. Longitudinal studies are therefore needed to reveal whether depression predicts reduced PA and whether reduced PA increases the risk for depression in children, as has been shown in adolescents and adults.[5,6,16] Moreover, to our knowledge, no longitudinal study has examined the relationship between PA and depression in middle childhood by using a community based sample.

To identify the potentially beneficial effects of PA on depression (and vice versa) in nonreferred children, we examine the bidirectional relation between MVPA and symptoms of depression, while addressing several important methodological issues. First, previous observational studies have nearly exclusively measured depression by means of rating scales; however, the correspondence between rating scale scores and the results from clinical diagnostic interviews are only moderate.[17] Second, studies of the PA-depression relationship in children and adolescents have mainly used indirect methods to measure children's PA (ie, parent report or self-report, which are only moderately associated with objectively measured PA); in fact, PA in community children may be overestimated by using indirect methods.[18] Hence, to avoid confounding due to reporting bias, the PA–depression relationship should be investigated by using objective measures of PA. Third, sedentary activity and MVPA are negatively, but far from perfectly, correlated.[19] In other words, some children may be periodically highly active but may nonetheless spend much time engaged in sedentary behavior. A substantial amount of research has focused on MVPA; however, several studies have revealed that sedentary behavior, not necessarily MVPA, might predict depression.[20,21] Thus, we will investigate the extent to which time spent in sedentary activities predicts symptoms of MDD over and above the effects of MVPA. Fourth, there is considerable comorbidity between depression and other psychiatric disorders in children,[22,23] and these disorders might be related to PA, confounding the relationship between depression and PA as a result. Fifth, although the evidence is mixed,[24] a bidirectional relationship between childhood depression and BMI is indicated,[25] and BMI should therefore be controlled for. To overcome these obstacles, we investigate the prospective reciprocal relations between *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) defined symptoms of major depression (obtained by using diagnostic interviews) and accelerometry-recorded MVPA and sedentary activity in a large community sample of Norwegian children monitored biannually from the ages of 6 to 10 years controlling for BMI and other psychiatric symptoms.

METHODS

Participants, Recruitment, and Procedure

The Trondheim Early Secure Study consists of children from the 2003 and 2004 birth cohorts in Trondheim, Norway (n = 3456) that were recruited by invitation letter, together with the Strengths and Difficulties Questionnaire (SDQ) 4–16 version.[26] Written consent to participate was obtained when attending ordinary community health checkups for their 4-year-olds and the completed SDQ was delivered. As can be seen in Fig 1, the vast majority (n = 3358, 97.2%) of children who were invited to participate appeared at the city's well-child clinics. The SDQ total problem scores (20 items) were divided into 4 strata (cutoffs: 0 to 4, 5 to 8, 9 to 11, and 12 to 40), where drawing probabilities increased with increasing SDQ scores (0.37, 0.48, 0.70, and 0.89 in the 4 strata) to increase sample variability. The PA measurements were included beginning with the second wave of the data collection (6 years) and onward; therefore, the data used in the present inquiry were taken from 6-year (2009 to 2011, n = 795), 8-year (2011 to 2013, n = 699), and 10-year (2013 to 2015, n = 702) assessments. In all, 799 children had usable data from at least 1 measurement, and thus constitute the analytical sample. Attrition was not selective according to the study variables, except that more hours in MVPA at age 8 predicted attrition at age 10 (odds ratio = 2.38; 95% confidence interval [CI]: 1.22 to 4.83, P = .01); a bias that was adjusted for in the analyses (see Statistical

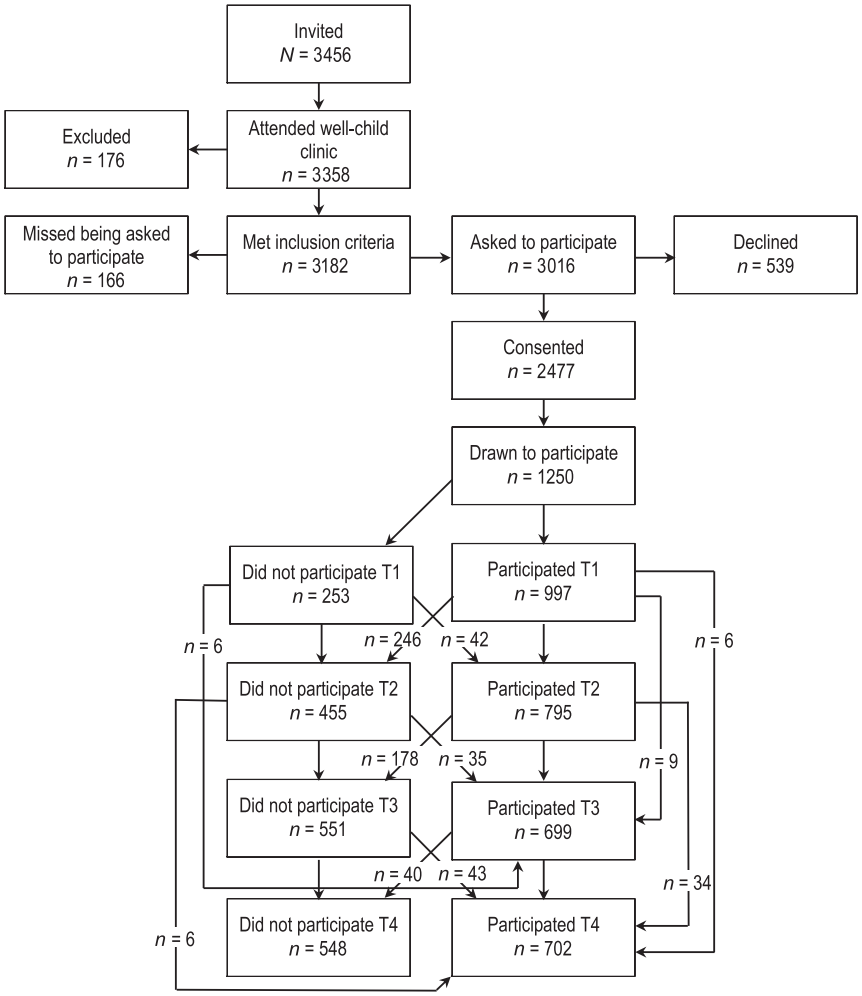

FIGURE 1
Sample recruitment and follow-up.

Analysis). The study was approved by the Regional Committee of Medical and Health Research Ethics, Mid-Norway.

Measurements

Physical Activity

The children were instructed to wear an ActiGraph GT3X accelerometer (Manufacturing Technology, Inc, Fort Walton Beach, FL) around their waist for 7 consecutive days, 24 hours a day, and only remove it when bathing or showering. Only daytime activity (06:00–23:59) was included. Sequences of consecutive zero counts lasting ≥20 minutes were interpreted as nonwear time.[27,28] Only those participants with ≥3 days of recordings and ≥480 minutes of activity per day were included. Detailed information on accelerometer compliance is shown in Supplemental Table 3. Because young children's activity is often intermittent with short bursts, we employed the commonly used 10 seconds epoch length.[27] We applied the Evenson et al[29] cutoff point of ≥2296 cpm for MVPA because it has shown superior classification ability in children across the ages relevant to the current study.[30] Minutes per day with ≤100 cpm was considered sedentary activity, a cutoff that is widely used and has excellent classification accuracy.[30] In the analyses, MVPA and sedentary activity were represented in hours per day intervals. Data were processed by using accelerometer analysis software (ActiGraph LLC, Pensacola, FL).

Symptoms of MDD

The Preschool Age Psychiatric Assessment (PAPA),[31] a psychiatric interview completed by parents using a structured protocol, with both mandatory and optional follow-up questions, was used to assess MDD symptoms at 6 years. A sum score of DSM-IV defined MDD symptoms constituted the outcome. At 8 and 10 years of age, the Child and Adolescent Psychiatric Assessment (CAPA)[32] was used. Both parents and children were interviewed and a symptom was considered to be present if it was reported by either child or parent. The PAPA and CAPA interviewers (n = 9) had at least a Bachelor's degree in a relevant field and were instructed by the developers of the PAPA and CAPA. For the PAPA, 9% of the interview audio recordings were recoded by blinded raters, as were 15% of the CAPA interviews. The interrater reliability between multiple pairs of raters was 0.90 for symptoms of MDD in the PAPA and 0.83 in the CAPA.

Symptoms of Other Psychiatric Disorders

Symptoms of anxiety (consisting of number of symptoms of social phobia, separation anxiety, generalized anxiety, and specific phobias), attention-deficit/hyperactivity (ADHD), oppositional defiant (ODD), and conduct disorders (CDs) were assessed following the same procedures as for symptoms of MDD. Only the parents were interviewed by using the CAPA with respect to ADHD. The interrater reliabilities for PAPA/CAPA ranged from 0.85 to 0.97.

Body Mass Index

The children's weight was measured by using a digital scale (Tanita BC20MA), and the height was assessed by using the Heightronic

Digital Stadiometer (QuickMedical Model 235A). Correction for indoor clothing (0.5 kg) was applied. BMI was calculated as kg/m^2.

Statistical Analysis

Reciprocal relations between PA and the symptoms of MDD were examined in Mplus 7.31,[33] using autoregressive cross-lagged analysis within a structural equation framework. The symptoms of MDD, MVPA, and sedentary activity at age 10 were regressed on measures of these variables and covariates at age 8, whereas age 8 measures were regressed on measures at age 6, as shown in Fig 2. To allow for sleeper effects (ie, the effects from age 6 to age 10 measures bypassing measures at age 8), autocorrelated paths were allowed from ages 6 to 10. Measures obtained at the same time point in time (ie, at ages 6, 8, and 10, respectively) were allowed to correlate. To examine overall changes in level of MDD, sedentary activity and MVPA latent growth curve analyses were conducted. Because the attrition analyses indicated that the data were missing not at random (MNAR), missing data were handled according to a full information maximum likelihood procedure. Because counts of depressive symptoms are right skewed,[34] a robust maximum likelihood estimator was used, which is robust to moderate deviations from normality. As oversampling was applied on the basis of mental health problems, the data were weighted back with a factor determined as the number of children in the population in each stratum divided by the number of participants in each stratum to arrive at correct population estimates. To examine gender differences in the estimates, a Wald test was employed to compare the fit of 2 models, one in which the path at hand was fixed as identical for the 2 genders and the other in which the path was freely estimated.[26]

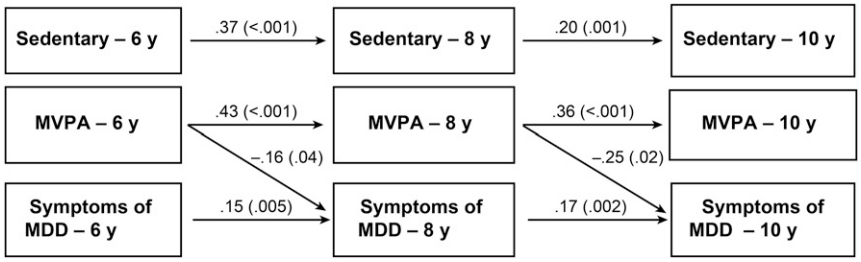

FIGURE 2
Autoregressive cross-lagged relations between MVPA, sedentary behavior, and major depressive symptoms. MVPA and sedentary activity were represented in hours per day intervals. Correlations among the variables within each time point and the nonsignificant paths are not shown to simplify the model illustration, as are the autoregressive paths from 6 to 10 years.

TABLE 1 Descriptive Statistics

Descriptives of Study Variables (Possible Range)	N	M	SD
1. Number of MDD symptoms 6 y (0 to 9)	793	0.52	0.73
2. Number of MDD symptoms 8 y (0 to 9)	697	0.46	0.79
3. Number of MDD symptoms 10 y (0 to 9)	629	0.52	0.90
4. MVPA 6 y (hours per day)	697	1.19	0.40
5. MVPA 8 y (hours per day)	607	1.18	0.43
6. MVPA 10 y (hours per day)	684	1.09	0.40
7. Sedentary 6 y (hours per day)	689	8.58	0.84
8. Sedentary 8 y (hours per day)	607	9.22	1.06
9. Sedentary 10 y (hours per day)	634	9.94	1.07
10. Anxiety 6 y (0 to 21)	793	0.87	1.52
11. Anxiety 8 y (0 to 21)	697	0.89	1.25
12. ADHD 6 y (0 to 18)	793	1.30	2.24
13. ADHD 8 y (0 to 18)	688	1.20	2.40
14. CD 6 y (0 to 9)[a]	793	0.22	0.50
15. CD 8 y (0 to 15)	697	0.30	0.60
16. ODD 6 y (0 to 8)	793	0.96	0,47
17. ODD 8 y (0 to 8)	697	1.08	1.39
18. BMI 6 y	658	15.60	1.51
19. BMI 8 y	675	16.62	1.97

[a] Six items in the CD scale were removed at age 6 because they were not considered age appropriate.

RESULTS

The descriptive statistics are shown in Table 1. The rate of DSM-IV defined MDD diagnosis, ranged from 0.3% (age 6) to 0.4% (age 8), underscoring the need, at this age, to analyze MDD continuously as symptom counts. Supplementary piecewise growth curve analyses revealed that MDD decreased from ages 6 to 8 years (M_{growth}= −0.13 [95% CI, −0.17 to −0.10]) but increased from ages 8 to 10 years (M_{growth}= 0.03 [95% CI, 0.00 to 0.06]). Minutes of MVPA per day did not change from ages 6 to 8 years (M_{growth}= −0.17 [95% CI, −1.35 to 1.01]) but decreased from ages 8 to 10 years (M_{growth}= −2.62 [95% CI, −3.75 to −1.49]). Finally, sedentary activity increased from ages 6 to 8 years (M_{growth}= 0.32 [95% CI, 0.27 to 0.37]) and increased further from ages 8 to 10 years (M_{growth}= 0.36 [95% CI, 0.30 to 0.42]). Regarding rank order stability, Table 2 shows that the symptoms for MDD and sedentary activity were modestly stable, whereas we found higher stability for MVPA.

Cross-Sectional Findings

The symptoms of MDD were negatively correlated with MVPA at ages 8 and 10, but were unrelated to sedentary activity (Table 2). As expected, the symptoms of MDD covaried with the symptoms of other disorders at all time points. The symptoms of these other disorders were generally unrelated to MVPA

TABLE 2 Bivariate Correlations Between Study Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. MDD 6 y	1	0.27***	0.19***	−0.01	0.02	−0.06	−0.04	0.00	0.06	0.48***	0.23***	0.35***	0.25***	0.17***	0.12**	0.44***	0.21***	0.06	0.05
2. MDD 8 y	—	1	0.25***	−0.08**	-0.10**	−0.03	0.02	−0.03	−0.00	0.19***	0.47***	0.20***	0.29***	0.10*	0.19***	0.21***	0.27***	0.03	0.05
3. MDD 10 y	—	—	1	−0.07	−0.16**	−0.17***	0.03	0.03	0.06	0.12*	0.21***	0.14***	0.19***	0.05	0.14*	0.19***	0.16*	0.05	0.03
4. MVPA 6 y	—	—	—	1	0.40***	0.37***	−0.40***	−0.10*	−0.16**	−0.06	−0.01	0.10**	0.07	0.04	0.08*	0.09*	0.07	−0.09*	−0.08
5. MVPA 8 y	—	—	—	—	1	0.47***	−0.18***	−0.42***	−0.17***	−0.03	−0.01	0.08	0.06	0.03	0.06	0.04	0.10*	−0.06	−0.10*
6. MVPA 10 y	—	—	—	—	—	1	−0.12**	−0.15***	−0.47***	−0.07	−0.06	−0.04	−0.01	0.04	0.06	0.06	0.04	−0.13**	−0.17***
7. Sedentary 6 y	—	—	—	—	—	—	1	0.30***	−0.22**	−0.06	−0.07	−0.10**	−0.09*	−0.04	−0.01	−0.11**	0.04	0.00	−0.03
8. Sedentary 8 y	—	—	—	—	—	—	—	1	0.28***	−0.00	−0.07	−0.07	−0.06	0.03	−0.04	−0.02	−0.05	0.05	−0.02
9. Sedentary 10 y	—	—	—	—	—	—	—	—	1	0.01	0.01	−0.07	−0.09	0.01	−0.06	−0.05	−0.04	−0.01	−0.03
10. Anxiety 6 y	—	—	—	—	—	—	—	—	—	1	0.32***	0.33***	0.28***	0.09*	0.08*	0.36***	0.17***	0.01	0.04
11. Anxiety 8 y	—	—	—	—	—	—	—	—	—	—	1	0.35***	0.47***	0.09*	0.22***	0.27***	0.35***	−0.03	−0.01
12. ADHD 6 y	—	—	—	—	—	—	—	—	—	—	—	1	0.58***	0.18***	0.27***	0.38***	0.30***	0.06	0.26
13. ADHD 8 y	—	—	—	—	—	—	—	—	—	—	—	—	1	0.12**	0.29***	0.30***	0.35***	−0.04	−0.04
14. CD 6 y	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.18***	0.34***	0.16***	0.03	0.07
15. CD 8 y	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.23***	0.33***	0.04	0.02
16. ODD 6 y	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.35***	−0.01	0.06
17. ODD 8 y	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.00	0.01
18. BMI 6 y	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.84***
19. BMI 8 y	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1

—, not applicable.
*** $P < .001$.
** $P < .01$.
* $P < .05$.

and sedentary activity, although we found higher MVPA among 6-year-old children who had more symptoms of anxiety disorders and less sedentary activity among those 6-year-old children who had elevated symptoms of ADHD.

Prospective Associations

The main results from the autoregressive cross-lagged model examining the bidirectional relationships between MVPA, sedentary activity, and major depression are shown in Fig 2. For complete model results, see Supplemental Table 4.

The model did fit the data well (χ^2 = 21.76, df = 24, P = .59, comparative fit index = 1.00, Tucker-Lewis index = 1.007, root mean square error of approximation = 0.000). At both 6 and 8 years, higher levels of MVPA predicted fewer symptoms of MDD 2 years later. The reduction was ~0.20 symptoms of depression per daily hour spent in MVPA. The effect of MVPA on depression from age 8 to 10 was seemingly stronger than the effect from age 6 to 8. Standardized coefficients revealed effect sizes of β −0.08 (at age 6 to 8) and β −0.11 at age 8 to 10), respectively. However, when comparing a model in which these 2 path coefficients were fixed as equal with a model in which they were freely estimated, no significant difference was found (Wald = 0.41, df = 1, P = .41). A similar procedure was used to test for the gender-specific effects of MVPA on later symptoms of MDD, and no such differences were found (6 to 8 years: Wald = 0.47, df = 1, P = .49; 8 to 10 years: Wald = 0.34, df = 1, P = .56). Because MDD symptoms are heavily right-skewed with many children evincing no symptoms and just a few evincing many symptoms, there is a possibility that the obtained effect of MVPA on MDD was due to skewness and count nature of MDD symptoms. We therefore run the path analysis treating MDD symptoms as

having a negative binominal (count) distribution. MVPA still predicted reduced numbers of MDD symptoms from age 6 to 8 (B = −0.58 [95% CI: −0.95 to −0.21], *P* = .001) and from age 8 to 10 (B = −0.58 [95% CI: −1.03 to −0.13], *P* = .002). Moreover, depression did not predict later MVPA, and no effects of sedentary activity on depression, or vice versa, were detected.

DISCUSSION

To aid the preventive and treatment efforts of depression among children, we examined the bidirectional relations between MVPA, sedentary activity, and MDD symptoms over 3 waves of data collection in a large community sample of children. Higher levels of MVPA at 6 and 8, respectively, predicted fewer MDD symptoms 2 years later. No effects of sedentary activity were found for MDD symptoms, and MDD symptoms did not predict later PA (or lack thereof).

MVPA Predicts Fewer Depressive Symptoms

The identified effects of PA on depression extend findings from observational studies of adolescents and adults[35] by documenting that this relationship is also present in middle childhood. We further add to existing knowledge by showing that predictive effects are present when we examine interview-based DSM-defined symptoms of MDD rather than questionnaires, and when applying objectively measured PA, and account for the potential effects of other psychiatric disorders and BMI. Although the effects of MVPA were small, they are similar to those obtained by psychosocial intervention programs in children[36] and adolescents.[37] Along with the fact that nearly all children can be targeted in efforts to increase MVPA, the gains at the population level might be substantial.

Although the current study did not address why PA may reduce future symptoms of MDD, 2 potential mechanisms related to PA's 2 not mutually exclusive components (the activity and the physical components), can be hypothesized. Treatment studies applying activity scheduling have indicated that increasing activity, not necessarily just PA, may reduce depression.[38] Several explanations for this MDD-reducing effect have been proposed: (1) Engaging in activities may distract from ruminating over negative events, and ruminations may worsen or prolong depression.[39,40] (2) A substantial part of MVPA in children consists of play or sports activities,[41] and playing or engaging in sports may bolster self-efficacy and self-esteem in children, which has been suggested to prevent depression.[42,43] (3) Finally, when children are physically active, they tend to be with other children.[41] Although peer-rejections and bullying also occur in sports,[44] physically active children may be more socially integrated in peer groups than less active children. Such peer acceptance, which is likely to result in social support, is a potential buffer against depression.[45]

Regarding the physical component of PA, several physiologic and biochemical mechanisms have been proposed, such as the demonstration of PA leading to higher availability of neurotransmitters, which is assumed to have antidepressant effects.[46,47] In addition, regular PA has a favorable impact on neuronal functions and structure along with increased cognitive functions.[48]

No Prospective Relation Between Sedentary Activity and Symptoms of MDD

Our study is the first to objectively examine sedentary activity and later depression in early and middle childhood, and we find no prospective relation between sedentary behavior and symptoms of MDD. Although there are some important exceptions,[49] research on adolescents and adults has suggested that sedentary behavior may increase depression.[20] It is thus likely that the effect of sedentariness on depression is age-dependent. However, because psychomotor retardation and loss of energy are among the symptoms of MDD, it is essential to adjust for previous MDD when examining sedentary activity's contribution to MDD, which has been investigated only to a limited extent.[21,49] Further, in many of these prospective studies, self-reports of inactivity and depression have been applied that may inflate their relationship on a prospective basis, due to the common methods that are employed. Moreover, it is essential to adjust for lack of MVPA when estimating the effects of sedentariness because MVPA and sedentary activity are negatively correlated. In sum, the lack of comparable studies underscores the need to replicate our findings.

Levels of PA and Symptoms of MDD During Middle Childhood

The level of symptoms of MDD was stable from 6 to 10 years. MDD symptoms evidenced some homotypical continuity, which extends the findings from short-term longitudinal studies on MDD in young children.[9,50] The observed reduction in MVPA and increase in sedentary behavior are consistent with findings from previous research.[19]

Limitations

Although individuals fulfilling the DSM cutoff of 5 or more MDD symptoms do not seem qualitatively different from those with just under cutoffs,[51] and even though the correlates and predictors of subclinical depression are similar to those of the disorder,[52] our findings do not necessarily generalize to the disorder itself. Thus, research with substantially larger samples is required to determine whether objectively measured MVPA would decrease the risk of MDD in community children. Nonetheless, because previous research has

shown that there is a continuity in depressive symptoms from childhood to adolescence and later adulthood,[53] that an elevated level of MDD symptoms increases the risk of later MDD,[54,55] and that subclinical depression may entail substantial impairment (also in the long run),[56] our findings suggest that increasing MVPA at the population level may lead to reduced symptoms of depression—and the impairment that accompanies these symptoms in some children. Second, data were MNAR, which may have led to biased results. However, the selectivity of this attrition was modest and we used all available data in a full information maximum likelihood procedure, which leads to less biased results than complete case analysis when the data are MNAR.[57] Nonetheless, we cannot exclude that such bias along with unmeasured confounders such as self-image enhancement[58] or increased social interactions[59] may explain at least some of the results. The prevalence of psychiatric disorders is generally low in Norway,[60] but whether the impact of MVPA on depressive symptoms also differ between countries should be examined in future studies.

CONCLUSIONS

MVPA predicts fewer future MDD symptoms in middle childhood, and such symptoms are moderately stable from the ages of 6 to 10 years. Sedentary activity in children does not alter the risk of future symptoms of depression, and depression does not influence the likelihood of MVPA or inactivity. Although the effect was small, our results indicate that increasing MVPA in children at the population level may prevent depression, at least at subclinical levels.

ABBREVIATIONS

ADHD: attention-deficit/hyperactivity disorder
CAPA: Child and Adolescent Psychiatric Assessment
CD: conduct disorder
CI: confidence interval
DSM-IV: *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*
MDD: major depressive disorder
MNAR: missing not at random
MVPA: moderate-to-vigorous physical activity
PA: physical activity
PAPA: Preschool Age Psychiatric Assessment
ODD: oppositional defiant disorder
SDQ: Strengths and Difficulties Questionnaire

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

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