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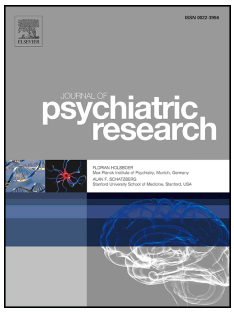

Longitudinal association between physical activity engagement during adolescence and mental health outcomes in young adults: A 21-year birth cohort study

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Running title: Physical Activity Engagement during Adolescence and Mental Health Outcomes in Young Adults

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Abstract

Objective

Previous studies provide mixed evidence that physical activity engagement (PAE) in adolescence is associated with later mental health outcomes. This study aimed to examine the association between PAE at age 14 and mental health outcomes at age 21 using a large birth cohort study.

Material and methods

Prospective data from the Mater-University of Queensland Study of Pregnancy, consisting of 3,493 young adults, were analyzed. PAE at age 14 was estimated using self-report, and participants were categorized into; (1) frequent, (2) infrequent, or (3) no PAE group. Mental health outcomes at age 21 consisted of; (1) common mental disorders, (2) psychosis-related outcomes, and, (3) emotional and behavioral problems. The association between PAE in adolescence and later mental health outcomes in young adulthood was examined using logistic regression, adjusted for age, sex, body mass index, and adolescent psychopathology.

Results

No PAE at age 14 was associated with the increased likelihood of lifetime diagnosis of any affective disorder, elevated delusional ideation, and endorsement of visual perceptual disturbance at age 21. Conversely, infrequent PAE at age 14 was associated with the decreased likelihood of subsequent lifetime diagnosis of any substance use disorder.

Conclusion

Our findings suggest that lack of PAE in adolescence influences some, but not all, later mental health outcomes. Interventions to increase PAE in adolescence may represent an opportunity to prevent future mental health problems.

Key words

Physical activity; common mental disorders; psychotic disorders; longitudinal study; epidemiology.

Introduction

Many mental disorders have their age of onset early in life (Kessler et al., 2007a; Kessler et al., 2007b). People living with mental disorders are significantly less physically active compared to the general population (Schuch, F. et al., 2016; Stubbs et al., 2016) and consequently, at an increased risk of physical comorbidity (Galletly et al., 2012; Scott et al., 2016) and associated premature mortality (Hjorthoj et al., 2017; Lawrence et al., 2013; Walker et al., 2015). Combined with the accumulating evidence base indicating that physical activity is beneficial for both mental and physical health of people with mental disorders (Firth et al., 2015; Rosenbaum et al., 2016; Schuch, F.B. et al., 2016; Stubbs et al., 2017), the exploration of potential protective effects of physical activity against risk of developing mental disorders is of interest.

Prospective studies examining the association between physical activity engagement (PAE) during adolescence and later mental health outcomes report inconsistent results. In studies examining depressive and anxiety symptoms, some found no longitudinal association between baseline PAE and subsequent mental health status (Birkeland et al., 2009; Brunet et al., 2013; Gunnell et al., 2016; Rothon et al., 2010; Toseeb et al., 2014), while others found an inverse association between PAE and anxiety/ depressive symptoms (Ashdown-Franks et al., 2017; Jewett et al., 2014). Some studies found that the association was significant in either females only (Hoegh Poulsen et al., 2016; Jerstad et al., 2010) or in males only (Flotnes et al., 2011; Sagatun et al., 2007). In terms of substance use, a review of longitudinal studies demonstrated that sports engagement in adolescence was associated with increased future alcohol use but reduced future illicit substance use (Kwan et al., 2014). In addition, Strohle and colleagues (Strohle et al., 2007) examined PAE in young people aged 14-24 at baseline and subsequent incidence of multiple types of mental disorder (affective, anxiety, and substance use disorders) diagnoses within the same cohort four years later. They found that compared to those who had infrequent PAE at the onset of the study, participants who were in

frequent PAE had reduced incidence of any anxiety disorder, but there was no association with incident mood or substance use disorders. Furthermore, three Scandinavian studies have found that low PAE in childhood and adolescence was associated with higher likelihood of developing psychotic disorders later in life (Koivukangas et al., 2010; Okkenhaug et al., 2016; Sormunen et al., 2017).

There are several factors that may explain these inconsistent findings. First, mental health outcome measures varied among these studies. Most studies relied on self-reported questionnaires (Ashdown-Franks et al., 2017; Birkeland et al., 2009; Brunet et al., 2013; Gunnell et al., 2016; Hoegh Poulsen et al., 2016; Jewett et al., 2014; Rothon et al., 2010) with only a few (Jerstad et al., 2010; Strohle et al., 2007; Toseeb et al., 2014) utilizing structured interviews to assess for diagnoses of mental disorders of the participants. Likewise, there is a lack of consensus around physical activity measurements. Even though all but one study (Toseeb et al., 2014) described above have used self-reported questionnaires to estimate the PAE, some only assessed physical activity outside of school (Jerstad et al., 2010) or focused on sports engagement only (Ashdown-Franks et al., 2017; Jewett et al., 2014). Further, there were differences in both the age of the participants at baseline (ranging from nine (Sormunen et al., 2017) to 24 (Strohle et al., 2007)) and the duration of follow up (ranging from two years (Rothon et al., 2010) to ten years (Birkeland et al., 2009; Brunet et al., 2013)), as well as participant numbers (ranging from 496 participants (Jerstad et al., 2010) to 6,987 participants (Koivukangas et al., 2010)). Moreover, all the studies above were conducted in either Europe or North America. Finally, to our knowledge, only one study - the aforementioned study by Strohle and colleagues (Strohle et al., 2007) - examined multiple mental health outcomes within the same cohort.

Using data from a large Australian birth cohort, the current study addressed these limitations by having both self-report questionnaires and structured interviews to measure outcomes that included both symptoms and diagnoses of mental disorders. This allowed the current study to investigate the effect of PAE on emotional and behavioral problems, common mental disorders (CMD), and psychosis-related outcomes within the same cohort over seven years. Furthermore, the physical activity question used in the study was able to capture both exercise and sports engagement at and outside of school. The aim of the current study was to examine the prospective relationship between PAE during adolescence and multiple mental health outcomes in young adulthood. Given the sex difference evident in the current literature, the cohort was further analyzed stratified by sex.

Material and methods

Participants

The Mater-University of Queensland Study of Pregnancy is a prospective longitudinal cohort study of mothers and their offspring who received antenatal care at a major public hospital in Queensland, Australia, between 1981 and 1983. Data were collected on 7,223 singleton live-birth offspring and their mothers. The cohort members and their mothers were followed up at six months, five years, 14 years, and 21 years. For this analysis, 3,493 young adults who completed the PA question at the 14 year follow-up and the Young Adult Self-Report (YASR) questionnaires at the 21 year follow-up were included (Figure 1). Full details of the Mater-University Study of Pregnancy study design, sampling strategy, attrition, and follow-up sample characteristics are available elsewhere (Najman et al., 2015; Najman et al., 2005). Written informed consent was obtained from the mother at all data collection phases and from the young adult at the 21 year follow-up. Ethical approval of the study was obtained from the University of Queensland Ethics Committee.

(Insert Figure 1 here)

Measurement of Physical Activity Engagement (PAE)

At the 14 year old follow-up, participants were asked: "How often did you exercise or play sports in the last week?" They were asked to choose a response from the following; "Not at all", "1 day", "2 or 3 days", "4 or 5 days", or "6 or 7 days". The responses were then categorized; "frequent" (those who responded "4 or 5 days", or "6 or 7 days"), "infrequent" (those who responded "1 day" or "2 or 3 days"), or "no" (those who responded "Not at all") PAE group.

Measurement of Mental Health Related Outcomes

A range of mental health related outcomes were measured at the 21 year follow-up, including measures of CMD, psychosis-related outcomes, and YASR scores. In the current study, 2,575 cohort members were administered the lifetime version of the Composite International Diagnostic Interview (CIDI) computerised version(World Health Organization (WHO), 1992). While not all cohort members received the CIDI, this was due to insufficient funding rather than any systematic bias (Najman et al., 2015). For CMD outcome, 'caseness' was defined as having a lifetime ever Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) diagnosis of affective disorder (major depression or dysthymia), anxiety disorder (panic disorder, agoraphobia, social phobia, generalized anxiety disorder, specific phobia, or post-traumatic stress disorder), or substance use disorder (alcohol, opioid, cannabis, sedative, cocaine, amphetamine, hallucinogen, inhalant, phencyclidine, and other substance abuse or dependence). These three diagnostic categories were further combined to create "common mental disorder" diagnostic category (i.e. those who meet the criteria for a lifetime diagnosis of affective disorder, anxiety disorder or substance use disorder versus those who did not meet any of above diagnoses).

Likewise, for psychosis-related outcomes, 'caseness' was defined for psychotic disorder as those meeting the DSM –IV criteria for any of the following diagnoses; schizophrenia, schizophreniform disorder, schizoaffective disorder, delusional disorder, manic disorder, and brief psychotic disorder. Delusional ideation was measured with the 21-item version of the Peters Delusional Inventory (PDI), an instrument used to measure delusional-like experiences in clinical and community populations (Peters et al., 2004; Peters et al., 1999). Participants were dichotomized into those in the highest decile ("High") and the rest ("Normal or mild") for the total PDI score. In addition, two specific YASR items designed to assess the presence of auditory and visual perceptual disturbances were examined. These items were: "I hear sound or voices that other people think are not there" ("Auditory perceptual disturbances" hereafter), and "I see things that other people think are not there" ("Visual perceptual disturbances" hereafter). The responses were recorded on three Likert scales: (i) not true, (ii) somewhat or sometimes true, and (iii) very true or very often true. The latter two were combined into one category, and responses were dichotomized as "No" (those who responded "not true"), and "Yes" (those who responded "somewhat or sometime true", or "very true or very often true").

Finally, the Youth Self Report (YSR) (Achenbach, 1991) was used at the 14 year follow-up to measure adolescent psychopathology. The YSR is a self-report questionnaire about emotions and behavior in the previous six months. The total YSR score was dichotomized into either "high" psychopathology group (those in the highest decile) or "low-normal" psychopathology group (the remaining 90% of the sample). Similarly, the YASR (Achenbach, 1997) was used to identify those who were experiencing elevated emotional and behavioral difficulties at the 21 year follow-up. The YASR is a 115 item self-report questionnaire assessing a broad range of emotional and behavioral problems in the previous six months. The problem items are scored 0 if the behavior is "not true", 1 if the

behavior is “sometimes or somewhat true” and 2 if the behavior is “very true or often true”. The YSR and the YASR consist of eight subscales. The internalizing problems score is the sum of three subscales: withdrawn, somatic complaints, and anxiety/depressed symptoms. The externalizing problem score is the sum of two subscales: delinquent and aggressive behaviour. Internalizing and externalizing scores and the other three subscales (social problems, thought problems, and attention problems) are summed to produce the total score. Participants were dichotomized into those in the highest decile (“High psychopathology”) and the rest (“Low-Normal psychopathology”) for each assessment.

Statistical Analyses

Descriptive statistics were used to summarize the demographic characteristics of the cohort and the main variables of interest. For the main analysis, logistic regression was used to examine the association between PAE at age 14 and mental health outcomes at age 21. As previous studies have shown that age at interview (the data collection occurred over 3 years, and the ages of cohort members at the 21 year follow-up ranged from 18 to 23 years), sex, and body mass index (BMI) are associated with both PAE and mental health wellbeing (Bauman et al., 2012; Cureau et al., 2017; Kessler et al., 2007b; Scott et al., 2008), the analyses were adjusted for these variables. Further, the analyses were also adjusted for the YSR score at the 14 year follow-up to control for psychopathology at baseline. In addition, given the sex differences reported in the existing literature, the study cohort was stratified by sex and the main analyses were repeated for males and females separately. Those in the frequent PAE group was used as the reference group. Odds ratios (OR) with 95% confidence intervals (CI) were used to estimate the likelihood of participants being in the psychopathology group (e.g. having a lifetime diagnosis of a CMD or psychotic disorder, being in the “high psychopathology” for the total score or subscales of the YASR, having high levels of delusional ideation, or endorsing perceptual disturbance items) compared to those in the non-

psychopathology group for each mental health outcome. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

Table 1 summaries the frequencies and proportion of demographic and clinical variables. In total, 3,493 subjects were included in this study. 1641 (47.0%) were male with mean (standard deviation) ages of 13.9 (0.3) at the 14 year follow-up and 20.6 (0.9) at the 21 year follow-up. At the 14 year follow-up, 49.9% (n = 1,742) of participants had frequent PAE and 46.3% (1,616) of participants were in the infrequent PAE group, while 3.9% (n = 135) of participants had engaged in no physical activity at all.

(Insert Table 1 here)

Table 2 presents the longitudinal relationship between PAE at age 14 and different CMD diagnoses at age 21. Compared to those in the frequent PAE group, individuals in the no PAE group had significantly increased odds of developing any affective disorder at age 21 (OR = 1.79, 95% CI: 1.05 – 3.06). Conversely, compared to those in the frequent PAE group, individuals in the infrequent PAE group had significantly reduced odds of developing any substance use disorder at age 21 (OR = 0.75, 95% CI: 0.62 – 0.91). No significant association was found between PAE at age 14 and having any anxiety disorder diagnosis or having any CMD diagnosis at age 21. In sub-analyses stratified by sex, males, but not females, with no PAE had a significantly increased risk of developing any anxiety disorder at age 21 compared to those with frequent PAE. Further, females, but not males, with infrequent PAE had a significantly reduced odds of developing ay substance use disorder at age 21.

(Insert Table 2 here)

Table 3 illustrates the longitudinal relationship between PAE at age 14 and psychosis-related outcomes at age 21. Compared to those in the frequent PAE group, individuals in the no PAE group at age 14 were more likely to score high in the PDI total score (OR = 2.52, 95% CI: 1.47 – 4.30) and to endorse the visual perceptual disturbance question (OR 2.36, 95% CI: 1.30 – 4.27) at age 21. No statistically significant association was found between PAE at age 14 and having the diagnosis of any psychotic disorder or endorsing the auditory perceptual disturbance question at age 21.

(Insert Table 3 here)

Finally, table 4 summaries the longitudinal association between PAE at age 14 and the YASR scores at age 21. There was no statistically significant association between PAE at age 14 and any of the YASR scores examined at age 21.

(Insert Table 4 here)

Discussion

In the longitudinal analysis consisting of 3,493 young people, the current study found that having no PAE at age 14 was associated with the increased likelihood of the following mental health outcomes at age 21; (i) lifetime diagnosis of any affective disorder, (ii) elevated delusional ideation, and (iii) endorsement of visual perceptual disturbance. No other inverse associations between PAE at age 14

and increased likelihood of having adverse mental health outcomes at age 21 were found in the main analysis. The current study also found that compared to individuals with frequent PAE, those in the infrequent PAE group, but not those in the no PAE group, at age 14 were significantly *less* likely to develop lifetime diagnosis of any substance use disorder at age 21. Additionally, when stratified by sex, having no PAE at age 14 was associated with the increased likelihood of having any anxiety disorder diagnosis in males but not in females at age 21.

The current study found an inverse relationship between PAE at age 14 and subsequent affective disorders diagnosis at age 21. This is consistent with a systematic review that demonstrated baseline physical activity status was negatively associated with a risk of subsequent depression (Mammen and Faulkner, 2013). There are a range of possible explanations for this inverse association. From a biological perspective, PAE reduces activity in oxidative and inflammatory pathways (Moylan et al., 2013), which have been associated with depression in adolescents (Mills et al., 2013). PAE during adolescence also represents an opportunity for increased social interaction and development of social skills (Sagatun et al., 2007). Furthermore, physical activity is a constructive strategy for coping with stress and is also associated with improved self-concept (Babic et al., 2014) and self-efficacy (Bauman et al., 2012) in youth, thereby conferring resilience in those with higher levels of PAE. Therefore adolescents who do not engage in physical activity during this developmental phase may be at an elevated risk of future affective disorders. Conversely, it was found that individuals with reduced PAE demonstrated a *reduced* likelihood of developing any substance use disorder. This finding was more prominent in females. Sports engagement in adolescence is associated with increased subsequent alcohol use (Kwan et al., 2014). Further, a recent large United States study (n = 8,179) consisting of young people aged between 9 and 18 found that being a female engaged in team sports was associated with increases in alcohol use over time (Lisha et al., 2014). Combined with the current findings, PAE, specifically sports engagement, in

adolescence may be a risk factor for subsequent substance use disorder, particularly in females. Given the well-established other health benefits associated with PA in adolescence (Ekelund et al., 2012; Janssen and Leblanc, 2010), it is important young people continue to be encouraged to participate in physical activity. It is also important that the culture of alcohol and other substance use in sports is reviewed so as to discourage and reduce this risk.

Unlike previous studies (Koivukangas et al., 2010; Okkenhaug et al., 2016; Sormunen et al., 2017), no association was found between PAE in adolescence and subsequent diagnoses of psychotic disorders. This may be due to the follow-up point being relatively young at age 21, thus not capturing those who may yet develop psychotic disorders (McGrath et al., 2016a). Interestingly, there were significant inverse associations between having no PAE at age 14 and more general measures of psychotic experiences at age 21 such as the high PDI score and the endorsement for visual perceptual disturbance. Given that psychotic experiences are associated with a wide range of poor mental health outcomes (McGrath et al., 2016b), combined with the particularly adverse consequences of reduced physical activity status in people with psychotic disorders (Suetani et al., 2016), further research exploration of this association is warranted. Finally, after controlling for adolescent psychopathology as measured by the YSR, no association was found between PAE in adolescence and the subsequent YASR scores.

The findings from the current study suggest that protective benefits of PAE during adolescence for mental health outcomes in young adulthood *per se* are likely to be small in size. It is, however, important to acknowledge the concept of the prevention paradox; "*a measure that brings large benefits to the community offers little to each participating individual*" (Rose, 1981). Therefore, especially in view other potential benefits of PAE in adolescence such as physical health (Ekelund et

al., 2012; Janssen and Leblanc, 2010) and social connectedness (Eime et al., 2013), public health programs aimed at increasing adolescent PAE remain important in achieving subsequent general wellbeing in young adults at the population level.

A major strength of the current study was that the study design allowed for an examination of a longitudinal relationship between PAE and a wide range of mental health outcomes over a long period of time. The current study was also able to utilize both self-reported measures as well as structured diagnostic interviews, thus incorporating both symptoms and categorical diagnoses of mental health outcomes. Furthermore, the current study was able to control for adolescent psychopathology at baseline, and conduct comprehensive sub-analyses for each sex. However, several limitations are notable and the interpretation of our findings requires caution. First, the current study relied on a self-report questionnaire to estimate PAE. The questionnaire only assessed the number of days on which physical activity was performed and did not reflect the amount of physical activity performed. Even though almost all other previous studies in the field have utilized similar self-reports, it is possible that PAE in the current study has been overestimated (Lee et al., 2011), and more precise measures of PAE would have allowed for more accurate exploration of the relationship. Second, like other longitudinal studies of antecedents of psychopathology (Welham et al., 2009), the generalizability of the findings may be affected by differential attrition. While this was primarily due to lack of resources to track all original cohort members rather than refusal to participate, participants lost to follow-up differed on a range of variables such as birth weight and various maternal variables at first clinic visit related to age, education, marital status, mental health, and smoking. In any event, extensive modelling of the impact of biased loss to follow-up has consistently suggested that findings are only minimally affected (Najman et al., 2015; Najman et al., 2005). Furthermore, the current study was unable to determine the age of onset or exact duration for mental disorders and related outcomes. While adjustment was made for the adolescent

psychopathology using the YSR, it was not possible to determine the presence or absence of mental disorders at baseline as a diagnostic instrument was not administered at the 14 year follow-up. Finally, the current study was conducted in Australia, thus the findings may not be globally generalizable.

In conclusion, our findings suggest that lack of PAE in adolescence influences some, but not all, mental health outcomes at age 21. Even though it is important that the risks of future mental disorders in those adolescents who are physically inactive are not overstated, interventions to improve PAE in adolescence may represent an opportunity to prevent a possible life-time trajectory of poor mental and physical health.

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Contributions

SS, JJM and JGS planned the study. JGS, SS and AM planned the statistical analysis which was conducted by SS. SS and JGS wrote the initial drafts of the manuscript. All authors were involved in later revisions and all authors approved the final manuscript.

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Table 1. Frequencies and proportions of demographic and clinical variables[1]

Age (years)	Mean (Standard deviation)
At age 14 follow-up	13.9 (0.3)
At age 21 follow-up	20.6 (0.9)
Sex	N (%)
Male	1641 (47.0)
Female	1852 (53.0)
Physical activity engagement (PAE) at age 14	N (%)
Frequent PAE (4 or more days per week)	1742 (49.9)
Infrequent PAE (1 to 3 days per week)	1616 (46.3)
No PAE (0 day per week)	135 (3.9)
Any Affective Disorder at Age 21	N (%)
No lifetime diagnosis	1904 (80.2)
Lifetime diagnosis	471 (19.8)
Any Anxiety Disorder at Age 21	N (%)
No lifetime diagnosis	1790 (75.2)
Lifetime diagnosis	592 (24.9)
Any Substance Disorder at Age 21	N (%)
No lifetime diagnosis	1491 (62.9)
Lifetime diagnosis	878 (37.1)
Any Common Mental Disorder at Age 21	N (%)
No lifetime diagnosis	1059 (44.6)
Lifetime diagnosis	1317 (55.4)
Any Psychotic Disorder at Age 21	N (%)
No lifetime diagnosis	2307 (97.0)
Lifetime diagnosis	72 (3.0)

Peters Delusional Inventory scores at age 21	N (%)
Normal or mild	3147 (90.9)
High	316 (9.1)
Auditory Perceptual Disturbance at age 21	N (%)
No	3243 (93.0)
Yes	243 (7.0)
Visual Perceptual Disturbance at age 21	N (%)
No	3240 (93.1)
Yes	242 (7.0)
Young Adult Self Report at age 21 Internalising symptoms	N (%)
Low-Normal Psychopathology	3156 (90.4)
High Psychopathology (upper decile)	337 (9.7)
Young Adult Self Report at age 21 Externalising symptoms	N (%)
Low-Normal Psychopathology	3178 (91.0)
High Psychopathology (upper decile)	315 (9.0)
Young Adult Self Report at age 21 Total Problems	N (%)
Low-Normal Psychopathology	3155 (90.3)
High Psychopathology	338 (9.7)

[1]Totals may vary due to missing variables. Only a subsample (n = 2,575) of the participants completed the CIDI.

Table 2. Longitudinal relationship between physical activity engagement at age 14 and Different Common Mental Disorders diagnoses at age 21

Physical activity engagement (PAE) at age 14	No Lifetime Diagnosis	Lifetime Diagnosis Odds ratio (95% CI)[a]	Males Odds ratio (95% CI)	Females Odds ratio (95% CI)
	Any Affective Disorder[1]			
	N = 1904	N = 471	N = 974	N = 1041
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	1.05 (0.83 – 1.32)	1.46 (0.99 – 2.16)	0.88 (0.66 – 1.17)
No PAE	*Reference*	**1.79 (1.05 – 3.06)**	2.17 (0.98 – 4.82)	1.69 (0.81 – 3.53)
	Any Anxiety Disorder[2]			
	N = 1790	N = 592	N = 976	N = 1044
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	1.03 (0.83 – 1.29)	1.10 (0.75 – 1.61)	1.00 (0.77 – 1.31)
No PAE	*Reference*	1.16 (0.67 – 1.99)	**2.24 (1.10 – 4.57)**	0.56 (0.24 – 1.29)
	Any Substance Use Disorder[3]			
	N = 1491	N = 878	N = 970	N = 1042
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	**0.75 (0.62 – 0.91)**	0.77 (0.59 – 1.01)	**0.71 (0.54 – 0.95)**
No PAE	*Reference*	0.92 (0.56 – 1.51)	1.16 (0.61 – 2.21)	0.69 (0.30 – 1.58)
	Common mental disorder[4]			
	N = 1059	N = 1317	N = 975	N = 1042
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	0.88 (0.73 – 1.06)	0.83 (0.63 – 1.09)	0.93 (0.72 – 1.20)
No PAE	*Reference*	1.17 (0.72 – 1.90)	1.41 (0.72 – 2.77)	0.97 (0.48 – 2.00)

[a]Odds likelihood of having the lifetime diagnosis compared to the frequent PAE group, adjusted for age, sex, body mass index, and adolescent psychopathology at age 14. Totals may vary due to missing data.

[1]Lifetime diagnosis of major depression, or dysthymia, [2]Lifetime diagnosis of panic disorder, agoraphobia, social phobia, generalised anxiety disorder, specific phobias or post-traumatic stress disorder, [3]Lifetime diagnosis of alcohol, opioid, cannabis, sedative, cocaine, amphetamine, hallucinogen, inhalant, phencyclidine and other substance abuse or dependence.

Table 3. Longitudinal relationship between physical activity engagement at age 14 and Psychosis-related outcomes at age 21

Physical activity engagement (PAE) at age 14		Odds ratio (95% CI)[a]	Males Odds ratio (95% CI)	Females Odds ratio (95% CI)
	Any Psychotic Disorder[1]			
	No Lifetime Diagnosis	Lifetime Diagnosis		
	N = 2302	N = 72	N = 973	N = 1042
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	0.73 (0.43 – 1.25)	0.63 (0.26 – 1.54)	0.83 (0.42 – 1.64)
No PAE	*Reference*	0.30 (0.04 – 2.28)	0.60 (0.08 – 4.74)	No participant in this group
	Peters Delusional Inventory			
	Normal or Mild	High		
	N = 3147	N = 316	N = 1272	N = 1408
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	1.01 (0.76 – 1.36)	1.00 (0.65 – 1.55)	1.02 (0.68 – 1.54)
No PAE	*Reference*	**2.52 (1.47 – 4.30)**	**2.68 (1.30 – 5.55)**	**2.30 (1.03 – 5.13)**
	Auditory Perceptual Disturbance			
	No	Yes		
	N = 3243	N = 243	N = 1283	N = 1415
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	0.94 (0.68 – 1.29)	0.96 (0.60 – 1.53)	0.92 (0.60 – 1.42)
No PAE	*Reference*	1.34 (0.68 – 2.64)	1.45 (0.57 – 3.66)	1.29 (0.48 – 3.50)
	Visual Perceptual Disturbance			
	No	Yes		
	N = 3240	N = 242	N = 1281	N = 1413
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	1.05 (0.76 – 1.46)	0.94 (0.59 – 1.52)	1.22 (0.76 – 1.94)
No PAE	*Reference*	**2.36 (1.30 – 4.27)**	**2.72 (1.24 – 6.00)**	2.46 (0.99 – 6.11)

[a]Odds likelihood of having the lifetime diagnosis compared to the frequent PAE group, adjusted for age, sex, body mass index, and adolescent psychopathology at age 14. Totals may vary due to missing data.

[1]Lifetime diagnosis of schizophrenia, schizophreniform disorder, schizoaffective disorder, delusional disorder, manic disorder, and brief psychotic disorder.

Table 4. Longitudinal relationship between physical activity engagement at age 14 and Young Adult Self Report scores at age 21

Physical activity engagement (PAE) at age 14		Odds ratio (95% CI)[a]	Males Odds ratio (95% CI)	Females Odds ratio (95% CI)
	Internalising symptoms			
	Low-Normal Psychopathology N = 3156	High Psychopathology N = 337	N = 1288	N = 1417
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	1.13 (0.86 – 1.49)	0.95 (0.62 – 1.48)	1.27 (0.89 – 1.83)
No PAE	*Reference*	1.28 (0.68 – 2.40)	0.96 (0.36 – 2.60)	1.65 (0.72 – 3.76)
	Externalising symptoms			
	Low-Normal Psychopathology N = 3178	High Psychopathology N = 315	N = 1288	N = 1417
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	0.75 (0.56 – 1.01)	0.79 (0.54 – 1.16)	0.72 (0.46 – 1.12)
No PAE	*Reference*	1.51 (0.85 – 2.68)	1.60 (0.78 – 3.28)	1.38 (0.53 – 3.59)
	Total Score			
	Low-Normal Psychopathology N = 3155	High Psychopathology N = 338	N = 1288	N = 1417
Frequent PAE	*Reference*	*Reference*	*Reference*	*Reference*
Infrequent PAE	*Reference*	1.00 (0.75 – 1.32)	1.05 (0.69 – 1.59)	0.98 (0.66 – 1.45)
No PAE	*Reference*	1.33 (0.72 – 2.45)	1.00 (0.40 – 2.52)	1.88 (0.82 – 4.31)

[a]Odds likelihood of having the lifetime diagnosis compared to the frequent PAE group, adjusted for age, sex, body mass index, and adolescent psychopathology at age 14. Totals may vary due to missing data.

Figure 1. Flowchart of study cohort.