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# Does active leisure protect cognition? Evidence from a national birth cohort

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**Abstract**

Social, physical and intellectual activities are thought to facilitate cognitive performance and slow the rate of age associated cognitive decline, but little is known about this association in younger adulthood. We used multiple regression to test the association between two kinds of activity at 36 years—physical exercise and spare-time activity—and verbal memory at 43 and 53 years in 1919 males and females enrolled in the MRC National Survey of Health and Development (the British 1946 birth cohort). Both kinds of activities were significantly and positively associated with memory performance at 43 years, after controlling for sex, education, occupational social class, IQ at 15 years, and recurrent ill health and significant mental distress. Furthermore, physical exercise at 36 years (but not spare-time activity) was associated with a significantly slower rate of decline in memory from 43 to 53 years, after controlling for the same factors, with evidence that continuing physical exercise after 36 years was important for protection. We conclude that physical exercise and spare-time activity are significantly associated with benefit to memory in midlife, although these two kinds of voluntary activity may exert their effects on cognition via different paths. 

*Keywords:* Spare-time activity; Physical exercise; Verbal memory; Birth cohort; Britain

## Introduction

The identification of controllable factors that modify rate of age-associated cognitive decline has major public health implications. The suggestion that engagement in challenging spare-time activities can diminish (Schaie, 1984), and perhaps even reverse (Schaie & Willis, 1986) the rate of this decline is therefore of considerable importance. There are, however, several theoretical and methodological problems in interpreting findings in this area.

First, it is unclear which activities are most important for cognitive maintenance. Significant effects have been reported for intellectual stimulation (Arbuckle, Gold, Andres, Schwartzman, & Chaikelson, 1992; Hultsch, Hertzog, Small, & Dixon, 1999), social engagement (Bassuk, Glass, & Berkman, 1999) and physical exercise (Albert et al., 1995; Carmelli, Swan, LaRue, & Eslinger, 1997; Kramer et al., 1999). Unfortunately these different components are not easy to isolate from each other. This is important, however, for understanding biological pathways to neural development, and for formulating possible intervention strategies for minimising cognitive decline.

Second, direction of causality is problematic. While it is possible that activity directly promotes cognitive growth and maintenance, those with high cognitive ability are also likely to engage in such activities. Similarly, decline in cognitive performance may lead to diminution of activity. This issue is difficult to resolve, even with longitudinal data (Hultsch et al., 1999).

Third, some studies do not control for factors that may account for the association between activity and cognition, particularly education and occupational social class (Schaie, 1984; Gold et al., 1995).

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Fourth, it is unclear whether there is a sensitive period for activity engagement. Most studies have focused on later life, and little is known about the effects of activity on cognition in earlier adulthood. It is particularly important to determine if patterns of activity established early in life are more effective than activities begun later, and whether any benefit of this activity depends on the extent to which it is sustained.

The Medical Research Council National Survey of Health and Development (the British 1946 birth cohort) provides an opportunity to examine effects of activity on memory performance in a pre-retirement population. Participants were asked about physical exercise and spare-time activities at 36 years. Verbal memory was then measured at 43 and 53 years. We investigated the association between the above two types of activity and verbal memory at these ages, controlling for sex, educational attainment, socioeconomic status, and mental and physical health status. In addition, general intellectual ability was measured at 15 years in this cohort. Since this is highly correlated with adult IQ (Birren, Kinney, Schaie, & Woodruff, 1981; Deary, Whalley, Lemmon, Crawford, & Starr, 2000) we therefore had a rare opportunity to adjust these analyses for baseline IQ. This would reduce the likelihood that any apparent effect of activity on memory arose from those of high cognitive ability simply being more likely to engage in stimulating activities.

## Method

### *Participants*

Participants comprised the study population of the MRC National Survey of Health and Development (NSHD), also known as the British 1946 birth cohort, and initially consisting of 5362 children of non-manual and agricultural workers and a random sample of one in four of manual workers selected from all single and legitimate births that occurred in England, Scotland and Wales during one week in March 1946 (Wadsworth, 1991). The cohort has been studied on 21 occasions between birth and 53 years, with information about sociodemographic factors and medical, cognitive and psychological function being obtained by interview, examination and postal questionnaire. The most recent contact was an interview in 1999 at 53 years, when sample size was 3035. In 1989 the cohort was shown to be a representative sample, in most respects, of the UK population legitimately and singly born in the immediate post-war era (Wadsworth et al., 1992). Exceptions were an over-representation among non-responders of the never married, the least literate, those always in manual social class circumstances, and those with psychiatric illness (Wadsworth et al., 1992). By 43 years permanent losses comprised 365 (6.8%) deaths, and 540 (10.1%) refusals, and temporary losses were 607 (11.3%) emigrations or residence overseas and 370 (6.9%) failures to contact. Losses through death have been greater among those in manual rather than non-manual social classes (Pless, Crips, Davies, & Wadsworth, 1989).

### *Data collection*

All measures in this study were obtained by research nurses, who underwent standardised training for all measures, including cognitive testing.

### *Measures*

*Outcome: verbal memory at 43 and 53 years*

Cognitive function was assessed at 43 and 53 years by measures of memory, speed and concentration. Memory was chosen as the outcome measure because prominence is assigned to memory in classification criteria for mild cognitive impairment (Ritchie & Touchon, 2000) and dementia (American Psychiatric Association, 1994), and because poor memory, unlike letter search and praxis, is a predictor of clinically significant cognitive decline (Masur, Sliwinski, Lipton, Blau, & Crystal, 1994; Jacobs et al., 1995). At both ages this was assessed by a 15-item word learning task devised by the NSHD. Each word was shown for 2 s. When all 15 words were shown, the cohort member was asked to write down as many of the words as possible. This was repeated twice more. Total number of words correctly recalled over the three trials (max = 45) was summed to provide an overall score for this test.

*Exposure: activities at 36 years*

(1) *Physical exercise*: Questions about physical exercise were based on the Minnesota leisure time physical activity questionnaire (Taylor et al., 1978). These asked about engagement in sports and recreational activities in the previous month, utilising a checklist of 25 activities (Table 1). Responses were coded into no activity, 1–4 activities or 5+ activities per month (Kuh & Cooper, 1992). Preliminary analysis failed to demonstrate a dose–response effect with memory across these three categories, resulting in this measure being dichotomised to none versus any.

A similar measure was available at 43 years, although this was based on answers to an open-ended question about sports, vigorous leisure activities or exercises, rather than the above checklist. However, responses were able to be categorised in a similar way to the 36 year measure.

(2) *Spare-time activity*. Participants were asked about current engagement (yes/no) in seven spare time activities (Table 1). A total spare-time activity score was obtained by summing these items. Because of

Table 1
Physical exercise and spare-time activities at 36 years

| | |
|---|---|
| *Physical exercise* | |
| Badminton | Table tennis |
| Bowls | Tennis |
| Cricket | Yoga |
| Exercises like press ups, sit ups (gym or home) | Water skiing |
| Football (including refereeing) | Volleyball |
| Golf | Skuba diving |
| Hill or mountain climbing | Basketball |
| Jogging | Fishing |
| Rowing | Riding |
| Running or athletics | Movement to music |
| Sailing | Weight training |
| Squash or rackets | Dancing |
| Swimming | |
| *Spare-time activities* | |
| Chess, bridge or similar games | Local government, trade union or political work |
| Church or religious activities | Playing a musical instrument with others |
| Going to the cinema, theatre or concerts | Voluntary social welfare work |
| Helping to run a club, playgroup or school | |

diminishing numbers engaging in more than three activities, this score was recoded into 0, 1, 2 and 3+ activities. Preliminary analysis showed that the largest increase in memory was associated with a change from 0 to 1 activity, with relatively small increases across the remaining two categories. The score was therefore dichotomised to none versus any.

Spare-time activities were also enquired about at 43 years. However, (a) and (c) (Table 1) were omitted, an item about constructive activities (e.g. making things by hand) was added, and (f) (Table 1) was broadened to include musical, artistic or other creative activities (not necessarily with others). Post-hoc analysis (see Results) revealed that the resulting spare-time activity measure was not comparable to the one at 36 years.

*Potential confounding variables*

1. *Sex, and educational and occupational attainment:* educational attainment by 26 years was classified as no qualification, below ordinary secondary qualifications, ordinary secondary qualifications ('O' levels and their training equivalents), advanced secondary education ('A' levels and their equivalents), or higher education (degree level or equivalent). Occupational social class at 36 years, or between 26 and 36 years if this was unknown, was classified according to the Registrar General, and dichotomised into manual vs. non-manual.
2. General intellectual ability: No measure of IQ was available at 36 years. However, tests of verbal and non-verbal ability were given at 8, 11 and 15 years. Of these, the most comprehensive measures were given at 15 years (Pidgeon, 1968). At this age, verbal and non-verbal intelligence (AH4) was assessed, along with reading comprehension (Watts Vernon), and mathematics. Summing these test scores derived a global score, representing general intellectual ability.
3. *Health status at 36 years:* At 36 years participants were asked if they had any recurrent physical problems (i.e. 'all or most of the time'), using a checklist of 21 items (Table 2). A total score was obtained and recoded into 0, 1 and 2+ problems, which yielded approximately equal numbers in each category. Mental distress was measured by the Present State Examination (Wing, Cooper, & Sartorius, 1974), and participants were classified into cases or non-cases according to the index of definition (Wing & Sturt, 1978), using the cut-off for threshold disorder or above. The potential confounding effects of employment status, marital status, number of children living in the home, body mass index, resting pulse rate, systolic and diastolic blood pressure or peak expiratory flow rate (PEFR), all at 36 years, were also investigated.
4. *Cardiovascular risk at 53 years:* At 53 years participants were classified with, or at risk for, cardiovascular disease if any of the following self-reported conditions were present over the previous 10 years: angina, coronary thrombosis, myocardial infarction, valvular disease, aortic stenosis, ischaemic heart disease, tachycardia, palpitations or heart murmur,

Table 2
Physical problems enquired about at 36 years

| | |
|---|---|
| Bronchitis | Heart trouble |
| Sciatica, lumbago or recurring backache | Trouble with varicose veins |
| Arthritis or rheumatism | Diabetes |
| Persistent skin trouble (e.g. exzema) | Trouble with gums or mouth |
| Asthma | Cataracts |
| Hay fever | Stroke |
| Recurring stomach trouble (e.g. ulcers) | Epilepsy |
| Gall bladder trouble | Kidney or bladder infections |
| Hernia | Dizziness and unsteadyness |
| Headaches or migrane | Cancer |
| High blood pressure | |

other heart trouble, blood pressure problems, stroke, transient ischaemic attack or diabetes. In addition, the following physiological measures were obtained: resting pulse, systolic and diastolic blood pressure, forced expiratory volume (FEV) and forced vital capacity (FVC).

### *Statistics*

Multiple regression models were used to test the association between the two kinds of activity measured at 36 years (coded as dichotomous variables), and verbal memory at 43 and 53 years (retained as continuous variables). First, the association between activity and memory at 43 years was investigated, progressively adjusting for sex, educational attainment and social class. To assess whether any association between activity and memory was simply due to those of high intellectual ability being more likely to engage in activities, the models were further adjusted for intellectual ability at 15 years (retained as a continuous score). Formal tests confirmed a linear relationship between this ability score and the memory score. Finally, the models were adjusted for health status at 36 years (physical complaints and PSE caseness). The potential confounding effects of employment status, marital status, number of children living in the home, body mass index, resting pulse rate, blood pressure or PEFR were investigated by adding and removing these variables in turn to the models, already adjusted for all the above background variables. Both kinds of activity were then included in the same model, to assess whether their associations with memory were independent of each other.

Next, to test whether activity was associated with rate of change in memory from 43 to 53 years, the analyses were repeated using the memory score at 53 years as an outcome, controlling for memory at 43 years (conditional model for change), as well as sex, education, social class, IQ at 15 years and health status at 36 and 53 years.

Finally, to test whether change in activity engagement from 36 to 43 years was associated with rate of change in memory from 43 to 53 years, physical exercise at 43 years was added to the above conditional model for change for this type of activity. A comparable analysis for spare-time activity was not possible, because the relevant measures at 36 and 43 years were too dissimilar.

## Results

### *Sample size and missing data*

Of the 3035 cohort members interviewed at 53 years, 1116 had missing data for at least one of the variables in the analysis. Analyses were therefore performed on the remaining 1919 cohort members. Those with missing data had a significantly lower general intellectual ability at 15 years than those with complete memory data ($t = 8.10$, $p < 0.001$).

### *Activity at 36 years and memory at 43 years*

Of the 1919 participants in the analysis, 36.6% had not undertaken any physical exercise during the past month, and 24.2% had not engaged in any of the spare-time activities.

Unadjusted regression coefficients representing the mean difference in the memory score at 43 years between those engaging in activities at 36 years and those not, are shown in Table 3.

Engagement in physical exercise and spare-time activity at 36 years was strongly associated with higher memory score at 43 years. These associations were not significantly reduced by adjustment for sex (Table 3). Indeed, that for physical exercise was strengthened, since women engaged in this less frequently than men, but achieved higher memory scores. Controlling for education reduced the strength of these associations by ~50%, although they both remained significant at the 5% level. Adjusting for social class had little additional effect. Adding baseline IQ reduced the associations for activity further, although again, the associations remained significant at the 5% level for both kinds of activity. Final adjustment for health status (physical disorders and significant mental distress according to the

Table 3
Estimates (regression coefficients and 95% confidence intervals) of the effect of spare-time activity on verbal memory, progressively adjusting for sex, education, social class, cognition at 15 years, and health status[a] at 36 years

| | Regression coefficient (95% CI) | p-value |
|---|---|---|
| Physical exercise (baseline = none) | | |
| Unadjusted | 1.57 (0.99, 2.14) | <0.0001 |
| + Sex | 1.79 (1.22, 2.35) | <0.0001 |
| + Education | 0.85 (0.34, 1.36) | 0.001 |
| + Social class | 0.80 (0.29, 1.30) | 0.002 |
| + Cognition at 15 years | 0.60 (0.12, 1.08) | 0.02 |
| + Health status | 0.58 (0.10, 1.06) | 0.02 |
| Spare-time activity (baseline = none) | | |
| Unadjusted | 3.22 (2.59, 3.85) | <0.0001 |
| + Sex | 3.18 (2.56, 3.81) | <0.0001 |
| + Education | 1.79 (1.21, 2.36) | <0.0001 |
| + Social class | 1.65 (1.08, 2.22) | <0.0001 |
| + Cognition | 1.39 (0.85, 1.94) | <0.0001 |
| + Health status | 1.38 (0.84, 1.93) | <0.0001 |

[a] Persistent physical complaints and PSE caseness.

Table 4
Estimates (95% confidence intervals) from the fully adjusted regression model of the effect of spare-time activity on verbal memory at 43 years

| | B (95% CI) | P |
|---|---|---|
| Any physical exercise | 0.44 (-0.04, 0.93) | 0.07 |
| Any spare-time activity | 1.32 (0.77, 1.87) | <0.0001 |
| Female sex | 2.43 (1.95, 2.91) | <0.0001 |
| Education[a] | | |
| 0 | (Baseline) | |
| 1 | 0.21 (−1.10, 0.69) | 0.65 |
| 2 | 1.37 (0.66, 2.07) | 0.0002 |
| 3 | 1.95 (1.22, 2.68) | <0.0001 |
| 4 | 3.65 (2.59, 4.71) | <0.0001 |
| Manual social class | −0.84 (−1.39, −0.29) | 0.003 |
| Cognition at 15 | 0.21[b] (0.18, 0.24) | <0.0001 |
| Physical disorder at 36 | | |
| 0 | (Baseline) | |
| 1 disorder | −0.15 (−0.70, 0.41) | 0.60 |
| 2+disorders | −0.22 (−0.78, 0.34) | 0.44 |
| Mental disorder[c] at 36 | −0.51 (−1.51, 0.49) | 0.32 |

[a] 0 = no qualification (baseline), 1 = vocational only, 2 = ordinary ('O') level, 3 = advanced ('A') level, 4 = degree or equivalent.
[b] Per item increase in score.
[c] PSE caseness.

PSE) had little additional effect. Thus for a given baseline IQ score (at 15 years), and after controlling for sex, education, social class and health status, those who engaged in physical exercise at 36 years scored on average half a point more on the memory test at 43 years than those who did no physical exercise. Similarly, those who engaged in spare-time activity scored on average 1.4 points more.

The effect sizes for both kinds of activity were not significantly altered by additional adjustment, in turn, for employment status, marital status, number of children living in the home, body mass index, resting pulse rate, blood pressure or PEFR at 36 years.

When physical exercise and spare-time activity were simultaneously entered into the model, along with all the above background variables, the association between spare-time activity and verbal memory remained significant at the 5% level, with only a slight attenuation of the effect, although this was no longer the case for physical exercise (Table 3). The full model, with both kinds of activity and the principal background variables, is shown in Table 4.

The interaction term between physical exercise and spare-time activity was not significant ($p = 0.32$).

To check the extent to which the effect of spare-time activity was driven by an intellectual component, the analysis for spare-time activity was re-run after omitting the challenging games item (chess, bridge or similar games) from the score. The strength of association was slightly reduced, but remained highly significant at the 5% level (regression coefficient = 1.07, 95% confidence interval = 0.54, 1.60, $p<0.001$). However, post hoc analysis revealed that the individual spare-time activity most strongly associated with memory was that concerned with going to the cinema, theatre or concerts (see Table 1). Indeed, this was the most frequently endorsed spare-time item (52.4%, compared to 25.7% for the next most frequent category, engaging in church or religious activities). When this item was removed from the score the association with memory was reduced by over 50% (regression coefficient = 0.56, 95% confidence interval = 0.09, 1.03, $p = 0.02$).

Table 4 also shows that sex was strongly and independently associated with memory at 43 years, with women scoring an average of 2.4 points higher than men. Baseline IQ, educational attainment, and social class at age 36 were also independently associated with memory at 43, although the effect was weakest for social class.

*Activity at 36 years and change in memory between 43 and 53 years*

To assess the association between activity at 36 years and rate of change in memory between 43 and 53 years, the full model was repeated using memory at 53 years as the outcome, adjusted for memory at 43 years. Results are shown in Table 5.

Physical exercise was significantly associated with slower rate of decline in memory score over the 10-year period, after adjusting for spare-time activity and the principal background variables, with those engaging in physical activity showing an average half-point slower decrease over those not engaging. This association was not significantly altered by further adjusting, in turn, for cardiovascular disease (see Methodology), resting pulse, systolic and diastolic blood pressure, FEV and FVC at 53 years. Spare-time activity, on the other hand, was not associated with change in memory over this interval.

To assess whether change in physical exercise engagement from 36 to 43 years was associated with change in memory from 43 to 53 years, the above analysis was repeated, adding the similar measure of physical exercise at 43 years. This strongly reduced the association between physical exercise at 36 years and memory change (regression coefficient = 0.25, 95% confidence interval = −0.18, 0.69, $p = 0.27$). However, there was a significant association between physical exercise at 43 years and memory change (regression coefficient = 0.75, 95% confidence interval = 0.33, 1.18, $p = 0.0005$). Overall, this suggests little protection in memory in those who stopped physical exercise after 36 years, but protection in those who began it after this time. Since the interaction term between physical exercise at 36 and 43 years was not significant at the 5% level ($p = 0.88$),

Table 5
Estimates (95% confidence intervals) from the fully adjusted regression model of the effect of spare-time activity on change in verbal memory from 43 to 53 years

| | B (95% CI) | p |
|---|---|---|
| Any physical exercise | 0.44 (0.01, 0.87) | 0.04 |
| Any spare-time activity | 0.06 (−0.43, 0.55) | 0.82 |
| Female sex | 1.44 (1.00, 1.87) | <0.0001 |
| Education[a] 0 | (Baseline) | |
| 1 | −0.30 (−1.10, 0.49) | 0.46 |
| 2 | 0.97 (0.34, 1.60) | 0.002 |
| 3 | 0.91 (0.25, 1.56) | 0.007 |
| 4 | 0.92 (−0.04, 1.87) | 0.06 |
| Manual social class | −0.85 (−1.34, -0.36) | 0.0007 |
| Cognition at 15 | 0.14[b] (0.11, 0.16) | <0.0001 |
| Physical disorder at 36 | | |
| 0 | (Baseline) | |
| 1 Disorder | −0.30 (−0.79, 0.19) | 0.23 |
| 2+ Disorders | −0.21 (−0.71, 0.29) | 0.41 |
| Mental disorder[c] at 36 | −0.40 (−1.29, 0.48) | 0.37 |

[a] 0 = no qualification (baseline), 1 = vocational only, 2 = ordinary ('O') level, 3 = advanced ('A') level, 4 = degree or equivalent.
[b] per item increase in score.
[c] PSE caseness.

the effect on memory of engaging in physical activity on both occasions (36 and 43 years) was additive, with those engaged at both occasions having an average decline 1.01 points slower than those engaged at neither age.

The association between change in spare-time activity and change in memory was not investigated because the measures of spare-time activity at 36 and 43 years were not comparable.

## Discussion

In a large population-based birth cohort study we investigated associations between two kinds of activity—physical exercise and spare-time at 36 years, and verbal memory. Both kinds of activities were significantly associated with memory at 43 years, and while these associations were reduced by adjusting for sex, educational and occupational attainment, and health status, they remained significant at the 5% level. However, the effect was stronger for spare-time activity than for physical exercise, and once spare-time activity was taken into account, there was no independent effect of physical exercise on memory at this time. Crucially, this effect of spare-time activity was also independent of baseline IQ, as measured by general cognitive ability at 15 years. Thus the effect of activity at 36 years on memory at 43 years can be interpreted as the difference in mean memory score for a given IQ at 15 years, and was therefore unlikely to reflect reverse causality, i.e. those of high lifetime ability being more likely to engage in spare-time activity.

This suggestion is reinforced by the additional finding that engagement in physical exercise at 36 years was associated with a slower rate of decline in memory score between 43 and 53 years, again independently of all the principal background variables. The effect of the 43 year measure was stronger, so that those who gave up exercise after 36 years did not show the same benefit as those who exercised at 43 years (either new or continuing). Not only does this strengthen the suggestion of a causal link between physical activity and protection of memory in midlife, but it also implies that the cognitive benefit of physical exercise is enhanced by persistent or more recent activity. Conversely, and consistent with the 'disuse' concept of Salthouse (1991) (more loosely, the 'use it or lose it' adage), these findings suggest that this benefit is lost if activity is not maintained. Unfortunately a comparative analysis of change in spare-time activity would not have been informative, since a key item asked at 36 years (going to the cinema, theatre or concerts) was not repeated at 43 years. Nevertheless, the association between spare-time activity at 36 years and memory at 43 years, but not change in memory from 43 to 53 years, suggests that the cognitive benefit from this form of engagement, once established, remains relatively unchanged across the ages studied.

We should highlight the disproportionate dropout of survey members with low cognitive scores. This is a hazard of longitudinal cognitive studies, limiting generalisability and probably leading to under-estimation of the true population effect sizes. With this limitation in mind, what is the nature of the association between activity and memory?

To begin with, it is worth noting that neuronal plasticity and development is by no means confined to early life. For example, licensed London taxi drivers, who are required to undertake intensive navigational study of the city as part of their training, show significantly larger posterior hippocampi than controls, the size correlating with amount of occupational experience (Maguire et al., 2000). Benefits thus accrued in adult life may increase cognitive reserve (Stern, Alexander, Prohovnik, & Mayeux, 1992), conferring protection against cognitive decline. The paths through which different kinds of activity influence cognition may be diverse, however.

One possible way in which physical exercise protects cognitive function is through increased cerebral oxygenation, leading to improved neurotransmitter metabolism (Dustman, Emmerson, & Shearer, 1990). We did not find that measures of lung function modified the association between physical exercise and memory in the present study, either at 36 or 53 years. The possibility of neural protection by exercise, however, is supported by evidence from animal studies that learning potentiates the effect of physical activity on neural growth in the brain (Gomez-Pinilla, So, & Kesslak, 1998). An alternative is that exercise reduces the risk of diseases that impair cognitive function, such as hypertension diabetes and cardiovascular disease (Anstey & Christensen, 2000). This seems unlikely to be a crucial factor in this relatively young cohort, however, and, indeed, the association between physical exercise and change in memory was not modified by controlling for a range of cardiovascular risk factors.

An equally difficult task is to determine which aspects of spare-time activity are important for protecting cognition. Evidence from the Victoria Longitudinal Study suggests that the intellectual component carries the greatest weight (Hultsch et al., 1999), although in our study the effect of spare-time activity was still significant after removing an analogous item on intellectual stimulation (chess, bridge or similar games) from the score. Social engagement was found to protect against cognitive decline in the New Haven EPESE cohort (Bassuk et al., 1999). However, the social measures in that study included exercise and working at a hobby, which would have been classified in our study as physical exercise and spare-time activity (respectively). In fact most of these activities, whether physical or non-physical, involve social interaction. Furthermore, all involve some degree of volition. The finding that physical exercise but not spare-time activity protected memory minimises the role of such non-specific components, however.

What are the public health implications of the present results? Our study suggests that uptake of physical exercise in young to middle adulthood benefits memory, an aspect of cognitive function likely to be important for conduct of activities of daily living during ageing. Furthermore, sustained physical activity appears to reinforce this benefit, whereas abandonment of this activity appears to result in its loss. It is therefore important to investigate whether uptake of physical activity in later life can result in cognitive benefit, or whether this is more likely to be observed following long-established patterns of activity. Continuing follow-up of this cohort will help to resolve this question.

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