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ORIGINAL ARTICLE

# The association between adolescent psychopathology and subsequent physical activity in young adulthood: a 21-year birth cohort study

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**Background.** The beneficial effects of physical activity (PA) for both physical and mental wellbeing are well established. Given that adolescence presents a critical developmental period during which life-long patterns of PA become established, the exploration of the longitudinal impact of adolescent psychopathology on adult PA status is of interest.

**Methods.** We analysed prospective data from 3663 young adults who participated in the Mater-University of Queensland Study of Pregnancy. Psychopathology was measured using the Youth Self-Report (YSR) at age 14. Participants' engagement in three types of PA (vigorous exercise, moderate exercise and walking) at age 21 were dichotomised into either 'none' or 'any'. For our main analysis, we examined the association between the YSR score and subsequent PA engagement using logistic regression. We also conducted sensitivity analyses of longitudinal associations between the YSR internalising and externalising symptoms score at age 14 and PA engagement at age 21.

**Results.** We found no longitudinal association between the total YSR score at age 14 and PA engagement at age 21. In addition, there was no longitudinal association between the YSR internalising or externalising symptoms and PA engagement.

**Conclusion.** Our findings suggest that there is no longitudinal association between adolescent psychopathology and PA in young adulthood.

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**Key words**: Longitudinal study, physical activity, psychopathology.

## Background

There is convincing evidence that adults with established psychopathology are at an increased risk of general medical comorbidity (Galletly *et al.* 2012; Scott *et al.* 2016), in particular cardiometabolic conditions such as metabolic syndrome and type II diabetes mellitus (Vancampfort *et al.* 2014; Vancampfort *et al.* 2016), and associated premature mortality (Walker *et al.* 2015; Hjorthoj *et al.* 2017). There is also overwhelming evidence demonstrating the beneficial effect of physical activity (PA) in reducing physical morbidities and mortality (Lee *et al.* 2012), even in children and adolescents (Ekelund *et al.* 2012). Moreover, people with mental disorders are significantly less likely to be physically active compared with the general population (Schuch *et al.* 2016*a*; Stubbs *et al.* 2016) suggesting that low PA may be a particularly important modifiable risk factor for the excess morbidity and mortality associated with mental ill health. Many mental disorders have their age of onset early in life with approximately half emerging during adolescence (Kessler *et al.* 2007*a*, *b*). Given that adolescence may present a critical developmental period during which life-long patterns of PA become established (Due *et al.* 2011), the exploration of the longitudinal impact of psychopathology during adolescence on adult PA status is of interest.

A number of studies (Sagatun *et al.* 2007; Toseeb *et al.* 2014; Hoegh Poulsen *et al.* 2016; Sormunen *et al.* 2017) have examined the effect of PA during adolescence on

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the subsequent psychopathology in adulthood with equivocal results, some demonstrating positive associations and others finding no effect. However, we are only aware of three studies that have explored the reciprocal relationship. First, a Canadian study ($n = 860$) found those with higher depressive symptom scores at age 12 were less likely to engage in moderate-intensity PA or team sports at age 21, but there was no significant association for vigorous-intensity PA (Sabiston *et al.* 2013). Second, a Norwegian study ($n = 924$) found that the baseline depressive symptoms at age 13 was *not* associated with moderate-to-vigorous PA engagement at age 23 (Birkeland *et al.* 2009). Finally, a British birth cohort study ($n = 12\,776$) found that higher externalising symptoms at age 16 predicted lower PA status at age 42, but not at age 33 or 50. Nor was there any association between internalising symptoms at age 16 and mid-life PA status (Pinto Pereira *et al.* 2014). In sum, few prospective studies have examined the relationship between psychopathology during adolescence and PA engagement in young adulthood and the findings of these studies are inconsistent. Using data from a large Australian birth cohort study, we aimed to further examine the longitudinal association between adolescent psychopathology and subsequent PA in young adulthood.

## Methods

### *Participants*

The Mater-University of Queensland Study of Pregnancy (MUSP) 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 7223 singleton live-birth offspring and their mothers. The cohort members and their mothers were followed up at 6 months, 5, 14 and 21 years. For the current study, we included 3663 young adults who completed all the PA-related questions at age 21. Full details of the MUSP study design, sampling strategy, attrition and follow-up sample characteristics are available elsewhere (Najman *et al.* 2005; Najman *et al.* 2015). 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.

### *Measurement of psychopathology*

The Youth Self-Report (YSR) (Achenbach, 1991) was used at the 14-year follow-up to measure adolescent psychopathology. The YSR is a self-completed questionnaire assessing emotional and behavioural problems in the previous 6 months that has been designed for individuals aged 11–18 years. It consists of 112 items assessing eight subscales. The internalising problems score is the sum of three subscales: withdrawn, somatic complaints and anxiety/depressed symptoms. The externalising problem score is the sum of two subscales: delinquent and aggressive behaviour. Internalising and externalising scores and the other three subscales (social problems, thought problems and attention problems) are summed to produce the total score. Achenbach identified scores in the top 10% as reflective of clinical psychopathology (Achenbach, 1991). In keeping with previous analyses (Hayatbakhsh *et al.* 2008), we dichotomised the total YSR score ($\alpha = 0.94$), the internalising problems score ($\alpha = 0.87$) and the externalising problems score ($\alpha = 0.87$) into either 'high' psychopathology group (those in the highest decile) or 'low-normal' psychopathology group (the remaining 90% of the sample). Likewise, the Young Adult Self-Report (YASR) (Achenbach, 1997) was used to estimate the psychopathology in young adulthood at the 21-year follow-up. Similar to the YSR, the YASR is a self-completed questionnaire about behaviour in the previous 6 months that consists of 115 items. Again, we dichotomised the total YASR score ($\alpha = 0.96$), the internalising problems score ($\alpha = 0.92$) and the externalising problems ($\alpha = 0.87$) into either 'high' psychopathology group (those in the top decile) *v.* the 'low-normal' psychopathology group (the remaining 90% of the sample).

### *Measurement of PA*

We used a general measure of frequencies and types of PA to estimate the PA engagement at age 21. Participants were asked a range of questions related to their PA at the 21-year follow-up. Vigorous exercise was defined as 'exercise which makes you breathe harder or puff and pant'. Moderate exercise was defined as exercise 'which did not make you breathe harder or puff and pant'. Frequency of each type of PA used in the current study was assessed with the following questions: 'How many sessions of vigorous exercise did you have over the 2-week period?' (vigorous exercise), 'How many sessions of less vigorous exercise did you have over the 2-week period?' (moderate exercise) and 'How many times did you walk for recreation or exercise?' (walking). While we were unable to assess the amount or duration of PA accurately, there is now an accumulating body of evidence to indicate that any amount of PA is significantly more beneficial than no PA (Arem *et al.* 2015; O'Donovan *et al.* 2017). In view of this, we dichotomised each PA subtype into either 'none' (those who

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engaged in no session in the last 2 weeks), or 'any' (those who engaged in more than one session in the last 2 weeks). In addition, the PA engagement at the 14-year-old follow-up was estimated using the response to the question: 'How often did you exercise or play sports in the last week?' The participants 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'.

### *Measurement of confounding factors*

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 PA status (De Moor *et al.* 2006; Ten Have *et al.* 2011; Cureau *et al.* 2017) and adolescent psychopathology (Mamun *et al.* 2009; Scott *et al.* 2009), we adjusted for these variables in our analyses. The participant's BMI at the 14-year follow-up was calculated using the average of two measures of the child's weight, lightly clothed with a scale accurate to 0.2 kg. We used the BMI *z*-score at age 14 as a continuous variable in the analyses. We also adjusted for: (1) the exercise or sports engagement at age 14 and (2) the psychopathology in young adulthood as measured by YASR scores.

### *Statistical analyses*

Descriptive statistics were used to summarise the characteristics of PA engagement in this cohort. We used logistic regression to examine the association between the YSR total score at age 14 and PA engagement at age 21. For model 1, we adjusted the analysis for age, sex and BMI at the 14-year follow-up. For model 2, we further adjusted the analysis for age, sex and BMI, as well as exercise and sports engagement at age 14, and the YASR total score at age 21. Odds ratios (OR) with 95% confidence intervals (CI) were used to estimate the likelihood of participants being in "any" PA for each of the three groups with the 'none' PA group as the reference category. For planned sensitivity analyses, we examined the YSR internalising score and the YSR externalising score separately as predictor variables. Similar to our main analysis, we adjusted for age, sex and BMI at age 14 in model 1 and further adjusted for exercise and sports engagement at age 14, and the YASR internalising or externalising score at age 21 in model 2.

In addition, we conducted two further post hoc analyses. First, we conducted cross-sectional analyses of the relationship between psychopathology and PA status at age 14 and at age 21 adjusted for age, sex and BMI at each follow-up point. For the cross-sectional analysis at age 14, we dichotomised the responses to the PA question into either: 'infrequent' (those who responded 'not at all', '1 day', or '2 or 3 days'), or 'frequent' (those who responded '4 or 5 days', or '6 or 7 days'). Unlike the 21-year follow-up, a very small number of participants at 14 years (3.9%) endorsed 'not at all' to the PA question, thereby preventing use of this group by itself due to lack of power for the analyses. The use of these two groups to estimate PA at age 14 was further justified by (i) PA question at age 14 did not explore different types of PA, and (ii) most school aged children in Australia engage in at least 2–3 days of exercise within the school curriculum. Second, we repeated the main analyses using multivariable linear regression by treating both predictor variable (psychopathology at age 14) and response variable (PA at age 21) as continuous variables, with confounding factors (age, sex, BMI, exercise and sports engagement at age 14, as well as YASR scores) incorporated in the model.

We examined the influence of attrition using three methods. First, we used SAS PROC MI and MIANALYZE to explore the data under assumption that they were missing randomly. For the multiple imputation, we included the main variables of interest (YSR score at age 14 and PA engagement at age 21) and potential confounders that were examined specifically in this study (age at assessment, sex, BMI, exercise and sports engagement at age 14, and YASR scores at age 21), as well as auxiliary variables known to be associated with attrition in this cohort (birth weight and various maternal variables at first clinic visit related to age, education, marital status, mental health and smoking). We used logistic regression based on 30 imputed data sets. Second, to examine whether adolescent psychopathology was differentially associated with attrition, we examined whether being lost to follow-up at age 21 was associated with YSR total score at age 14. Finally, based on the assumption that the data were missing in a non-random fashion, we undertook post hoc modelling exercises to explore the robustness of the main findings. Given our finding that there was no association between psychopathology at age 14 and PA status at age 21, if we assume cohort members who were lost to follow-up had high scores on the YSR, then our analyses would have underestimated the effect size of the relationship. Thus, in the modelled scenario, we constructed a model where we assumed that those who were lost to follow-up at age 21 would have had the same level of psychopathology as they did at age 14 (either high or normal-low) but still had no PA engagement had they remained in the cohort. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, North Carolina, USA).

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**Table 1.** *Longitudinal association between total YSR score at age 14 and physical activity engagement at Age 21*

| | Physical activity session at age 21<br>*N* (%) | Physical activity session at age 21<br>*N* (%)<br>Model 1 – OR[a] (95% CI)[b]<br>Model 2 – OR[c] (95% CI) |
|---|---|---|
| | No engagement in vigorous exercise ($n = 1613$) | Any vigorous exercise ($n = 1835$) |
| YSR total score at age 14 | 1437 (89.1) | 1692 (92.2) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR total score at age 14 | 176 (10.9) | 143 (7.8) |
| High | Reference | 0.78 (0.60–1.02)[a] |
| | Reference | 0.98 (0.74–1.30)[c] |
| | No engagement in moderate exercise ($n = 1327$) | Any moderate exercise ($n = 2121$) |
| YSR total score at age 14 | 1194 (90.0) | 1935 (91.2) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR total score at age 14 | 133 (10.0) | 186 (8.8) |
| High | Reference | 0.86 (0.65–1.12)[a] |
| | Reference | 0.98 (0.74–1.30)[c] |
| | No engagement in walking ($n = 1499$) | Any walking ($n = 1949$) |
| YSR total score at age 14 | 1355 (90.4) | 1774 (91.0) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR total score at age 14 | 144 (9.6) | 175 (9.0) |
| High | Reference | 0.77 (0.59–1.01)[a] |
| | Reference | 0.76 (0.57–1.01)[c] |

[a] Adjusted for age, sex and BMI at age 14.
[b] OR used to estimate the odds likelihood of participants being in the 'any' group.
[c] Adjusted for age, sex and BMI at age 14, as well as exercise and sports engagement at age 14 and YASR total score at age 21.

## Results

In total, 3633 subjects were included in this study of whom 1724 (47.1%) were male. The mean age for the participants at the 21-year follow-up was 20.6 years (S.D. = 0.9). Over half (52.9%) of the cohort members had engaged in at least one session of vigorous exercise in the past 2 weeks. Likewise, 60.9% and 56.9% of the cohort members had engaged in at least one session of moderate exercise and walking in the past 2 weeks, respectively.

Table 1 describes the longitudinal association between the total YSR score at age 14 and PA engagement at age 21. We found no statistically significant association between the total YSR score and the three types of PA engagement.

In the planned sensitivity analyses, we examined the longitudinal associations between the internalising YSR score at age 14 and externalising YSR score at age 14 with PA engagement at age 21. High YSR internalising score was associated with reduced vigorous exercise in model 1 (OR 0.69, 95% CI 0.53–0.90), but this association became statistically non-significant after further adjustment in model 2. Thus, we found no statistically significant association between internalising YSR score nor externalising YSR score and the PA engagement in model 2 (Tables 2 and 3).

Tables 4 and 5 present the cross-sectional associations between psychopathology and PA engagement at age 21 and at age 14. After adjusting for age, sex and BMI, individuals with clinical levels of psychopathology at 21 years were significantly less likely to engage in vigorous exercise (OR 0.63, 95% CI 0.48–0.82) or moderate exercise (OR 0.76, 95% CI 0.58–1.00). There was no association between the total YASR score and engagement in walking. The cross-sectional analysis at age 14 showed a significant inverse association between the total YAR score and frequent PA engagement (OR 0.55, 95% CI 0.42–0.73).

In the post hoc analyses, we repeated the main and sensitivity analyses by treating predictor and response variables as continuous. We found the results of the multivariable linear regression were largely consistent with the logistic regression. We found only one statistically significant inverse association (YSR

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**Table 2.** *Longitudinal association between YSR internalising score at age 14 and physical activity engagement at age 21*

| | Physical activity session at age 21<br>None<br>*N* (%) | Physical activity session at age 21<br>Any<br>*N* (%)<br>Model 1 – OR[a] (95% CI)[b]<br>Model 2 – OR[c] (95% CI) |
|---|---|---|
| | No engagement in vigorous exercise ($n = 1613$) | Any vigorous exercise ($n = 1835$) |
| YSR internalising score at age 14 | 1420 (88.0) | 1695 (92.4) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR internalising score at age 14 | 193 (12.0) | 140 (7.6) |
| High | Reference | 0.69 (0.53–0.90)[a] |
| | Reference | 0.83 (0.63–1.08)[c] |
| | No engagement in moderate exercise ($n = 1327$) | Any moderate exercise ($n = 2121$) |
| YSR internalising score at Age 14 | 1192 (89.8) | 1923 (90.7) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR internalising score at age 14 | 135 (10.2) | 198 (9.3) |
| High | Reference | 0.89 (0.68–1.16)[a] |
| | Reference | 1.00 (0.76–1.31)[c] |
| | No engagement in walking ($n = 1499$) | Any walking ($n = 1949$) |
| YSR internalising score at age 14 | 1371 (91.5) | 1744 (89.5) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR internalising score at age 14 | 128 (8.5) | 205 (10.5) |
| High | Reference | 1.01 (0.77–1.33)[a] |
| | Reference | 1.05 (0.80–1.39)[c] |

[a] Adjusted for age, sex and BMI at age 14.

[b] OR used to estimate the odds likelihood of participants being in the 'any' group.

[c] Adjusted for age, sex and BMI at age 14, as well as exercise and sports engagement at age 14 and YASR internalising score at age 21.

externalising score at age 14 and moderate exercise at age 21, $\beta = -0.024$, $p = 0.014$). None of the other eight longitudinal relationships examined between psychopathology and PA engagement showed any significant association (online Supplementary Table S1).

With respect to differential attrition, there was no statistically significant association between the total YSR score at age 14 and PA engagement at age 21 based on 30 imputed data sets, consistent with our main analysis (online Supplementary Table S2). There was no significant association between the YSR score at age 14 and being lost to follow-up at age 21 (online Supplementary Table S3). Furthermore, under the modelled scenario (under assumptions that those who were lost to follow-up would have had the same level of psychopathology but no PA engagement at age 21), we found an inverse association between the YSR score and walking (modelled OR 0.75, 95% CI 0.58–0.99), but there were no associations evident in vigorous exercise or moderate exercise (online Supplementary Table S4).

## Discussion

Using data from a large cohort study, we found no association between psychopathology during adolescence and subsequent PA engagement in young adulthood. Our findings remained largely consistent in the multivariable linear regression treating each variable as continuous. These results were broadly consistent with existing literature. For example, in the Canadian study (Sabiston *et al.* 2013), the authors found no association between psychopathology during adolescence and vigorous-intensity PA in adulthood. They also found no association between the psychopathology and meeting the 150 min per week PA guidelines. In the Norwegian study (Birkeland *et al.* 2009), there was no association between depressed mood at aged 13 and the PA status at age 23. However, it should be noted that Birkeland *et al.* assessed PA using only one question ('Outside school hours, how often do you do sports or exercise until you are out of breath or sweat?'). While the authors argue that this kind of

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**Table 3.** *Longitudinal association between YSR externalising score at age 14 and physical activity engagement at age 21*

| | Physical activity session at age 21<br>*N* (%) | Physical activity session at age 21<br>*N* (%)<br>Model 1 – OR[a] (95% CI)[b]<br>Model 2 – OR[c] (95% CI) |
|---|---|---|
| | No engagement in vigorous exercise (*n* = 1613) | Any vigorous exercise (*n* = 1835) |
| YSR externalising score at age 14 | 1448 (90.4) | 1683 (91.7) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR externalising score at age 14 | 155 (9.6) | 152 (8.3) |
| High | Reference | 0.80 (0.61–1.05)[a] |
| | Reference | 0.85 (0.64–1.12)[c] |
| | No engagement in moderate exercise (*n* = 1327) | Any moderate exercise (*n* = 2121) |
| YSR externalising score at age 14 | 1191 (89.8) | 1950 (91.9) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR externalising score at age 14 | 136 (10.3) | 171 (8.1) |
| High | Reference | 0.80 (0.61–1.05)[a] |
| | Reference | 0.86 (0.64–1.14)[c] |
| | No engagement in walking (*n* = 1499) | Any walking (*n* = 1949) |
| YSR externalising score at age 14 | 1353 (90.3) | 1788 (91.7) |
| Low-normal | Reference | Reference |
| | Reference | Reference |
| YSR externalising score at age 14 | 146 (9.7) | 161 (8.3) |
| High | Reference | 0.90 (0.68–1.18)[a] |
| | Reference | 0.92 (0.69–1.22)[c] |

[a] Adjusted for age, sex and BMI at age 14.
[b] OR used to estimate the odds likelihood of participants being in the 'any' group.
[c] Adjusted for age, sex and BMI at age 14, as well as exercise and sports engagement at age 14 and YASR externalising score at age 21.

**Table 4.** *Cross-sectional association between the total YASR score and physical activity engagement at age 21*

| | Physical activity session at age 21<br>*N* (%) | Physical activity session at age 21<br>*N* (%)<br>Adjusted[a] OR[b] (95% CI) |
|---|---|---|
| | No engagement in vigorous exercise (*n* = 1706) | Any vigorous exercise (*n* = 1917) |
| YASR total score at age 21 | 1504 (88.2) | 1764 (92.0) |
| Low-normal | Reference | Reference |
| YASR total score at age 21 | 202 (11.8) | 153 (8.0) |
| High | Reference | 0.63 (0.48–0.82) |
| | No engagement in less vigorous exercise (*n* = 1411) | Any less vigorous exercise (*n* = 2212) |
| YASR total score at age 21 | 1254 (88.9) | 2014 (91.1) |
| Low-normal | Reference | Reference |
| YASR total score at age 21 | 157 (11.1) | 198 (9.0) |
| High | Reference | 0.76 (0.58–1.00) |
| | No engagement in walking (*n* = 1559) | Any walking (*n* = 2064) |
| YASR total score at age 21 | 1415 (90.8) | 1853 (89.8) |
| Low-normal | Reference | Reference |
| YASR total score at age 21 | 144 (9.2) | 211 (10.2) |
| High | Reference | 1.17 (0.90–1.55) |

[a] Adjusted for age, sex and BMI at age 21.
[b] OR used to estimate the odds likelihood of participants being in the 'any' group.

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**Table 5.** *Cross-sectional association between the total YSR score and physical activity engagement at age 14*

| | Physical activity session at age 14<br>*N* (%) | Physical activity session at age 14<br>*N* (%)<br>Adjusted[a] OR[b] (95% CI) |
|---|---|---|
| | Infrequent engagement ($n = 1710$) | Frequent engagement ($n = 1720$) |
| YSR total score at age 14 | 1500 (87.7) | 1612 (93.7) |
| Low-normal | Reference | Reference |
| YSR total score at age 14 | 210 (12.3) | 108 (6.3) |
| High | Reference | 0.55 (0.42–0.73) |

[a] Adjusted for age, sex and BMI at age 14.
[b] OR used to estimate the odds likelihood of participants being in the 'frequent' group.

'sweat question' has been shown to correlate well with physical fitness (Birkeland *et al.* 2009), this measure may have underestimated the amount of PA done by participants. Finally, in the 1958 British Birth Cohort study, Pinto Pereira *et al.* found a small effect size for the association between externalising behaviour at age 16 and the likelihood of being physically inactive at age 42 (OR 1.06, 95% CI 1.01–1.11) (Pinto Pereira *et al.* 2014). Consistent with our findings, however, the authors found no association between internalising behaviour at age 16 and subsequent PA status at ages 33, 42 or 50. They also did not find any association between externalising behaviour at age 16 and PA status at ages 33 and 50. Of note, the study utilised two measures of adolescent psychopathology (externalising behaviour and internalising behaviour derived of items from the Rutter Behaviour Scale) based only on teachers' report. The use of self-reports to estimate psychopathology measures in the current study has likely enabled assessment of participants' distress in a much wider range of situations outside of classroom.

There is a convincing body of evidence indicating that PA benefits people with mental disorders (Firth *et al.* 2015; Firth *et al.* 2016; Rosenbaum *et al.* 2016). Our findings are encouraging as they suggest that even those with an elevated psychopathology in adolescence are not disadvantaged from engaging in PA in young adulthood. Moreover, in our cross-sectional analyses, we found a statistically significant association between high psychopathology and reduced PA engagement for vigorous exercise and for moderate exercise at age 21. We also found that an increased psychopathology was associated with reduced PA engagement at age 14. This is largely consistent with the existing body of evidence. For example, a meta-analysis by Schuch *et al.* (2016*a*) found that people with major depressive disorder were less likely to engage in moderate-to-vigorous PA compared with the control group. Likewise, a meta-analysis by Stubbs *et al.* (2016) found that people with schizophrenia were less likely to engage in moderate and vigorous PA compared with the control group, but there was no difference in the amount of walking between the two groups. The relationship is likely bidirectional whereby those with high levels of psychopathology are less inclined to participate in PA, and concurrently, those not engaging in PA are more likely to experience mental health problems. We intend to examine this hypothesis of the bidirectional relationship between PA and psychopathology using the same cohort in a future study. In addition, there may be an indirect relationship whereby reduced PA engagement is a result of reduced social connectedness experienced by many young people with high psychopathology. Using data from large Australian population studies, we have previously demonstrated that social connectedness is an important factor associated with PA status in the general population and people with common mental disorders (Suetani *et al.* 2016*a*), as well as for those with severe mental disorders (Suetani *et al.* 2016*b*). It is plausible that young people with mental health disorders are less likely to engage in team sports and other organised activities which promote PA because of reduced social connectedness (Sabiston *et al.* 2013). Thus, we argue that the care of young people with mental health problems should also include assessments of PA and encouragement to engage in PA-related activities (Rosenbaum *et al.* 2016; Stubbs *et al.* 2017; Yung & Firth, 2017).

In terms of possible future directions in this field, there is a growing interest in the potential role of cardiorespiratory fitness (CRF) as an independent modifiable risk factor for physical wellbeing of people with mental disorders (Vancampfort *et al.* 2017). CRF is the ability of the circulatory and respiratory systems to supply oxygen to working muscles during sustained PA. People with mental disorders have significantly lower CRF compared with the general population, but it is markedly improved with PA interventions (Vancampfort *et al.* 2017). Moreover, in a recent

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meta-analysis consisting of three longitudinal studies by Schuch *et al.*, the authors demonstrated that low CRF was associated with a higher risk of subsequent depression (Schuch *et al.* 2016*b*). While we were unable to assess CRF in our current study, future population studies may yield further insights from incorporating CRF-related variables [e.g. $VO_2$max testing, the 6 min walk test (Vancampfort *et al.* 2011)] in addition to measures of PA status.

A strength of the current study was the prospective study design involving a large sample, which allowed examination of the longitudinal relationship between psychopathology during adolescence and different types of PA engagement in young adulthood. However, several limitations are notable. First, the outcome variable used to estimate PA status is not a validated measure and relied on self-report, thus potentially underestimating PA status (Lee *et al.* 2011). The measure was also limited in enquiring specifically about exercise (i.e. PA that is planned and structured) for two out of three questions examined for the current study, thus not fully capturing other forms of PA such as occupational PA (Caspersen *et al.* 1985). Second, like other longitudinal studies of antecedents of psychopathology (Welham *et al.* 2009), the generalisability of our findings may be affected by differential attrition. The attrition for the current study since inception was 49.3%. As previously reported, while this was primarily due to lack of resources to track all original cohort members rather than refusal to participate, the loss to follow-up was more common in participants with low birth weight, and those who had mothers who were, at first clinic visit, less educated, in their teenage years, single, smokers and had poorer mental health (Najman *et al.* 2005). However, multiple imputation analysis controlling for these variables did not change the findings of our main analysis in the current study. Further, there was no association between adolescent psychopathology and being lost to follow-up at age 21, and the modelling exercise demonstrated that the null association between adolescent psychopathology and vigorous or moderate exercise in young adulthood remained robust. A final limitation was that as an Australian, the findings may not be globally generalisable.

In conclusion, these findings add to the existing literature in supporting that there is no convincing association between psychopathology in adolescence and engagement in PA in young adulthood. However, we found cross-sectional associations between poor mental health and lower likelihood of PA engagement at both ages 14 and 21. Therefore, young people with elevated psychopathology should be assessed for engagement in PA, and where reduced, prescription of exercise in addition to other evidence-based interventions may assist recovery and improve wellbeing.

## Supplementary material

The supplementary material for this article can be found at https://doi.org/10.1017/S0033291717001660.

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