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The relation between non-occupational physical activity and years lived with and without disability

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ABSTRACT

Objectives: The effects of non-occupational physical activity were assessed on the number of years lived with and without disability between age 50 and 80 years.

Methods: Using the GLOBE study and the Longitudinal Study of Aging, multi-state life tables were constructed yielding the number of years with and without disability between age 50 and 80 years. To obtain life tables by level of physical activity (low, moderate, high), hazard ratios were derived for different physical activity levels per transition (non-disabled to disabled, non-disabled to death, disabled to non-disabled, disabled to death) adjusted for age, sex and confounders.

Results: Moderate, compared to low non-occupational physical activity reduced incidence of disability (HR 0.66, 95% CI 0.51 to 0.86), increased recovery (HR 1.95, 95% CI 1.32 to 2.87), and represents a gain of disability-free years and a loss of years with disability (male 3.1 and 1.2; female 4.0 and 2.8 years). Performing high levels of non-occupational physical activity further reduced incidence, and showed a higher gain in disability-free years (male 4.1; female 4.7), but a similar reduction in years with disability.

Conclusion: Among 50–80-year-olds promoting physical activity is a fundamental factor to achieve healthy ageing.

In 2025 1.2 billion people worldwide will be aged 60 years and over.[1] Living longer is a societal achievement, but also a source of concern as prevalence of major chronic diseases and disability increase with age. A rising share of older age groups in the population will increase the burden of morbidity and will put an upward pressure on costs. The number of older people with severe disability may be 40% to 75% higher by 2030 because of population ageing.[2] Health and long-term care spending is projected to almost double by 2050 across members of the Organization of Economic Cooperation and Development (OECD). In the approach of "healthy" ageing, however, these consequences might be mitigated.

Physical activity is an important candidate tool to achieve healthy ageing. Physical activity reduces mortality,[3] extends life expectancy[4] and delays the onset of chronic diseases, including cardiovascular disease (CVD), cancer and diabetes.[3–5] Increasing evidence exists that physical activity also delays the onset of disability,[6–22] and increases the chances[8 15 22–24] and duration of recovery from disability.[23]

Although an active lifestyle has been found to increase life expectancy in some studies and to reduce disability in others, its overall effect on health is still largely unknown. There are limited data about the effects of physical activity on the number of years with and without disability and these effects are not easy to predict. The effects of risk factors for both disability and death, such as physical activity, can follow different directions.[25] Therefore, it is unclear whether the extra years gained by engaging in a physically active lifestyle will be free of disability or will add to the time lived with disability.

The aim of this study is to assess the effects of non-occupational physical activity on life expectancy and the number of years lived with and without disability in 50–80-year-olds.

METHODS

Multi-state life tables (MSLTs) were constructed to calculate the number of years with and without disability. A MSLT consists of different states (in this study "non-disabled", "disabled" and "death") that persons can leave and (re)enter.[26] Transition rates were estimated between these states, and the influence of physical activity on these transition rates was assessed by including information on their association (hazard ratios, HR) and the prevalence of physical activity.

Survey design

The primary dataset used was the GLOBE study. GLOBE is the Dutch acronym for Health and Living Conditions in the population of Eindhoven and Surroundings.[27] A postal questionnaire was sent in 1991 to approximately 27 000 Dutch nationals aged 15–74 years living in the city of Eindhoven and surrounding municipalities (response rate 70.3%) This questionnaire was extended with an oral interview in two sub-samples. The first was a random selection of 3529 people from respondents of the postal survey (response rate 79.3%, n = 2800). In the second sub-sample of 3970 respondents, people with diabetes mellitus, heart disease, chronic bronchitis, or chronic back complaints were oversampled (response rate 72.2%, n = 2867). Both sub-samples were followed up in 1993, 1995 and 1997 allowing for 2-year observation intervals. To increase the power of the study, the sub-samples were pooled (n = 5667). Follow-up information was available for 4496 subjects (79.4%, including deaths 81.1%) in 1993, 4105 (72.4%, 76.4%) in 1995 and 4246 (74.9%, 81.4%) in 1997. Data on mortality were obtained from administrative follow-up in municipal population registers.

As the GLOBE study did not comprise persons above age 74 at baseline, the Longitudinal Study of

Aging (LSOA) was used for the estimation of transition rates above age 74. The LSOA started in 1984 and studied residents of the United States of America who were 70 years and over (n = 7527).[28] The complete sample was re-interviewed in 1988 (n = 4984, response 66.2%, 89.0% including deaths) and in 1990 (n = 4142, 55.0%, 87.4%), and a sub-sample in 1986 (n = 4113, 79.8%, 92.4%), also allowing for 2-year observation intervals. Information on mortality was available from linkage with the National Death Index.

Sample population

Of the 5667 respondents of the GLOBE study, 5629 were present at the start of one of the 2-year observation intervals. From these, 3759 subjects were selected who were 50 years and over at the start of the interval. Complete information on disability and mortality at the start and end of the 2-year observation interval was available for 2966 subjects (78.9%; 6160 observation-intervals).

For the LSOA study, of the 7527 respondents, 6491 were present at the start of one of the 2-year observation intervals. There was no selection on age. Complete information on disability and mortality at the start and end of the 2-year observation interval was available for 5547 subjects (85.9%; 10 904 observation intervals).

Disability

Disability was measured using the OECD questionnaire[29] and a questionnaire with additional items on Activities of Daily Living (ADL) and mobility.[30] Subjects were asked whether they were able to get in/out of bed, get in/out of a chair, bathe, dress, lift/carry something, walk up/downstairs, get outside, and walk a quarter of a mile. Similar questions were also included in the LSOA questionnaire. Subjects were asked to assess their level of ability: "with no difficulty", "some difficulty", "a lot of difficulty", "needed help" or "were unable to". Respondents to one or more of the latter three categories were considered disabled.

Physical activity

Questions on physical activity in the 1991 postal survey of the GLOBE study were: (1) time spent daily on walking or biking to shops or work (minutes); (2) time spent weekly on walking, biking or gardening in leisure time (<30 minutes, 30 minutes–1 hour, 1–2 hours, >2 hours); and (3) time spent weekly on sports (<30 minutes, 30 minutes–1 hour, 1–2 hours, >2 hours). If a person reported they did sports, the main type of sport was assessed. Less than 30 minutes per week was regarded as 0, 30 minutes to 1 hour as 50 minutes, 1–2 hours as 90 minutes, and >2 hours as 130 minutes. We calculated a summary measure by multiplying the number of hours (minutes/60) per week with the appropriate Metabolic Equivalent Task-hours (MET value) from the Compendium of physical activity.[31] A MET score of 1 represents the energy spent sitting quietly and is equivalent to 3.5 mL O_2 per kilogram of body weight per hour. A MET score of 4 was used for walking or biking to the shops or work, and for walking, biking or gardening in leisure time.[31] For sports, the MET score corresponding to the main sport was derived from the Compendium.[31] The weekly summary measure of physical activity in the study sample ranged from 0 to 27.8 (90% trimmed range). Based on tertiles, the population was classified into low (<12), moderate (12–17.33) and high (>17.33) physical activity levels.

Potential confounders

All analyses were stratified by, or adjusted for age and sex. Based on the literature,[32] the following variables were considered as potential confounders: education, smoking (never/ever/current), marital status (single/married/widowed/divorced), self-reported diseases at baseline, and psychosocial factors (locus of control/coping/social support). Education was categorised as high (vocational schooling and university), 2 (intermediate vocational or intermediate/higher schooling), 3 (lower vocational or secondary schooling) and low (primary school only). Diseases at baseline comprised any of the following: cancer, CVD, COPD, back complaints, arthritis and neurological diseases. Detailed information on the measurement of these variables is given elsewhere.[33] If the number of missing cases for a confounder exceeded 100, a category was added for missing values to avoid changes in the HRs due to selection of non-missing observations.

Body Mass Index (BMI) was not considered a confounder but an intermediate variable[34], as BMI may represent a step in the causal chain between physical activity, and disability or mortality.

Data analyses

Overall transition rates

Overall transition rates were estimated based on all 17 064 (6160 GLOBE+10 904 LSOA) 2-year observation intervals for the transitions: non-disabled to disabled (incidence), disabled to non-disabled (recovery), non-disabled to death (non-disabled mortality), and disabled to death (disabled mortality). A previous study showed that the GLOBE and LSOA studies could be adequately pooled for the calculation of these transition rates, and that the frequency of disability and mortality in both studies closely represented the Dutch levels.[35] Less than 4% (n = 85) of the respondents experienced the same transition twice. Age-specific transition rates were estimated with Poisson regression using exponential curves to model the association of the transitions with age.

Hazard ratios (HRs)

To assess whether physical activity was associated with each of the transitions, data from the GLOBE study were used with Poisson regression. The effect of potential confounders (education, smoking, marital status, chronic disease at baseline, and psychosocial factors) was analysed by first adjusting for age and sex, and by adding those variables that substantially changed the HRs in the final model (education, chronic disease at baseline). To correct for reverse causation (i.e. lower physical activity levels might have been caused by ill health), the analyses were repeated after excluding the first 2 years' post-measurement of physical activity.

Transition rates by level of physical activity

For each transition the transition rates were estimated by level of physical activity, using the (1) overall transition rates, (2) adjusted HRs (based on the final model and excluding the first 2 years' post-measurement of physical activity), and (3) prevalence of physical activity levels (based on the GLOBE population stratified by age, sex and disability status).[35]

Partial life expectancies by level of physical activity

To calculate the number of years lived with and without disability between age 50 and 80 (i.e. partial life expectancies), separate MSLTs were created for each sex and physical activity

Table 1 Baseline characteristics of the GLOBE study population by levels of physical activity (low, moderate, high, missing)

	Physical activity level‡			
	Low	Moderate	High	Missing
N	891	1239	744	92
Age (mean (SD))	61.9 (7.7)	61.3 (7.2)	59.5 (6.8)	65.7 (7.6)
Women (%)	47	46	53	70
Education (%)				
1 High	12	14	21	5
2	16	16	22	4
3	38	40	42	34
4 Low	32	28	14	38
Missing*	3	2	1	18
Marital status (%)				
Married	80	81	85	58
Single	5	5	3	9
Divorced	6	6	6	13
Widowed	8	7	6	12
Smoking status (%)				
Never	20	25	31	42
Former	39	41	46	32
Current	39	33	22	20
Chronic disease† (%))				
No	37	40	49	27
Yes	61	58	49	68
Missing	2	2	2	4
Disability (%)	28	16	10	45
BMI (mean (SD))	25.5 (3.8)	25.1 (3.1)	24.6 (2.8)	26.5 (2.8)

*Number of subjects with missing education exceeded 100.
†Any of the following self-reported diseases: cardiovascular disease, cancer, COPD, arthritis back complaints, neurological diseases.
‡Based on tertiles, the population was classified into low- (<12), moderate- (12–17.33) and high-physical-activity (>17.33) levels.

category. These MSLTs started at age 50 with a population initially free of disability.

To explore whether the outcomes apply to the elderly population (including those aged 80 and over), the range of effects of physical activity on life expectancy with(out) disability at age 50 were assessed. The HRs for ages 80 and over were assumed to range between those for the age range 50–80 and 1 (no protective effect).

Poisson regression was performed in GLIM (Generalized Linear Interactive Modelling 4 NAG Ltd., Oxford, UK). Normalised weights (with a mean of one) were used to take into account the complex sampling design and non-response (specifically, the overrepresentation of persons with chronic diseases in the GLOBE study and the difference in completeness of information on disability and mortality in both GLOBE and LSOA). Excel was used for the MSLT analyses and Monte Carlo simulation (parametric bootstrapping)[36] in @RISK (Anonymous 2000; MathSoft Inc 1999) to calculate confidence intervals for the number of years with(out) disability and differences herein (10 000 runs).

RESULTS

Baseline characteristics

Respondents in the high-physical-activity group were significantly more likely to have received higher education and be married, and were less likely to be smokers, to have a chronic disease and to have disability, and had an almost 1 kg/m^2 lower BMI as compared with respondents in the low-activity group (table 1).

Hazard ratios for level of physical activity

Moderate physical activity levels, as compared with low levels, were associated with lower chances of incidence and mortality in those who were non-disabled, and with lower chances of mortality and higher chances of recovery once disabled (table 2).

These findings were more pronounced for the highest level of physical activity, although chances of recovery in this group were lower compared with moderate levels. A similar pattern of results was seen in the analyses adjusted solely for age and sex, adjusted for all relevant variables, and excluding the first 2 years' post-measurement of physical activity (table 2).

Numbers of years lived with and without disability

Taking all physical activity levels together, men are expected to live 25.0 years (22.7 without and 2.3 with disability) and women 27.4 years (22.4 without and 5.0 with disability) (data not shown). Those with a moderate physical activity level can expect to live significantly more years free of disability and fewer years with disability, compared with those with low activity levels (table 3). Respondents with high activity levels gained even more years free of disability than those with a moderate level, but showed no further reduction in years living with disability. Although for women, gains in partial life expectancy associated with physical activity were smaller than for men, more years were free of disability (figure 1). Explorative analyses including the oldest old showed that at least moderate activity as compared with low, increased life expectancy free of disability at age 50, but not life expectancy with disability (data available on request).

DISCUSSION

Moderate non-occupational physical activity lowers the rates of incidence of disability and death and increases the rates of recovery from disability in 50–80-year-olds. The overall effect on health being that moderate physical activity contributes to healthy ageing (i.e. extending disability-free years by 3 (men) to 4 (women) years) and fewer years with disability. Compared with moderate levels, higher levels of physical activity increased the number of years free of disability by 25%, but did not change the number of years lived with disability any further.

Recovery from disability was not further enhanced by higher compared with moderate levels of physical activity. This could be attributed to either (1) moderate levels of physical activity being sufficient and attaining the highest possible degree of recovery, (2) higher levels of physical activity provoking other disability, levelling out any gains attained on the initial disability, or (3) that among the disabled those with high levels of physical activity were following a rehabilitation programme and, hence, were subject to "inverse" misclassification.[12]

To our knowledge, this study is one of the first to prospectively study the impact of physical activity on the number of disabled and non-disabled years. Most previous studies evaluated physical activity in combination with other risk factors,[8 37–39] or, if only physical activity was studied, there was no correction for potential confounding.[38] Moreover, prior studies focused on either life expectancy or on a single health state transition.[6 7 12 22 24 40 41] This limits a clear overview as the diverse studies are hard to combine due to differences in the study population, length of follow-up, confounders included, measurement and classification of physical activity and disability. The perspective presented in this study covering all four potential transitions (incidence, recovery, non-disabled and disabled mortality) does provide such an overview.

Table 2 Hazard ratios (95% CI) for the transitions non-disabled to disabled (incidence), disabled to non-disabled (recovery), non-disabled to death (non-disabled mortality), and disabled to death (disabled mortality) by level of physical activity (low, moderate, high) from the GLOBE study

	Transition			
	Non-disabled to disabled (incidence)	Non-disabled to death	Disabled to death	Disabled to non-disabled (recovery)
Including first two years of follow-up				
	Number of events and person years			
Number of events	350	117	106	264
Person-years	9881	9881	2216	2216
Weighted person-years†	13 118	16 792	3601	2589
	Age- and sex-adjusted hazard ratios			
Level of physical activity				
Low	1.00	1.00	1.00	1.00
Moderate	0.75 (0.60 to 0.96)‡	0.71 (0.47 to 1.08)	1.06 (0.70 to 1.58)	1.97 (1.48 to 2.63)‡
High	0.41 (0.30 to 0.56)‡	0.39 (0.23 to 0.69)‡	0.63 (0.27 to 1.45)	1.94 (1.33 to 2.82)‡
Missing	1.12 (0.62 to 2.02)	3.55 (1.77 to 7.15)‡	0.30 (0.08 to 1.06)	1.55 (0.95 to 2.52)
	Multivariate* adjusted hazard ratios			
Level of physical activity				
Low	1.00	1.00	1.00	1.00
Moderate	0.72 (0.57 to 0.92)‡	0.73 (0.48 to 1.11)	1.00 (0.78 to 1.51)	1.98 (1.48 to 2.65)‡
High	0.49 (0.36 to 0.67)‡	0.43 (0.25 to 0.76)‡	0.67 (0.29 to 1.55)	1.64 (1.12 to 2.41)‡
Missing	0.81 (0.44 to 1.47)	2.76 (1.31 to 5.81)‡	0.34 (0.09 to 1.24)	2.03 (1.22 to 3.37)‡
Excluding first two years of follow-up				
	Number of events and person years			
Number of events	294	84	83	148
Person-years	7694	7694	1609	1609
Weighted person-years†	9774	11 938	2613	1787
	Age- and sex-adjusted hazard ratios			
Level of physical activity				
Low	1.00	1.00	1.00	1.00
Moderate	0.69 (0.54 to 0.90)‡	0.70 (0.42 to 1.15)	0.92 (0.58 to 1.47)	1.88 (1.28 to 2.77)‡
High	0.42 (0.30 to 0.58)‡	0.50 (0.27 to 0.94)‡	0.69 (0.28 to 1.67)	1.56 (0.93 to 2.63)
Missing	1.13 (0.61 to 2.11)	4.53 (2.08 to 9.83)‡	0.22 (0.05 to 1.10)	2.02 (1.11 to 3.68)‡
	Multivariate* adjusted hazard ratios			
Level of physical activity				
Low	1.00	1.00	1.00	1.00
Moderate	0.66 (0.51 to 0.86)‡	0.71 (0.42 to 1.18)	0.87 (0.55 to 1.38)	1.95 (1.32 to 2.87)‡
High	0.50 (0.36 to 0.69)‡	0.51 (0.27 to 0.96)‡	0.71 (0.29 to 1.74)	1.32 (0.77 to 2.25)
Missing	0.81 (0.43 to 1.52)	4.43 (1.98 to 9.98)‡	0.25 (0.05 to 1.28)	2.55 (1.36 to 4.77)‡

*Hazard ratios are derived from the GLOBE study and are adjusted for age, sex, education, chronic disease with chronic disease being any of the following: cardiovascular disease, cancer, COPD, arthritis back complaints, neurological diseases.
†Normalised weights (with a mean of one) were to take into account the complex sampling design and non-response.
‡HRs are significant at the 0.05 level.

Certain limitations should be acknowledged. These data are observational and, therefore, randomised trials are required to determine causality between physical activity and longer disability-free lives. Bias might have occurred by confounding or reverse causation. In this study, it was possible to adjust for the most obvious confounders between physical activity and disability (education, marital status, smoking, chronic disease, psychosocial factors) and to exclude the first 2 years' post-measurement of physical activity. While correcting for baseline chronic diseases reduces reverse causation, if chronic diseases are in the causal pathway from physical inactivity to disability or death, it results in an underestimation of the effects of physical activity. However, correction for chronic diseases did not modify the present results. Another potential limitation was the measurement and classification of physical activity. Physical activity was based on self-reported information on the duration and type of physical activity. Hence, if respondents gave socially desirable answers, the effects would be less pronounced compared with other measures of physical activity.[3] There is no reason to expect that physical activity levels are rated differently by disabled versus non-disabled people resulting in *differential* misclassification, apart from disabled people over-estimating their physical activity because of the greater effort experienced.[40] To classify persons into low, moderate and high physical activity levels, values were assigned to each time interval and METS scores to each group of activities. Assigning 0, 40, 75, and 125 minutes, respectively, for the time intervals (<30 minutes, 30 minutes–1 hour, 1–2 hours, >2 hours) and a MET score of 3.5 for walking/biking to work and the shops and walking, biking, gardening, would not change the tertile classification substantially (change of only 2.7% of the cases). Pooling the GLOBE and LSOA studies may also have introduced bias. However, as the LSOA study was used only to obtain transition rates, and prior analyses have shown that both studies together provide valid transition rates for the Netherlands,[35] it is not expected to modify our conclusions. A final limitation is that the analysis is based in some cases on non-significant HRs. However, if these were all set to 1 (i.e. ignoring non-significant effects) the major conclusions did not change (data available on request).

The present findings are in line with studies showing physical activity to reduce mortality[3] and increase life expectancy.[4] The

Table 3 Partial life expectancy at age 50 (in years), total, free of disability and with disability (mean (95%CI)) according to level of physical activity (PA), stratified by sex, from the GLOBE and LSOA study

	Number of years					
	Partial life expectancy		Years free of disability		Years with disability	
	Absolute number	Difference compared to low level of PA	Absolute number	Difference compared to low level of PA	Absolute number	Difference compared to low level of PA
Males						
Level of physical activity						
Low	23.8 (22.8 to 24.8)	Ref	20.7 (19.6 to 21.8)	Ref	3.1 (2.6 to 3.7)	Ref
Moderate	25.7 (24.6 to 26.7)	1.9 (0.3 to 3.4)‡	23.8 (22.7 to 24.8)	3.1 (1.5 to 4.6)‡	1.9 (1.5 to 2.4)	−1.2 (−2.0 to −0.5)‡
High	26.7 (25.0 to 27.9)	2.9 (0.9 to 4.3)‡	24.8 (23.1 to 26.1)	4.1 (2.2 to 5.6)‡	1.9 (1.2 to 2.8)	−1.2 (−2.1 to −0.3)‡
Females						
Level of physical activity						
Low	26.5 (25.8 to 27.2)	Ref	19.3 (18.1 to 20.5)	Ref	7.2 (6.2 to 8.2)	Ref
Moderate	27.7 (27.0 to 28.3)	1.3 (0.3 to 2.1)‡	23.3 (22.1 to 24.4)	4.0 (2.3 to 5.6)‡	4.4 (3.5 to 5.4)	−2.8 (−4.1 to −1.4)‡
High	28.3 (27.2 to 29.0)	1.8 (0.5 to 2.7)‡	24.0 (22.3 to 25.5)	4.7 (2.6 to 6.5)‡	4.3 (3.0 to 5.7)	−2.9 (−4.5 to −1.2)‡

*All life expectancies have been calculated with hazard ratios adjusted for age, sex, education, chronic disease with chronic disease being any of the following: cardiovascular disease, cancer, COPD, arthritis back complaints, neurological diseases, derived from the GLOBE study and overall transition rates derived from the GLOBE and LSOA study.
‡Differences are significant at the 0.05 level.

results agree with a randomised clinical trial showing physical activity to reduce the incidence of disability[7] and other studies that merely focused on this transition.[6–22] Finally, the results are in line with prior studies showing that among those with disability, physical activity reduces mortality[40 41] and increases recovery.[15 24 42]

There are many possible explanations why physical activity would not only prolong life but also reduce the years with disability. Evidence of causal associations and biological plausibility exists for diabetes, CVD, and obesity, and to some extent for osteoporosis and low back pain,[43] which are risk factors of disability.[6 44] Physical activity helps to maintain basic abilities that oppose disability such as improving strength, flexibility and aerobic capacity.[45 46] Furthermore, it prevents psychosocial dysfunction which also generates disability.[47–49]

The present results emphasise the importance of following and promoting a physically active lifestyle among the ageing population. The higher number of years of life lived without disability combined with the fewer years lived with disability in those with higher physical activity levels, suggests that ageing will not necessarily result in a medical and socio-economical burden. Instead, living longer and living more healthily may go hand in hand. Safely raising the levels of physical activity among the elderly will be a crucial step towards achieving healthy ageing.

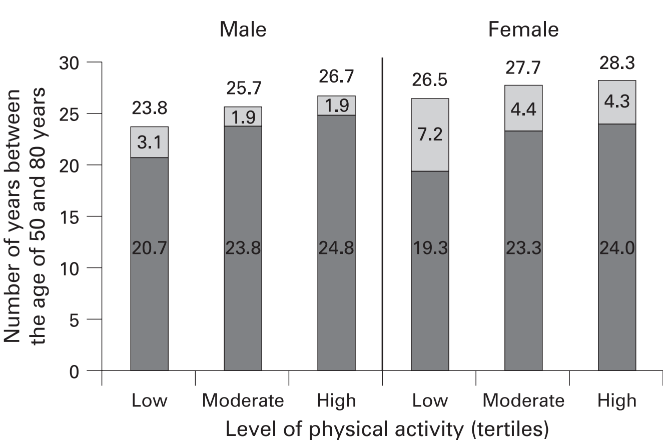

Figure 1 Partial life expectancy, years without and years with disability according to level of physical activity. Total number of years between the age of 50 and 80 (partial life expectancy), years without and years with disability according to level of physical activity. Data are shown for males and females separately. Years without disability are shown in solid grey columns. Years with disability in light grey columns on top of the columns representing the years without disability.

What is already known on this subject

- Physical activity reduces the risks of mortality, chronic diseases and disability.
- It is unknown whether the increased life expectancy is due to an increased number of years with disability and/or disability-free years.

What this study adds

- Among 50–80-year-olds, physical activity extends the number of disability-free years and reduces the number of years with disability.
- Hence, physical activity may reduce the suggested medical and socio-economical burden associated with ageing.

Policy implication

Safely raising the levels of physical activity among the elderly will be a crucial step towards achieving healthy ageing and should be actively advocated.

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