Original article

Prospective associations of leisure-time physical activity with psychological distress and wellbeing: A 12-year cohort study

Running title: **Leisure-time physical activity and mental health**

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ABSTRACT

Objective: To investigate the associations of leisure-time physical activity with psychological distress and wellbeing, and potential mediators.

Methods: We used data from the 1970 British Cohort Study (N=5,197 - 2,688 men), including waves 34y (2004), 42y (2012), and 46y (2016) waves. Participants reported leisure-time physical activity frequency and intensity (exposure) at age 34 (baseline), cognition (vocabulary test), body mass index, disability, mobility and pain perception (potential mediators) at age 42, and psychological distress (Malaise inventory) and wellbeing (Warwick-Edinburgh scale) at age 46. Baseline confounders included sex, country, education, employment status, alcohol use, tobacco smoking, and psychological distress. Main analyses included logistic regression and mediation models.

Results: Higher leisure-time physical activity intensity at baseline was associated with lower psychological distress at 46y [β: -0.038 (95%CI: -0.069 to -0.007)], but not leisure-time physical activity frequency. Baseline leisure-time physical activity frequency and intensity were associated with higher psychological well-being at 46y [frequency: β: 0.089 (95%CI: 0.002 to 0.176); intensity: β: 0.262 (95%CI: 0.123 to 0.401); and total: β: 0.041 (95%CI: 0.013 to 0.069)]. Only body mass index at 42y partially mediated the association between leisure-time physical activity frequency (15.7%) and total leisure-time physical activity (6.2%) at 34y, with psychological wellbeing at 46y.

Conclusions: These findings highlight the role of leisure-time physical activity in psychological distress and wellbeing, with greater effect sizes associated with higher frequency and intensity of leisure-time physical activity. Future interventions should consider examining potential mediators of the association of leisure-time physical activity with psychological wellbeing, such as body mass index.

Keywords: exercise; mood; mental health, wellbeing, physical activity, sport

List of abbreviations

y = years.

LTPA = leisure-time physical activity.

BMI = body mass index.

BCS70 = 1970 British Cohort Study.

CI = confidence interval.

INTRODUCTION

Mental illness is a major contributor to the overall global burden of disease and one of the leading causes of disability worldwide (1). There is growing evidence that physical activity reduces the risk of mental illness such as depression and anxiety (2,3). Physical activity may also improve psychological wellbeing and reduce psychological distress (4–7).

Psychological wellbeing refers to a positive state where individuals realize their potential while maintaining interpersonal relationships, working productively, contributing to their community, and coping with psychological distress (8). Psychological distress is the presence of negative emotions that disrupt normal daily functioning (8,9). Higher psychological distress and lower wellbeing are independently associated with an increased risk for cardiovascular diseases and premature mortality (10–13). Furthermore, lower psychological wellbeing and increased psychological distress are associated with an elevated risk of mental disorders (14).

There is emerging evidence that physical activity is prospectively associated with reduced psychological distress (5–7) and increased psychological wellbeing (4). Much of these associations refer to leisure-time physical activity (LTPA), which includes discretionary activities that are not essential for daily living, such as recreational sports or exercises (15). However, there is insufficient research on the dose-response relationship of leisure-time physical activity with psychological distress and psychological wellbeing, including the optimal frequency, intensity, and duration. Several cross-sectional studies have found that just one session of LTPA per week is associated with lower psychological distress and increased psychological wellbeing (16,17). However, some cross-sectional studies have found that increased durations and intensities of physical activity are associated with greater reductions in psychological distress (16–18).

There is a lack of longitudinal studies exploring dose-response associations of LTPA with psychological distress and psychological wellbeing. Higher psychological distress and lower wellbeing may be associated with lower leisure-time physical activity (19), which cross-sectional studies cannot examine. Understanding prospective, dose-response associations of LTPA with psychological distress and psychological wellbeing is relevant to inform the development of effective public mental health interventions.

There is also a lack of research on potential mediators of the associations between LTPA with psychological distress and psychological wellbeing. There are indications that the body mass index (BMI) (20), physical disability, pain (21,22), and cognition (23) are potential mediators of the association between LTPA with psychological distress and psychological wellbeing. For example, lower LTPA levels are associated with increased BMI, disability, and poor cognition, which could negatively impact psychological distress and wellbeing (24–26). However, the existing evidence is mostly from cross-sectional studies that are unable to disentangle the temporal relationships between the exposures, mediators, and outcomes.

Therefore, we conducted a prospective study to investigate the association between LTPA and future psychological distress and wellbeing. A secondary aim was to examine whether cognition, BMI, disability, or pain mediate the associations between LTPA and psychological distress and wellbeing. We used data from the 1970 British Cohort Study to examine these associations across three time points. We hypothesized that i) LTPA is prospectively associated with psychological distress and wellbeing and ii) cognition, BMI, disability, mobility, and pain could mediate the association between LTPA with psychological distress and psychological wellbeing.

METHODS

Sample

We used data from the 1970 British Birth Cohort Study (BCS70), full details of which are available elsewhere (27). Briefly, BCS70 is a multidisciplinary, longitudinal study that included people from England, Scotland, Wales, and Northern Ireland born in a specific week of 1970 (27). The sample was followed-up in 1975 (5y), 1980 (10y), 1986 (16y), 1996 (26y), 2000 (30y), 2004 (34y), 2008 (38y), 2012 (42y) and 2016 (46y). We analyzed data from 2004 (34y), 2012 (42y), and 2016 (46y) waves in 2020. We used the 34y wave as our baseline and 46y as a 23-year follow-up. We also included data from 42y to assess potential mediators in associations between LTPA at 34y and psychological distress and psychological wellbeing at 46. All questionnaires data were collected through face-to-face interviews, including self-reported questions. All procedures utilized for this study complied with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975. Participants provided informed consent.

The initial study sample included 17,284 people (at 1970). However, 6,608 provided complete data in the 2004, 2012 and 2016 waves. Additionally, 1,411 participants presented missing data in at least one variable from the present study and were excluded from the sample. Therefore, the final sample was composed of 5,197 participants (2,688 women). We conducted an attrition analysis by comparing the characteristics of the sample with valid data at baseline to the samples with valid data at the 42y and the 46y waves.

Psychological distress and wellbeing (34y and 46y)

The co-primary outcomes were psychological distress and wellbeing. Psychological distress was evaluated at 34y (covariate) and 46y (outcome) using the Malaise Inventory, which asks questions regarding depressive moods, lack of energy, anxiety and stress. The 9-question version was applied (with scores ranging 0 to 9) (28). The Malaise inventory of 24 Items presented good reliability (Cronbach alpha = 0.80) in a previous study among the UK population (29) and the 9-item version has a high correlation with the 24-item questionnaire (30). For wellbeing, the Warwick-Edinburgh mental wellbeing scale was used at 46y. The Warwick-Edinburgh scale includes questions on positive affect, satisfying interpersonal relationships, and positive functioning, with total scores ranging between 14 and 70 (31). A validation study found evidence of good reliability for the Warwick-Edinburgh scale in the UK population, with a Cronbach alpha of 0.92 (31).

Leisure time physical activity (34y)

LTPA was assessed at 34y (2004). Participants were shown a list of LTPA that asked whether they: take part in competitive sport of any kind, go to "keep fit" or aerobics classes, go running or jogging, go swimming, go cycling, go for walks, take part in water sports, take part in outdoor sports, go dancing, take part in any other sport or LTPA which involves physical exercise. Participants were also asked whether they took part in these activities regularly (yes or no). The definition of regularly was at least once a month, for most of the year. Participants who answered "yes" were also asked how often they engaged in this type of activity, with responses on a 6-point scale (everyday, 4 to 5 days a week, 2 to 3 days a week, once a week, 2 to 3 times a month, or less often). Participants were also asked whether the activity made them sweaty or out of breath, with responses on a 4-point scale (most times, sometimes, rarely, or never).

We used the question about the frequency to create the indicator of LTPA frequency and the question about got out of breath or sweaty (indicating higher intensity) to create the indicator of LTPA intensity. We only considered as habitual physical activity practice those reporting a frequency of at least once a week. People reporting less than once per week were scored 0. Otherwise the mean frequency (7 for "everyday", 4.5 for "4 to 5 days a week", 2.5 for "2 to 3 days a week" and 1 for "once a week") was multiplied with the intensity ("most times" = 4, "sometimes" = 3, "rarely" = 2 and "never" = 1) to create a score of approximate energy expenditure (32).

Potential mediators (42y)

All potential mediators were assessed at 42y. Cognition (recall) was estimated using the vocabulary test (33). The test included 20 words where cohort members were asked to select which of the five words next to it had a similar meaning to the original word. We used total score on this test as a measure of cognition and our potential mediator. A second mediator was BMI, which was measured using self-reported weight and height (weight / height^2).

Mobility was a third potential mediator and assessed via the self report question: "During the past 4 weeks, how much difficulty did you have doing your usual work or other daily activities because of your physical health?". Participants responded on a 5-point scale (none at all, little bit, some, quite a lot, or could not do). Those who reported at least some difficulty were considered as having a physical limitation. For pain perception, participants were asked: "During the past 4 weeks, how much bodily pain have you had?". Participants responded on a 6-point scale (none, very mild, mild, moderate, severe, or very severe). We considered those who reported moderate to very severe as positive for pain perception. Disability was defined

196 according to the European Union of Statistics on Income and Living Conditions (34) definition
197 of a longstanding illness or condition that reduces the ability to carry out day to day activities.
198
199 *Covariates (34y)*
200 Sex, country of origin, education, employment status, alcohol use, tobacco smoking and values
201 of the Malaise Inventory during baseline (34y) were included as covariates. Educational status
202 (highest qualification achieved) was categorized into three groups: none (no formal education or
203 incomplete secondary education), at least high school and more than high school. Employment
204 status was assessed during adulthood (having a full-time job or not having a full-time job).
205 Tobacco smoking was assessed through a question regarding the smoking frequency where those
206 who reported smoking at least occasionally were considered as smokers. Alcohol use was
207 assessed through a question asking about alcohol consumption frequency where participants who
208 reported four or more days of alcohol consumption per week were considered as frequent
209 consumers.
210
211 *Statistical analysis*
212 Descriptive statistics are presented using means and standard deviations or frequencies. For
213 comparisons between included and non-included sample, we used the chi-squares and t-tests.
214 Linear regression models were created to investigate the association between total, frequency,
215 intensity LTPA at 34y with psychological distress and psychological wellbeing at 46y, adjusting
216 for sex, country, education, employment, alcohol use, tobacco smoking and baseline values of
217 Malaise Inventory and including each mediator in separate models. Linear regression models

were also created to analyze the association between LTPA (frequency, intensity and total) and mediators (cognition, BMI, disability, mobility and pain).

We conducted mediation models analysing the role of potential mediators (42y) in the association of LTPA (34y) with psychological distress and psychological wellbeing (46y). Considering the assumptions of mediation analysis, we included potential mediators that were predicted by LTPA in preliminary analyses, using the method proposed by Valeri and Vanderweele (35). For this, the total effect was decomposed into total effect (i.e. the effect of LTPA on psychological distress and psychological wellbeing), controlled direct effects (i.e. the direct effect of LTPA on psychological distress and psychological wellbeing that was not explained by the mediators), reference interaction (i.e. the effect of LTPA due to the interaction with the mediators), mediated interaction (i.e. the effect of LTPA due to both mediation and interaction with the mediators), and pure indirect effects (i.e. mediation effect). We used command "med4way" on Stata 15.1 to conduct these analyses (36).

RESULTS

The characteristics of the sample are presented in **Table 1**. A comparisons of baseline characteristics between included and non-included sample demonstrated a higher total LTPA, LTPA intensity, and education levels in the included sample (**Table 2**).

Table 3 shows the prospective associations of LTPA at 34y with psychological distress and wellbeing at 46y. Frequency and total LTPA were not associated with psychological distress. Higher LTPA intensity at 34y was associated with lower psychological distress [β: -0.038 (95%CI: -0.069 to -0.007)]. Higher LTPA frequency [β: 0.089 (95%CI: 0.002 to 0.176)],

intensity [β: 0.262 (95%CI: 0.123 to 0.401)] and total LTPA [β: 0.041 (95%CI: 0.013 to 0.069)] were positively associated with psychological well-being.

The associations between exposures (at 34y) and mediators (at 42y) are presented in **Table 4**. Intensity and total LTPA were positively associated with cognition, while frequency and LTPA were inversely associated with BMI. LTPA was not associated with disability, mobility and pain.

After preliminary analyses, cognition and BMI were included as mediators in the association between LTPA intensity and psychological distress and the associations of frequency, intensity and total LTPA with psychological wellbeing (**Table 5**). There was a direct effect of LTPA in the association between LTPA intensity at 34y and psychological distress at 46y. Only BMI at 42y partially mediated the association between frequency of LTPA (15.7%) and total LTPA (6.2%) at 34 with later psychological wellbeing, such that lower levels of LTPA were associated with higher BMI, which was associated with lower psychological wellbeing. In the other models, LTPA had a direct effect on psychological wellbeing.

DISCUSSION

To the best of our knowledge the current study is the first to investigate the prospective associations of different LTPA domains with psychological distress and psychological wellbeing, and to explore their potential mediators. Our main finding was that LTPA at 34y was associated with lower levels of psychological distress and higher levels of psychological wellbeing at 46y. LTPA frequency and total LTPA were positive associated with wellbeing but not psychological distress. BMI partially mediated the associations of higher LTPA frequency and total LTPA with wellbeing.

Our results align with previous studies that also found that self-reported physical activity is associated with lower psychological distress and higher psychological wellbeing (4–6). While previous studies focused on total physical activity volume, we examined different physical activity components, including frequency and intensity. Our findings suggested that higher total LTPA and LTPA frequency and intensity were associated with higher psychological wellbeing. However, only LTPA at higher intensity levels was associated with lower psychological distress. Our longitudinal findings build on the results of previous cross-sectional studies to suggest that any dose of physical activity could reduce psychological distress and improve wellbeing, but higher frequencies and intensities could have a larger effect (16–18). These findings align with previous work suggesting that moderate-to-vigorous intensity is protective against mental health symptoms (17,18,37).

Different mechanisms could underlie the association of physical activity and psychological distress and wellbeing, including biological changes (38). For example, physical activity is associated with reduced inflammation (39) and psychological distress is associated with a pro-inflammatory state (40). Previous research have found that moderate-intensity physical activity can reduce mental health symptoms through potentially reducing tumor necrosis factor alpha, a pro-inflammatory cytokine (41). Physical activity could also protect against psychological distress through reducing cortisol or improving hippocampal structure or functioning (42–46). LTPA could also enable social network and support, which are associated with reduced psychological distress and increased wellbeing (47–49).

Our results also suggest that BMI partially mediated the association between LTPA and psychological wellbeing, and cognition mediated the association between LTPA and psychological distress. LTPA was not prospectively associated with physical limitations,

including disability, mobility and pain. Physical limitations typically increase with age (50), suggesting that these associations could be more pronounced in an older sample of adults than we used in this study (51,52).

Higher BMI can affect psychological distress and psychological wellbeing through different mechanisms, including weight-related stigmatization or physical self-esteem (53–55). Higher BMI could also lead to higher inflammation, including through a poor quality diet (40,56,57). However, we found that the association of LTPA with psychological distress and psychological wellbeing was predominantly through a direct effect, suggesting that other factors than BMI may predominantly explain the associations.

We study included prospective data from a large national birth cohort with a 12-years follow-up. However, potential limitations include the use of self-report measure of LTPA, psychological distress, wellbeing and potential mediators, which are prone to recall and social desirability bias. The LTPA and mediator measures were also unvalidated. There was considerable attrition throughout the study, which may have induced a selection bias. We were unable to adjust for unmeasured confounding, such as social relationships quality, loneliness, the presence of mental disorders, or genetic mental health risks. We were also unable adjust the analyses for baseline psychological wellbeing due to unavailability of data.

In conclusion, LTPA was prospectively associated with lower psychological distress and higher psychological wellbeing and this association varied according to frequency and intensity. We found some evidence that BMI partially mediated the association of LTPA with psychological wellbeing. Our findings highlight the public health importance of the LTPA in reducing mental health disorders in the population. Future research should explore the

prospective role of different physical activity intensities in its association with psychological distress and wellbeing and potential mediators of this association.

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480 **Table 1.** Characteristics of the sample (n = 5,197).

Variable	N (%) or mean ± SD
34 years	
Sex (Women), %	2,688 (51.7%)
Country of residence, %	
England	4,516 (86.9%)
Scotland	415 (8.0%)
Wales	266 (5.1%)
LTPA frequency, days/week	2.5 ± 2.4
LTPA intensity, score	2.4 ± 1.5
Total LTPA, score	7.4 ± 7.6
Psychological distress, score	1.5 ± 1.8
Education, %	
None	1,096 (21.1%)
Up to high school	2,587 (49.8%)
More than high school	1,514 (29.1%)
Employment (yes), %	3,891 (74.9%)
Tobacco smoking, %	1,437 (27.7%)
Alcohol use, %	881 (17.0%)
42 years	
Cognition, score	13.1 ± 3.4
Body mass index, kg/m^2	26.7 ± 5.1
Disability, %	642 (12.4%)
Mobility problems, %	1,129 (21.7%)
Pain, %	846 (16.3%)
46 years	
Psychological distress, score	1.7 ± 2.0
Well-being, score	50.6 ± 8.3

481 Note. Values are described using absolute and relative frequencies or means with standard
482 deviation. LTPA, leisure-time physical activity.
483

Table 2. Characteristics of included vs. non-included sample

Variable	Included (n = 5,197)	Non-included (n = 4,468)	p
Sex (Women), %	51.7	52.7	0.316
Country of residence, %			<0.001
England	86.9	83.2	
Scotland	8.0	6.0	
Wales	5.1	10.8	
Education, %			<0.001
None	21.1	36.9	
Up to high school	49.8	42.6	
More than high school	29.1	20.5	
LTPA frequency, days/week	2.5 (2.4)	2.5 (2.5)	0.668
LTPA intensity, score	2.4 (1.5)	2.2 (1.6)	<0.001
Total LTPA, score	7.4 (7.6)	7.1 (7.7)	0.024

Note. Values are presented using relative frequencies or means (standard deviations).

Table 3. Regression models of the association between different leisure-time physical activity indicators at 34 years with psychological distress and psychological wellbeing at 46 years.

Model		Psychological distress β (95%CI)	Wellbeing β (95%CI)
LTPA Frequency			
Crude model	Physical activity	-0.010 (-0.033 to 0.013)	0.150 (0.056 to 0.244)*
Adjusted model	Physical activity	-0.004 (-0.011 to 0.002)	0.089 (0.002 to 0.176)*
LTPA Intensity			
Crude model	Physical activity	-0.123 (-0.159 to -0.087)*	0.500 (0.353 to 0.647)*
Adjusted model	Physical activity	-0.038 (-0.069 to -0.007)*	0.262 (0.123 to 0.401)*
Total LTPA			
Crude model	Physical activity	-0.012 (-0.020 to -0.005)*	0.070 (0.040 to 0.099)*
Adjusted model	Physical activity	-0.001 (-0.021 to 0.018)	0.041 (0.013 to 0.069)*

Note. Adjusted for sex, country, education, employment, tobacco smoking, alcohol use and values of malaise inventory at age 34. CI, confidence interval. LTPA, leisure-time physical activity. *p<0.05.

494 **Table 4**. Association between leisure-time physical activity indicators (at 34 years) and mediators (at 42 years).

LTPA indicators	Cognition β (95%CI)	Body Mass Index β (95%CI)	Disability β (95%CI)	Mobility β (95%CI)	Pain β (95%CI)
Frequency	0.004 (-0.031 to 0.039)	-0.124 (-0.181 to -0.067)*	0.018 (-0.016 to 0.053)	0.002 (-0.026 to 0.030)	0.027 (-0.004 to 0.057)
Intensity	0.117 (0.061 to 0.173)*	-0.047 (-0.139 to 0.044)	-0.047 (-0.103 to 0.009)	-0.033 (-0.077 to 0.012)	-0.004 (-0.046 to 0.055)
Total	0.016 (0.005 to 0.027)*	-0.024 (-0.042 to -0.006)*	0.002 (-0.009 to 0.013)	-0.003 (-0.012 to 0.006)	0.008 (-0.002 to 0.018)

495 Note. Adjusted for sex, country, education, employment, tobacco smoking, alcohol use and malaise inventory during baseline (34
496 years). LTPA, leisure-time physical activity. *$p<0.05$.
497
498

Table 5. Mediation models of the association of leisure-time physical activity (at 34 years) with psychological distress and psychological wellbeing at 46 years.

	Total effect β (95%CI)	Controlled direct effect β (95%CI)	Reference interaction β (95%CI)	Mediated interaction β (95%CI)	Pure indirect effect β (95%CI)
Psychological distress					
LTPA Intensity					
Cognition	-0.038 (-0.069 to -0.007)*	-0.038 (-0.069 to -0.007)*	0.000 (-0.001 to 0.001)	0.000 (-0.001 to 0.001)	0.000 (-0.002 to 0.002)
Body Mass Index	-0.039 (-0.070 to -0.008)*	-0.038 (-0.069 to -0.007)*	0.000 (0.000 to 0.001)	0.000 (-0.001 to 0.001)	-0.001 (-0.002 to 0.001)
Wellbeing					
LTPA Frequency					
Cognition	0.088 (0.001 to 0.175)*	0.087 (0.001 to 0.175)*	0.000 (-0.001 to 0.001)	0.000 (0.000 to 0.000)	0.000 (-0.001 to 0.001)
Body Mass Index	0.093 (0.006 to 0.180)*	0.078 (-0.009 to 0.165)	0.002 (-0.001 to 0.006)	-0.002 (-0.005 to 0.001)	0.015 (0.006 to 0.023)*
LTPA Intensity					
Cognition	0.262 (0.123 to 0.401)*	0.260 (0.120 to 0.399)*	0.000 (-0.004 to 0.005)	0.000 (-0.004 to 0.005)	0.002 (-0.007 to 0.011)
Body Mass Index	0.261 (0.122 to 0.401)*	0.256 (0.117 to 0.396)*	0.000 (-0.001 to 0.001)	0.000 (-0.001 to 0.001)	0.005 (-0.005 to 0.015)
Total LTPA					
Cognition	0.042 (0.014 to 0.069)*	0.041 (0.013 to 0.069)*	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (-0.001 to 0.001)
Body Mass Index	0.041 (0.014 to 0.069)*	0.039 (0.011 to 0.066)*	0.000 (-0.001 to 0.001)	0.000 (0.000 to 0.000)	0.003 (0.001 to 0.005)*

Note. Adjusted for sex, country, education, employment, tobacco smoking, alcohol use and baseline values of malaise inventory. Percentage of mediation of the BMI on total physical activity model with wellbeing: 6.2%. BMI on physical activity frequency model with wellbeing: 15.7%. LTPA, leisure-time physical activity. *p<0.05.