



Dose-response relationship between physical activity and mental health: the Scottish Health Survey

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ABSTRACT

Objectives: Regular physical activity is thought to be associated with better mental health, although there is a lack of consensus regarding the optimal amount and type of activity to achieve these benefits. The association between mental health and physical activity behaviours was examined among a representative sample of men and women from the Scottish Health Surveys.

Methods: Self-reported physical activity was measured and the General Health Questionnaire (GHQ-12) was administered in order to obtain information on current mental health. Participants were 19 842 men and women. Risk estimates per category of physical activity sessions per week were calculated using logistic regression models.

Results: Psychological distress (based on a score of 4 or more on the GHQ-12) was evident in 3200 participants. Any form of daily physical activity was associated with a lower risk of psychological distress after adjustment for age, gender, social economic group, marital status, body mass index, long-standing illness, smoking and survey year (OR 0.59, 95% CI 0.52 to 0.66, $p < 0.001$). A dose-response relationship was apparent, with moderate reductions in psychological distress with less frequent activity (OR 0.67, 95% CI 0.61 to 0.75). Different types of activities including domestic (housework and gardening), walking and sports were all independently associated with lower odds of psychological distress, although the strongest effects were observed for sports (OR 0.67, 95% CI 0.54 to 0.82).

Conclusion: Mental health benefits were observed at a minimal level of at least 20 min/week of any physical activity, although a dose-response pattern was demonstrated with greater risk reduction for activity at a higher volume and/or intensity.

Mental illness is a risk factor for mortality and morbidity and is becoming an increasing health concern.¹ Regular physical activity is thought to be associated with better mental health. Prospective cohort studies have generally showed inverse associations between physical activity and incident depression^{2–6} and an association between reduced activity and emerging depression,⁷ although others have produced conflicting findings.^{8–11} There is also some evidence from prospective cohorts demonstrating an association between physical activity and lower risk of dementia and cognitive decline.¹² The results from clinical trials that have examined the effect of exercise on mental health have been generally difficult to interpret because of a lack of good quality studies with adequate follow-up,¹⁵ although recent studies have begun to address these limitations by employing credible control

groups and considering issues such as the confounding effects of psychotherapy.^{14 15}

The reason for some of the conflicting findings is largely related to incomplete measurements that did not enquire about all physical activity types, variation in the methods used to assess mental health, insufficient sample sizes and lack of adjustment for possible confounding factors. As a result, the amount and type of activity that is required to achieve mental health benefits has not been clearly established and at present is insufficient to inform public health policy. There is a limited amount of experimental work that has specifically examined the dose-response relationship. Previous work in children and adolescents demonstrated no significant differences when comparing the effects of vigorous with lower intensity exercise interventions on mental health outcomes.¹⁶ In contrast, Dunn *et al*¹⁷ showed that adults assigned to a higher energy expenditure exercise treatment (17.5 kcal/kg/week) had greater reductions in depression than a lower dose of 7.0 kcal/kg/week, although there were no effects of exercise frequency at 12 weeks.

The aim of the present study was therefore to examine the association of different types and amounts of physical activity with current mental health using the 12-item General Health Questionnaire (GHQ-12). We used a large sample of men and women from the Scottish Health Surveys (SHS; 1995, 1998, 2003) in which detailed data of self-reported physical activity was available, together with extensive information on other important confounding factors such as disease history and health behaviours.

METHODS

Study design and participants

The SHS is a periodic survey (typically every 3–5 years) that draws a nationally representative sample of the general population living in households. The sample was drawn using multistage stratified probability sampling with postcode sectors selected at the first stage and household addresses selected at the second stage. Stratification was based on geographical areas and not on individual characteristics of the population. Different samples were drawn for each survey. The present analyses included data from 19 842 respondents (53.9% female) aged 16 and over (mean (SD) age 45.2 (15.5) years) measured in the 1995, 1998 or 2003 SHS.

Procedures

Data were collected in two household visits. During the first visit trained interviewers collected

Table 1 Characteristics of the cohort with reference to physical activity levels

Variable	Physical activity quartiles (no of sessions/week >20 min)			
	≤ 3.5	3.51–5.00	5.01–6.75	> 6.75
Age (years)	50.7 (14.9)	48.6 (14.7)	41.9 (14.2)	38.9 (13.5)*
Gender (% men)	47.4	43.3	42.9	49.5
Marital status (%)				
Married	59.5	57.8	57.6	51.4*
Single/never married	14.9	17.2	22.6	28.2*
Social economic group (%)				
Professional	24.2	27.0	36.4	36.5*
Manual	33.4	28.6	26.7	24.6*
Body mass index (kg/m ²)	27.0 (5.1)	26.6 (4.8)	26.2 (4.7)	25.8 (3.9)*
GHQ-12 score	1.9 (3.1)	1.5 (2.7)	1.3 (2.5)	1.2 (2.4)*
Current smokers (%)	38.8	35.6	26.5	25.2*
Long-standing illness (%)	52.4	42.4	34.4	30.5*
Diabetes	6.5	4.6	2.1	2.1*
Hypertension	33.4	29.5	17.4	17.6*
CVD	12.1	7.6	3.7	2.3*

CVD, cardiovascular disease.

Data shown as mean (SD) values or percentages.

* $p < 0.001$, difference between groups.

self-reported data and measured height and weight. In the second visit nurses enquired about medical history. Detailed information on the survey method can be found elsewhere.¹⁸

Measurements

Interviewers took the height and weight measurements and asked demographic (marital status, social class) and health-related questions (smoking, physical activity and mental health). Social-occupational class was defined using the Registrar General classification (I/II professional/intermediate, III skilled non-manual or manual, IV/V part skilled/unskilled). Current mental health was assessed from the GHQ-12, which is a measure of psychological distress devised for population studies. The questionnaire enquires about general level of happiness, experience of depressive and anxiety symptoms, and sleep disturbance over the last 4 weeks. Interpretation of the answers is based on a 4-point response scale scored using a bimodal method (symptom present: not at all = 0, same as usual = 0, more than usual = 1 and much more than usual = 1). The GHQ-12 is a highly validated instrument and has been strongly associated with various psychological disorders such as depression and anxiety.¹⁹ A score of ≥ 4 was used to define psychological distress according to studies validating the GHQ-12 against standardised psychiatric interviews.²⁰ Physical activity interviews enquired about participation in the 4 weeks prior to the interview (1998 and 2003) or during a typical week (1995). Frequency of participation (for at least 20 min per occasion) was assessed across three domains of activity: leisure time sports (eg, cycling, swimming, running, aerobics, dancing and ball sports such as football and tennis), walking for any purpose and domestic physical activity (eg, heavy housework, home improvement activities, manual and gardening work). Participants were also asked whether participation in sports made them feel out of breath or sweaty to assess intensity. The validity of the physical activity questions is supported by data on 174 British adults where the output of individually calibrated heart rate monitors (four times over a year for four consecutive days on each occasion) was compared against an early version of the above questions. The SHS questionnaire appeared to be a valid measure of energy expenditure for the total physical activity score for men ($p = 0.05$) and women ($p < 0.05$). A

significant correlation was also observed between self-reported activity from the questionnaire and aerobic fitness in men ($p = 0.001$) and women ($p < 0.05$).

Analysis of data

Physical activity frequency quartiles were derived for the number of sessions per week of total physical activity of any intensity lasting at least 20 min. Three frequency categories (< 1 /week, $1-3$ /week, ≥ 4 /week) were derived for the three separate activity domains (domestic physical activity, walking and sports). We calculated odds ratios (OR) and 95% confidence intervals (CI) for the risk of psychological distress per category of physical activity using multiple logistic regression. In multivariate models we mutually adjusted for activity types, age, gender, social-occupational class, marital status (single/never married, married, widowed, separated/divorced), body mass index category (underweight, normal weight, overweight, obese, morbidly obese), presence of long-standing illness (yes, no), smoking (never, previous, current) and survey year. χ^2 and one-way ANOVA tests were used to examine differences in demographic and health-related variables with respect to physical activity quartiles. All analyses were conducted using SPSS Version 14.

RESULTS

We identified 3200 participants with psychological distress from the GHQ-12. Table 1 shows the characteristics of the sample split into total physical activity quartiles. Approximately 32% of the sample performed none or one session of physical activity per week lasting at least 20 min after the exclusion of domestic activities. Participants in the higher activity quartiles were more likely to be younger, not married, come from a higher socioeconomic stratum, not smoke, have lower body mass index, lower GHQ-12 scores, and less likely to have a long-standing illness.

Table 2 presents logistic regression models for physical activity frequency and risk of psychological distress, based on a GHQ-12 score of ≥ 4 . It can be seen that all types of activity were independently associated with lower odds of psychological distress, although a dose-response relationship was only demonstrated with sports and overall activity. Domestic

Table 2 Logistic regression models for physical activity and risk of psychological distress (GHQ-12 score ≥ 4)

	Cases/total N 3200/19 842	Age adjusted OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)
Domestic activity sessions				
<1/week	2293/13232	1.00	1.00	1.00
1–3/week	660/4902	0.74 (0.67 to 0.81)	0.74 (0.67 to 0.81)	0.76 (0.69 to 0.84)
≥ 4 /week	247/1708	0.80 (0.70 to 0.92)	0.80 (0.69 to 0.92)	0.84 (0.72 to 0.98)
Test for trend		$p < 0.001$	$p < 0.001$	$p < 0.001$
Walking activity sessions				
<1/week	1875/10746	1.00	1.00	1.00
1–3/week	511/3578	0.78 (0.70 to 0.87)	0.79 (0.71 to 0.88)	0.87 (0.78 to 0.97)
≥ 4 /week	814/5518	0.81 (0.74 to 0.89)	0.79 (0.73 to 0.87)	0.87 (0.79 to 0.95)
Test for trend		$p < 0.001$	$p < 0.001$	$p = 0.003$
Sports activity sessions				
<1/week	2639/15207	1.00	1.00	1.00
1–3/week	445/3540	0.66 (0.59 to 0.73)	0.67 (0.60 to 0.74)	0.76 (0.67 to 0.84)
≥ 4 /week	116/1095	0.53 (0.43 to 0.64)	0.56 (0.46 to 0.68)	0.67 (0.54 to 0.82)
Test for trend		$p < 0.001$	$p < 0.001$	$p < 0.001$
All activity sessions				
≤ 3.5 /week	1058/4803	1.00	1.00	1.00
3.51–5.00/week	1019/6769	0.61 (0.55 to 0.67)	0.60 (0.55 to 0.67)	0.67 (0.61 to 0.75)
5.01–6.75/week	470/3219	0.57 (0.51 to 0.65)	0.57 (0.50 to 0.66)	0.67 (0.59 to 0.76)
> 6.75 /week	653/5051	0.48 (0.43 to 0.54)	0.49 (0.43 to 0.54)	0.59 (0.52 to 0.66)
Test for trend		$p < 0.001$	$p < 0.001$	$p < 0.001$

Model 1: adjustment for age, gender, social economic group and marital status.

Model 2: adjustment for age, gender, social economic group, marital status, body mass index category, long-standing illness, smoking, survey year and mutual adjustment for all types of activity.

activity and walking had similar levels of risk reduction, in the region of 13–20%, although there was a greater risk reduction for sports activity of approximately 33% in the highest frequency category. Any type of daily physical activity was associated with the lowest odds of psychological distress (OR 0.59, 95% CI 0.52 to 0.66), and a dose-response relationship was evident such that less frequent activity (3.5–5/week) was associated with slightly less risk reduction (OR 0.67, 95% CI 0.61 to 0.75).

In subanalyses we examined associations among 1293 participants with existing cardiovascular disease (CVD), defined from a clinically confirmed CVD event or angina. In these analyses dose-response associations were again observed. Any type of daily activity was associated with the lowest odds of psychological distress (OR 0.27, 95% CI 0.16 to 0.47) and less frequent activity (3.5–5/week) was associated with slightly less risk reduction (OR 0.40, 95% CI 0.30 to 0.55).

DISCUSSION

The main findings from this study demonstrate strong associations between physical activity and reduced odds of psychological distress. The mental health benefits were observed at a minimum physical activity level of at least 20 min/week of any type of activity. A dose-response pattern was also observed with greater risk reduction at higher activity levels, especially for sports. Our findings relating to the dose-response relationship between physical activity and mental health are largely consistent with reports from previous population studies,^{2, 6, 21} although it is difficult to make direct comparisons with our data because of the differences in measures of mental health and assessment of physical activity. For example, in the Harvard Alumni Study, men who expended 1000–2499 or ≥ 2500 kcal/week were 17% and 28% less likely to develop clinically diagnosed depression compared with men who expended < 1000 kcal/week.⁶ Australian women who performed 2–3 sessions per week or daily moderate intensity

activity had approximately 20% and 40% reductions, respectively, in the risk of subclinical depressive symptoms after 5 years of follow-up.²

The mental health benefits of physical activity appear to be independent of potential confounding factors such as long-standing illness, obesity and smoking, although inclusion of these covariates reduced the strength of the association. Thus, the protective effects of physical activity may, in part, operate through these risk factors. Indeed, physical activity is associated with a reduced risk of chronic diseases such as CVD, diabetes, hypertension and some cancers.²² Exercise is also thought to improve a number of biological risk factors such as dyslipidaemia, glucose intolerance, inflammation and vascular dysfunction, which have been related to mental health disorders such as depression and dementia.^{23–25} Given that heightened responsiveness to daily stressors is a risk factor for psychological morbidity,²⁶ physical activity may also improve mental health by reducing biological stress reactivity.²⁷

This is the first study to our knowledge that has specifically considered the importance of different activity types in relation to mental health. Stamatakis *et al*²⁸ recently reported that, in contrast to leisure time activities, domestic activity was not associated with improvements in CVD risk factors which may partly explain why domestic activity contributed less to mental health benefits in the present analyses. Indeed, previous work has also shown a graded dose-response relationship between cardiorespiratory fitness and depressive symptoms,²¹ suggesting that participation in vigorous sports activities that produce greater fitness improvements is most beneficial for mental health. It is, however, possible that the additional benefits gained from participating in sports may have a psychological component, such as fostering social support networks and developing mastery and better coping abilities. In addition, the measurement of domestic activity may be less reliable than for other forms of activity, increasing error variance.

What is already known on this topic

- ▶ Mental illness such as depression is a risk factor for morbidity and mortality.
- ▶ Regular physical activity is thought to be associated with better mental health.
- ▶ The amount and type of activity that is required to achieve mental health benefits has not been clearly established.

What this study adds

- ▶ Lower levels of psychological distress were observed at a minimal level of at least 20 min/week of any physical activity (including domestic, walking or sports activities).
- ▶ A dose-response pattern was demonstrated with greater risk reduction for activity at a higher volume and/or intensity.

The limitations of the present study should be recognised. Given the cross-sectional nature of this study, we cannot exclude the possibility that the present results are explained by reverse causality or confounding from unmeasured variables. In particular, co-morbidities that cause functional impairment may have influenced the results because the association between depression and physical disability may be bidirectional.^{29, 30} However, we attempted to control for long-standing illness in our analyses and we found a strong inverse association between physical activity and psychological distress in participants with existing CVD, suggesting that these associations are not secondary to co-morbidity. Causality, however, remains an issue. Using a co-twin control method, Stubbe *et al*³¹ recently suggested that the association between exercise participation and higher levels of life satisfaction and happiness was non-causal and mediated by genetic factors that influence both exercise behaviour and well-being. However, further genetic studies are required to confirm these findings. In the present study we did not separately assess the association between physical activity and positive well-being, which appears to be an independent risk factor for health.³² A strength of the study is the large sample size of both men and women and the availability of detailed physical activity information covering both recreational and lifestyle (eg, walking, domestic) activity. Further studies should attempt to examine the effects of exercise intensity on mental health using objective measures.

In summary, mental health benefits were observed at a minimal level of at least 20 min/week of any physical activity, although a dose-response pattern was demonstrated with greater risk reduction for activity at a higher volume and/or intensity.

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