150 minutes of vigorous physical activity per week predicts survival and successful ageing: a population-based 11-year longitudinal study of 12 201 older Australian men

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ABSTRACT

Background Physical activity has been associated with improved survival, but it is unclear whether this increase in longevity is accompanied by preserved mental and physical functioning, also known as healthy ageing. We designed this study to determine whether physical activity is associated with healthy ageing in later life.

Methods We recruited a community-representative sample of 12 201 men aged 65–83 years and followed them for 10–13 years. We assessed physical activity at the beginning and the end of the follow-up period. Participants who reported 150 min or more of vigorous physical activity per week were considered physically active. We monitored survival during the follow-up period and, at study exit, assessed the mood, cognition and functional status of survivors. Healthy ageing was defined as being alive at the end of follow-up and having a Patient Health Questionnaire score <10, Telephone Interview for Cognitive Status score >27, and no major difficulty in any instrumental or basic activity of daily living. Cox regression and general linear models were used to estimate HR of death and risk ratio (RR) of healthy ageing. Analyses were adjusted for age, education, marital status, smoking, body mass index and history of hypertension, diabetes, coronary heart disease and stroke.

Results Two thousand and fifty-eight (16.9%) participants were physically active at study entry. Active men had lower HR of death over 10–13 years than physically inactive men (HR=0.74, 95% CI=0.68 to 0.81). Among survivors, completion of the follow-up assessment was higher in the physically active than inactive group (risk ratio, RR=1.18, 95% CI=1.08 to 1.30). Physically active men had greater chance of fulfilling criteria for healthy ageing than inactive men (RR=1.35, 95% CI=1.19 to 1.53). Men who were physically active at the baseline and follow-up assessments had the highest chance of healthy ageing compared with inactive men (RR=1.59, 95% CI=1.36 to 1.86).

Conclusions Sustained physical activity is associated with improved survival and healthy ageing in older men. Vigorous physical activity seems to promote healthy ageing and should be encouraged when safe and feasible.

INTRODUCTION

Regular engagement in vigorous physical activity has been associated with reduced mortality in middle age and in later life.[1 2] Active older people consume less health resources than their inactive counterparts,[3] possibly because physical activity reduces the morbidity associated with diabetes, musculoskeletal disorders, cardiovascular diseases and cancer,[4] as well as the risk of frailty.[5 6] These findings suggest that a physically active lifestyle contributes to increase longevity and, potentially, ageing free of significant medical morbidity. Such outcomes are akin to the concept of successful or healthy ageing.

Healthy ageing is a multidimensional phenotype characterised by various necessary but insufficient components, including preserved cognitive, affective and daily function.[7] A 5-year longitudinal study of 601 men who had reached their 80s showed that ageing free of clinically significant cognitive and mood disturbances was associated with higher education and physical activity, and that this association was independent of other sociodemographic, lifestyle and clinical measures.[8] Physical activity has also been associated with improved physical function in randomised trials of older sedentary people,[9] which suggests that a physically active lifestyle might contribute to preserve function and defer disability.[10] Recent reviews have concluded that physical activity is associated with increased survival[11] and with less cognitive decline and impairment.[12 13] Taken together, existing data indicate that physical activity may be an important factor in enabling people to age successfully.[13]

A sufficiently powered randomised controlled trial would be the best way to establish with certainty that physical activity causes older people to age successfully. Although there is trial evidence to prove that physical activity improves physical and mental function, such data have arisen predominantly from at-risk populations (such as sedentary people or older adults with mild cognitive impairment or depression) and are difficult to generalise.[9 12 14] Designing a trial of physical activity for an unselected community sample of older people would be challenging because of the high probability of contamination of the control group and loss of power. A longitudinal study of a community-representative sample of older people might be a more pragmatic way of ascertaining whether physical activity contributes to healthy ageing. Such a study should aim to minimise confounding (eg, age, education and body mass index), reverse-causality (eg, prevalent disease causing physical inactivity) and survivorship bias (eg, outcome data more likely to be available among those who are healthy) to ensure that its results are valid.

We examined the association between physical activity and healthy ageing in a community-representative sample of 12 201 older men. We collected survey data at two different time-points and used electronic administrative health records to optimise the validity of our analyses. We hypothesised that, compared with inactive men, participants who were physically active at the beginning of the follow-up period would have greater chance of being alive and free of affective, cognitive and physical functional impairment 10–13 years later.

METHODS

Study design and setting

Cohort study of a community-representative sample of older men living in the Perth metropolitan area, Australia.

Participants

We used the electoral roll to recruit a community-representative sample of 12 203 men aged 65–83 years into a study of abdominal aortic aneurysm, which served as the starting point for the Health In Men Study (HIMS). Details about the recruitment procedure have been described elsewhere.[15] Eligibility for the current study required availability of physical activity data at the baseline assessment, which led to the exclusion of two participants and resulted in a study sample of 12 201 men.

The study was conducted in accordance with the principles expressed by the Declaration of Helsinki for Human Rights. The Human Research Ethics Committee of the University of Western Australia approved the study protocol and all men provided written informed consent to participate.

Study measures: exposures (HIMS1)

During the baseline assessment (1996–1998), men completed a questionnaire that contained information about the date of assessment, participant's date of birth, highest level of education attained, marital status and lifestyle practices. We assessed physical activity with the following question: In a usual week do you do any vigorous exercise that makes you breathe harder or puff and pant, such as fast walking, jogging, aerobics, vigorous swimming, vigorous cycling, tennis, football, squash, etc? Men who indicated that they engaged in vigorous activity for 150 min or more per week were considered 'physically active'.[16] For convenience in this article, men who did not meet the 150 min threshold will be referred to as 'physically inactive'. This question about physical activity was derived from an Australian survey for the prevention of cardiovascular diseases.[17]

We also measured smoking status and alcohol use,[18] and considered men who had never smoked or had quit smoking for at least 5 years 'non-smokers for at least 5 years'. We chose this timeline because currently available evidence suggests that the health hazards associated with smoking require about 5 years of cessation to become apparent.[19] Men who consumed less than four drinks per day in a usual week were considered 'safe alcohol users'.[20] We used standard procedures to measure participant's height (to 0.5 cm) and weight (to 0.2 kg), and calculated the body mass index (BMI) in kg/m^2. BMI between 18.5 and 24.9 was considered normal. Finally, we asked participants the following question: Have you ever been told by a doctor that you had hypertension, diabetes, heart attack/angina/heart bypass surgery or angioplasty (coronary heart disease) or a stroke? (yes/no for each question).

Outcome measure: survival and healthy ageing 11 years later (HIMS2)

Outcome data were collected 9.8–12.6 years after the baseline assessment (mean±SD: 11.1±0.6). All cause mortality data were retrieved from the Western Australia Data Linkage System,[21] which include information about the date of death that we then used to calculate time to death.

We considered that surviving participants were 'healthy' if they showed no evidence of clinically significant symptoms of depression, impaired cognition or daily physical function at the follow-up assessment that was conducted in 2008–2009 (HIMS2). Men were considered free of clinically significant depressive symptoms if their total score on the Patient Health Questionnaire (PHQ-9) was lower than 10.[22] The presence of cognitive impairment was established by a score of 27 or lower on the Telephone Interview for Cognitive Status.[23 24] Men rated their functional limitations in grooming, eating normal food, bathing or taking a shower, dressing upper body, dressing lower body, getting up from a chair, walking inside the house and using the toilet (basic activities of daily living (ADL)),[25] as well as shopping for personal items or groceries, doing light housework (eg, washing dishes and dusting), doing heavy housework, laundry, managing money, preparing main meals, taking medications, using the telephone and doing leisure activities or hobbies (instrumental activities of daily living (IADL)).[26] Possible answers for each question were as follows: no difficulty, some difficulty, major difficulty, unable to do without help. We considered that men who indicated having 'major difficulty' or being 'unable to do without help' showed evidence of impaired function in the relevant area. For the purposes of this study, men who reported major difficulty or inability to perform any of the ADL tasks were considered to have impaired ADLs, and likewise for IADLs. A secondary endpoint of interest in this study was survival by 18 April 2009, which was the last date for the follow-up assessment, according to physical activity status at baseline (HIMS1).

As changes in physical activity between baseline and the follow-up assessment could conceivably confound the results of the study, we repeated the assessment of physical activity at the follow-up assessment. We asked the following question: If you add up all the times you spent in each activity last week, how much time did you spend all together doing more vigorous leisure activity or household/garden chores that make you breathe harder or puff and pant? We considered that men were physically active if they reported 150 min or more of vigorous activity.

Statistical analyses

Data were managed and analysed with the statistical package Stata release V. 12.1 (StataCorp, College Station, Texas, USA). We used descriptive statistics (mean, SD of the mean (SD) and proportions) to summarise our data, and t tests (for age) and Pearson χ^2 statistics (χ^2) to compare the characteristics of participants who were and were not physically active at the baseline assessment. We used Cox regression to estimate HR of death by 18 April 2009 according to physical activity status, and adjusted the results of the analyses for the effect of age, education, marital status, smoking, alcohol use, body mass index and the presence of hypertension, diabetes, coronary heart disease and history of stroke. The results were plotted using the Kaplan-Meyer survival function.

Exponentiated log-linked general linear models were used to estimate the risk ratio (RR), and 95% CI of RR of depression, cognitive impairment and impaired IADLs and ADLs at follow-up according to whether men were physically active or not at the baseline assessment. We followed the same procedures to estimate the crude and adjusted RR of being 'healthy' at the follow-up assessment according to physical activity status at baseline, and adjusted the analyses for the same variables described above.

Finally, we grouped participants according to their level of physical activity at the baseline and follow-up assessments: physically inactive at baseline and follow-up, physically inactive at baseline but active at follow-up, active at baseline but physically inactive at follow-up and active at both baseline and follow-up. We then estimated the RR (and 95% CI) of being 'healthy' at follow-up for each group. These analyses were adjusted for the same variables described above, as well as for the following follow-up variables: marital and smoking status, alcohol use and BMI group. The α was set at 5% and all statistical probability tests reported are two-tailed.

RESULTS

Of the 12 201 men who entered the study, 2058 (16.9%) were physically active. Physical activity decreased with increasing age, and active men were on average 1.1 years younger than their non-active counterparts (71.2±4.1 vs 72.3±4.4; t=10.68 (df=12 199), p<0.001). Table 1 summarises the demographic, lifestyle and clinical characteristics of men at the baseline assessment. A larger proportion of physically active than inactive men reported the completion of high school education, non-risk alcohol use or smoking, and BMI in the normal range. They were also less likely to report a clinical history of hypertension, coronary heart disease and stroke.

Eleven years later (mean: 11.1±0.6; range: 9.8–12.6) 4733 men had died, leaving a surviving sample of 7508 people. Of those, 3276 (43.6%) accepted our invitation to complete the follow-up assessment. Completion of the follow-up assessment was greater among men who were physically active than inactive at baseline (RR=1.18, 95%CI=1.08 to 1.30). Cox regression showed that active participants had lower hazard of death during follow-up (n=582/2058) than their physically inactive counterparts (n=4111/10 143): HR=0.74, 95% CI=0.68 to 0.81 (adjusted for age, marital status, education, smoking, alcohol use, body mass index and prevalent hypertension, diabetes, coronary heart disease and stroke; figure 1).

The RR of impaired cognitive function, IADL and ADL at the follow-up assessment was lower for active than inactive men (table 2), and was borderline non-significant for depression (p=0.053). The RR of reaching the follow-up assessment free of mood, cognitive and functional impairments was 1.21 among the survivors (95% CI=1.08 to 1.35; adjusted for age, marital status, education, smoking, alcohol use, body mass index and prevalent hypertension, diabetes, coronary heart disease and stroke). If we consider that those who died before the follow-up assessment could not be healthy, the adjusted RR of completing the follow-up assessment in good health was 1.35 (95% CI=1.19 to 1.53) for those who were active (n=259/1323) compared with those who were physically inactive (680/6646) at baseline. This last analysis excluded 4232 participants who were alive but did not complete the follow-up assessment.

Finally, we grouped surviving men who took part in both assessments according to their level of self-reported physical activity. The results of these analyses are summarised in table 3. Being physically active in at least one of the assessments increased the RR of follow-up completion in good health (RR=1.38, 95%CI=1.24 to 1.54; adjusted for age, marital status, education, smoking, alcohol use, body mass index and prevalent hypertension, diabetes, coronary heart disease and stroke). The health benefits associated with physical activity were non-significant among those who were active at baseline but not at follow-up, increased by 35% among those who were physically inactive at baseline but active at follow-up, and was nearly 60% greater for those who reported being active at both assessments (table 3).

DISCUSSION

The results of this community-based longitudinal study showed that a lifestyle that incorporates physical activity increases by 1.6-fold the chance of men aged 65–83 years remaining alive and free of functional or mental impairments after 10–13 years. We also found that the health benefits of physical activity appeared to be all but lost among active men who became inactive over the following decade, whereas men who were physically inactive and became active accrued the benefits of

Table 1 Demographic, lifestyle and clinical characteristics of older men at the beginning of the follow-up period according to their level of vigorous physical activity

	Physically inactive N=10 143 n (%)	Physically active N=2058 n (%)	Statistic	p Value
Age (years)				
65–69	3683 (36.3)	962 (46.7)	$\chi^2(3)=97.61$	<0.001
70–74	3578 (35.3)	683 (33.2)		
75–79	2234 (22.0)	336 (16.3)		
80+	648 (6.4)	77 (3.7)		
High school education	3827 (37.7)	1075 (52.3)	$\chi^2(1)=149.80$	<0.001
Marital status married	8231 (81.2)	1689 (82.1)	$\chi^2(1)=0.90$	0.341
Non-risk alcohol use	5414 (53.4)	1209 (58.7)	$\chi^2(1)=19.88$	<0.001
Non-smoker for at least 5 years	8326 (82.1)	1832 (89.0)	$\chi^2(1)=58.98$	<0.001
BMI in the normal range	3035 (29.9)	695 (33.8)	$\chi^2(1)=11.77$	0.001
Hypertension	3958 (40.4)	729 (37.3)	$\chi^2(1)=6.43$	0.011
Diabetes	1201 (11.8)	215 (10.4)	$\chi^2(1)=3.24$	0.072
Coronary heart disease	2490 (25.4)	448 (22.9)	$\chi^2(1)=5.34$	0.021
Stroke	799 (8.2)	104 (5.3)	$\chi^2(1)=18.40$	<0.001

We considered physically active men who reported 150 min or more of vigorous exertion during a typical week.
χ^2(degrees of freedom): Pearson χ^2 statistic; BMI: body mass index.

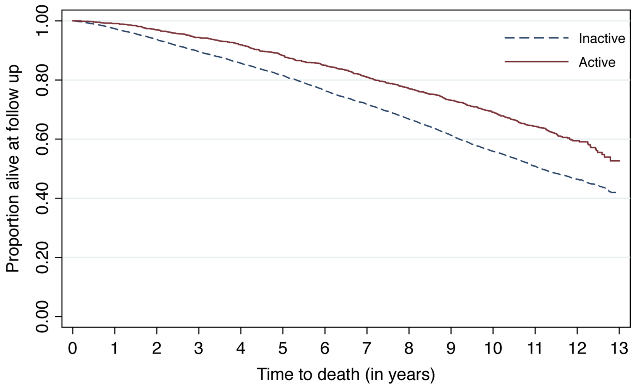

Figure 1 Survival of participants according to whether they were physically active. Participants who reported being vigorously active had lower hazard of dying between the assessments than inactive men (n=582/2058 vs 4111/10 143; HR=0.74, 95% CI 0.68 to 0.81; the analysis was adjusted for age, marital status, education, smoking, alcohol use, body mass index and prevalent hypertension, diabetes, coronary heart disease and cerebrovascular disease). The adjusted risk ratio (RR) of physically active survivors completing the follow-up assessment compared with physically inactive survivors was 1.18 (95% CI 1.08 to 1.30).

healthy ageing. Taken together, these results support the hypothesis that physical activity promotes healthy ageing.

Limitations of the study design

Before discussing the implications of these findings, we must consider the characteristics of the study that might have had an impact on the results. We used a random electoral roll list to recruit older men, voting being compulsory in Australia. The sample comprised 63% of all invitations, and previous studies have shown that those who took part were healthier than those who did not.[27] Such a bias could have led to the selection of a more physically active sample, although the results of other community surveys are not consistent with such an interpretation: our men were not more physically active than other older people living in Western Australia.[28] The assessment of physical activity is another factor that warrants consideration; it was based on the response of participants to a simple question designed to measure vigorous exertion that others have shown to have good face validity,[29] which gives us confidence that our findings reflect the level of physical activity of older men in the community. Nonetheless, replication of our findings by other studies using a more detailed assessment of physical activity would strengthen our confidence in the validity and generalisability of the results.

In addition, our definition of 'physically active' was limited to vigorous exertion, which could have contributed to misclassify as inactive men who engaged in sufficient amounts of moderate plus vigorous activity. In a previous study, we showed that self-reported non-vigorous physical activity was not associated with mental health outcomes,[8] which suggested to us that a stringent self-reported measure of sufficient activity would be required. However, we acknowledge that a more detailed assessment of physical activity could have yielded useful information about a possible dose-effect for this association. Finally, we acknowledge that our definition of 'physically active' was not exactly the same at study entry and at follow-up. Notwithstanding this caveat, the stratification of the analyses for the assessment of risk allowed us to investigate both approaches to the definition of physical activity in a way that minimises bias.

Loss to follow-up is an important source of bias in longitudinal studies. We had valid data on 12 201 men at study entry, of whom 4733 died and 44% of the survivors returned for a further assessment 10–13 years later. While survivorship bias is inevitable in a cohort study of older people, we were able to model both death and non-return as outcomes of the study, and showed that physically active men were more likely than their inactive counterparts to remain alive and return for assessment, demonstrating that physical activity makes a significant contribution to this critical aspect of healthy ageing: to be alive and engaged with one's environment.

Our pragmatic definition of healthy ageing took into account the functional capacity of participants, as well as their cognitive and affective state.[7] This strategy does not take into account important social variables, such as loneliness and financial stress, so that the proportion of men ageing successfully could be lower than that reported. The consequence of such a bias would be contamination of the sample of healthy ageing individuals, which most likely would have reduced the effect size of the associations with physical activity. Therefore, it is possible that the association between physical activity and healthy ageing could be even greater than that reported in this study.

We carefully adjusted our analyses for known confounding measures, including demographic, lifestyle and clinical variables, such as prevalent diabetes, hypertension, coronary heart disease and stroke. Notwithstanding the merit of our approach to the analyses, the possibility of residual confounding by unmeasured prognostic factors cannot be entirely dismissed. It is possible

Table 2 Clinical outcomes of older men according to their level of physical activity

Clinical outcomes at the follow-up assessment	Physically inactive N=2535 n (%)	Physically active N=741 n (%)	Risk ratio*	95% CI
Depression	168 (7.6)	36 (5.4)	0.71	0.50 to 1.01
Cognitive impairment	730 (33.0)	190 (28.4)	0.86	0.75 to 0.98
Impaired IADL	1460 (57.6)	349 (47.1)	0.82	0.75 to 0.89
Impaired ADL	958 (37.8)	220 (29.7)	0.79	0.70 to 0.89
No mood, cognitive or functional impairment*	680 (26.8)	259 (34.9)	1.30	1.16 to 1.47

Outcomes were collected 11 years after the assessment of physical activity.
We considered physically active men who reported 150 min or more of vigorous exertion during a typical week.
*Risk ratio of the outcome of men who are physically active relative to their insufficiently active counterparts.
†Risk ratio=1.21 (95% CI 1.08 to 1.35) after adjustment for age, education, marital status, smoking, alcohol use, body mass, hypertension, diabetes, coronary heart disease and cerebrovascular disease at the time of entry into the study.
IADL, instrumental activities of daily living; ADL, activities of daily living.

Table 3 Risk of being healthy after 11 years according to whether men were physically active at the baseline and the follow-up assessments

	Not healthy N=2337 n (%)	Healthy N=939 n (%)	Adjusted risk ratio*	95% CI
Inactive at baseline and follow-up	1390 (59.5)	421 (44.8)	1	Reference
Inactive at baseline, active at follow-up	465 (19.9)	259 (27.6)	1.35	1.17 to 1.54
Active at baseline, inactive at follow-up	305 (13.0)	119 (12.7)	1.07	0.90 to 1.30
Active at baseline and follow-up	177 (7.6)	140 (14.9)	1.59	1.36 to 1.86

We considered physically active men who reported 150 min or more of vigorous exertion during a typical week.
Note: 'Healthy' indicates that participants showed no evidence of clinically significant depressive symptoms or cognitive impairment at the follow-up assessment, nor did they show evidence of impairment in basic or instrumental activities of daily living. These analyses excluded participants who were not available for follow-up.
*The analyses were adjusted for age, education, marital status, smoking, alcohol use, body mass, hypertension, diabetes, coronary heart disease and cerebrovascular disease at the time of entry into the study, as well as for marital status, smoking, alcohol use and body mass at the follow-up assessment.

that the association between physical activity and healthy ageing could also be due to reverse causality. In this case, people would be physically active because they are healthy. The prospective design of the study and the statistical adjustment for prevalent morbidities minimises this possibility, as does the evidence that people who were physically inactive at baseline but became active at follow-up increased their chance of healthy ageing. Indeed, the chance of healthy ageing was highest among those who were active at both assessments, which seems consistent with a causal effect of physical activity.

Finally, we acknowledge that our results are restricted to men and that we cannot be certain they would be equally applicable to women, although data from other sources suggest that there are no reasons to believe they should not.[1 4]

Interpretation of findings

After considering the potential caveats of our study, it seems reasonable to ask the question: How does physical activity prolong life and maintain physical and mental function? There is robust observational and trial evidence to support the fact that physical activity decreases the incidence of type 2 diabetes mellitus and cardiovascular events, which are common diseases of older age.[30] Physical activity has also been associated with reduced blood pressure and risk of hypertension,[31 32] improved lipid profile,[33] increased survival and function in people with coronary heart disease,[34] decreased risk of stroke[35] and of some types of cancer,[36] as well as decreased risk of cognitive decline,[37] dementia[38] and depression.[39–41] Our study design prevented us from directly exploring mechanisms that could plausibly explain how physical activity promotes healthy ageing. However, the follow-up of men for an extended period of time, the use of a robust definition of healthy ageing that encompassed both physical function and mental health and our ability to adjust the statistical analyses for known confounding factors adds credence to the validity of our results and those of others.[13]

Given that the association between physical activity and healthy ageing seems to be valid and physiologically plausible, the remaining challenge is to enhance physical activity participation among older people living in the community. Three broad areas should be considered. The first is the creation of environments that are conducive to safe and regular activity: older people have lower risk of depression if they live in more walkable neighbourhoods,[42] particularly those that offer access to safe paths and green areas.[43] The second is the education of those at risk through campaigns and the promotion of events that encourage physical activity, although the effectiveness of such approach has not been tested yet. Third, health professionals must be trained and equipped to implement opportunistic interventions of physical activity for those at risk, although these interventions are likely to affect only a selected group of older people, possibly the most frail in our community.

In conclusion, physical activity increases 10-year to 13-year survival free of functional or mental impairment in later life. As communities worldwide experience a demographic transition towards older age, the number of people disabled by ill health will continue to increase.[44] Our findings indicate that physical activity could play a key role in ensuring that we add healthy life and not only years to our ageing population.

What are the key findings?

- Men aged 65–83 years who are physically active (>150 min/week of vigorous physical activity) are more likely than their counterparts to live an additional 10–13 years.
- Older men who are physically active have greater chance than their counterparts of surviving 10–13 years free of cognitive and functional impairment, as well as of depression.
- Older men who were active and became inactive lost some of the health benefits associated with physical activity. Those who reported <150 min/week of vigorous physical activity and subsequently became active gained health benefits, whereas those who remained physically active benefited the most: 60% increased chance of healthy ageing.

How might these results affect clinical practice in the near future?

- Health promotion messages should remind older adults that it is never too late to become active and to enjoy the health benefits associated with physical activity.
- Whenever feasible, clinicians should encourage physical activity to promote greater longevity and healthy ageing.

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Contributors OPA conceived and designed the experiments. OPA, GJH and LF performed the experiments. OPA analysed the data. OPA and KMK drafted the manuscript. All authors reviewed the manuscript for important intellectual content and approved its submission for publication.

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