J Nutr Health Aging. 2018;22(2):246-253

PHYSICAL ACTIVITY TYPES AND HEALTH-RELATED QUALITY OF LIFE AMONG MIDDLE-AGED AND ELDERLY ADULTS: THE ROTTERDAM STUDY

C.M. KOOLHAAS[1], K. DHANA[1,2], F.J.A. VAN ROOIJ[1], J.D. SCHOUFOUR[1], A. HOFMAN[1,2], O.H. FRANCO[1]

1. Department of Epidemiology, Erasmus MC, University Medical Center Rotterdam, the Netherlands; 2. Department of Nutrition, Harvard School of Public Health, 677 Huntington Ave, Boston, MA 02115, United States. Corresponding author: Chantal M. Koolhaas, MSc, Department of Epidemiology - Erasmus University Medical Center, PO Box 2040, 3000 CA Rotterdam, The Netherlands, Tel. +31 10 7043484, Email: c.koolhaas@erasmusmc.nl

Abstract: *Objectives:* Physical activity (PA) is associated with health-related quality of life (HRQL). The specific PA types that provide beneficial effects in an older population remain unclear. We assessed the association of total PA, walking, cycling, domestic work, sports and gardening with HRQL in middle-aged and elderly adults. *Design:* Cross-sectional study. *Setting:* Rotterdam, the Netherlands. *Participants:* 5,554 participants, with a mean age of 69 years. *Measurements:* Total PA was categorized in five groups to evaluate the dose-response effect of PA and specific PA types were categorized in tertiles. HRQL was measured with the EuroQoL 5-dimension. The outcome of every HRQL domain (i.e. mobility, self-care, daily activities, pain and mood) was expressed as having any problems versus not having problems. Logistic and linear regression analyses were used, adjusting for confounders, to examine associations of total PA and PA types with HRQL domains. *Results:* In both middle-aged (<65 years) and elderly adults (>65 years), we found a dose-response association between total PA and better HRQL (i.e. lower odds of having problems in HRQL domains). In the middle-aged, sports was the only PA type associated with lower odds of having problems with all HRQL domains. In the elderly, all PA types were associated with less problems with HRQL domains, but cycling contributed most to the beneficial effect. *Conclusions:* Total PA was associated with better HRQL. Sports and cycling were the activity types that contributed most to this association in the middle-aged and elderly, respectively. Since PA levels tend to decline with aging, cycling and sports should be promoted with the aim to improve HRQL.

Key words: Physical activity, cycling, domestic work, quality of life, elderly, Rotterdam Study.

Introduction

Recent studies have shown a consistent association between physical activity (PA) and health-related quality of life (HRQL) (1, 2). HRQL is defined as an individuals' perspective of well-being in physical, mental and social domains of life (3). Previous studies have mainly focused on the effect of overall PA (1, 2), whereas it remains unclear how specific PA types affect quality of life. To be able to make clear and effective public health recommendations, it is important to distinguish between different types of PA (e.g. cycling, walking) and HRQL.

In young adults, performing sports was reported to be associated with better HRQL in 20-70 year old adults (4) and domestic work was positively associated to general health in male university students (5). In men aged 18-55 years old, cycling frequency was associated with higher physical and psychological quality of life (6). However, information among older adults remains scarce. With increasing age, PA levels tend to decrease (7) and PA types in which older adults engage differ markedly from the activities performed by younger adults (8). This raises the question what kind of activities are beneficially associated with HRQL in the middle-aged and elderly. Additionally, because 65 years of age is considered the retirement age in many countries, it is interesting to explore whether different PA types are associated with HRQL before and after retirement age. Moreover, only a few studies have investigated the nature of the dose-response relation between PA and HRQL, with conflicting results and limited information among the elderly (2, 9-11). The Rotterdam study includes adults aged 45 years and older and has previously shown to be a relatively active population (12), which makes it an interesting population to study.

Therefore, we aimed to examine the association between total PA, PA types (walking, cycling, sports, domestic work, and gardening) and HRQL in a middle-aged and elderly population. In addition, we aimed to describe the dose-response relationship between PA and HRQL.

Methods

Study population

This study was embedded within the Rotterdam Study, a prospective population-based cohort in the Netherlands (13). The cohort was initially defined in 1990 (RS-I) and expanded in 2000 (RS-II) and 2005 (RS-III). In 1990 and 2000, all inhabitants aged 55 years and older of Ommoord, a suburb of Rotterdam, were invited to participate. In 2005, all inhabitants aged 45 years and older were invited. For the current study, we used data from participants attending the fifth examination of the original cohort (RS-I-5, between 2009 and 2011; n =2,147; aged 72 to 97 years), participants attending the third

Received November 8, 2016
Accepted for publication January 7, 2017

Published online March 9, 2017, http://dx.doi.org/10.1007/s12603-017-0902-7

examination of the extended cohort (RS-II-3, between 2011 and 2012; n=1,893; aged 64 to 97 years) and participants attending the second examination of the third cohort (RS-III-2, between 2012 and 2014; n=3,122; aged 51 to 92 years) (13, 14). Of this combined total, 5,573 completed both PA and HRQL collection (See Supplementary Figure S1). We did not exclude any participants based on their health status. However, 19 cases were excluded because their PA data was considered unreliable. After exclusion, 5,554 participants were available for the current analysis.

All subjects gave written informed consent, and the study protocol was approved by the medical ethics committee according to the Wet Bevolkingsonderzoek ERGO (Population Study Act Rotterdam Study), executed by the Ministry of Health, Welfare and Sport of The Netherlands. Detailed information on the design of the Rotterdam Study can be found elsewhere (13, 14).

Physical activity assessment

PA levels were assessed with the self-administered LASA Physical Activity Questionnaire (LAPAQ). This questionnaire has been validated in 439 participants from the Longitudinal Aging Study Amsterdam (LASA), in which the LAPAQ was completed twice and participants completed a 7-day activity diary and wore a pedometer for 7 days. The test-retest reliability was reasonably good (0.65–0.75) and the correlations with the pedometer and 7-day diary were 0.56 and 0.68, respectively (15). The LAPAQ contains questions regarding the frequency and duration of walking, cycling, sports, gardening, and housework. Participants were asked how many hours per week they spent in each activity in the past two weeks. Furthermore, the questionnaire provided two questions in which participants could mention other sports they participated in that were not captured by previous questions. Missing values for specific PA questions were imputed using age- and sex-specific means. For example, if participants indicated they participated in walking two times per week, but they did not fill in the walking duration, the age- and sex-specific mean was imputed.

To quantify activity intensity, we used metabolic equivalent of task (MET). MET-values were assigned to all activities in the questionnaire, according to the 2011 updated version of the Compendium of Physical Activities (16). Of all mentioned other activities, 14 (3.8%) were not sports and 16 (4,4%) were not in the compendium (e.g. 'treadmill', 'indoor sports', 'power plate'). For these activities, no MET-values were assigned and they were not used in the analyses.

Finally, we multiplied MET-values of specific activities with time (in hours) per week spent in that activity to calculate MET·hours·week^{-1} in total PA, defined as the sum of cycling, walking, sports, domestic work and gardening, and in every type of PA.

Covariates

Information on covariates was collected through home interviews, using an extensive questionnaire, or obtained at the study center visit, as described previously (17, 18). Briefly, alcohol use was defined as alcohol intake in grams per day. Smoking was divided in three categories: current, former and never. Education was assessed according to the standard classification of education, comparable to the international standard classification of education (19). We assessed living situation as a dichotomous variable describing whether the participant lived alone or not. Information on job status was categorized in employed/unemployed. Height and weight were measured and body mass index (BMI) was calculated (kg/m^2). Finally, comorbidity was defined as the presence of cancer, diabetes, stroke, or coronary heart disease in 2012 and used as a binary variable (yes/no).

Health-related quality of life (HRQL) assessment (Outcome)

HRQL was evaluated using the Dutch version of the EuroQoL, during the home interview. This questionnaire has been validated in 90 participants who completed the questionnaire at baseline and after six months (20), in which the Spearman retest correlation was 0.67. The EuroQoL consists of five dimensions: mobility, self-care, daily activities, pain/discomfort, and mood (i.e. anxiety/depression) (21, 22) and each of the dimensions is assessed based on a single question with three response levels (no problem, some or moderate problems, and extreme problems). For the current study, each dimension was recoded in two levels: no problems versus any problems. Furthermore, the EuroQoL includes a standard vertical 20 cm visual analogue scale (VAS), for recording an individual's rating for their current HRQL.

Statistical analysis

For all PA types, we categorized participants into tertiles based on MET·hours·week^{-1}, because of the non-normal distribution of all PA types. For activities not practiced by more than 60% of the population (cycling, gardening, sports, domestic work), the bottom category for PA levels was no participation and the remaining two categories were divided by using the median (23). The median levels were 6.0, 26.9, 8.0 and 14.9 MET·hours·week^{-1} for cycling, domestic work, gardening and sports, respectively. For total PA, we created five categories, based on percentiles, to examine the dose-response association between total PA and HRQL. The values on which the categories were based are 12.0, 27.5, 53.0 and 88.8 MET·hours·week^{-1}.

Logistic regression models were used to analyze associations between PA (total and per type) with binary HRQL outcomes and linear regression models were used to evaluate the association with the VAS. A lower odds ratio (OR) indicates lower odds of having problems in a particular HRQL domain. We performed separate analyses for middle-aged (≤65 years) and elderly adults (>65 years) because PA might have a different association with HRQL in both age groups (9). Analyses were adjusted for age, sex, living situation, smoking, alcohol consumption, education, job status and comorbidity. For PA types, models were additionally adjusted for the other PA types. The decision to include confounders in the multivariable regression models was based on previous literature or >10%-change of the effect estimate in the crude model (9, 10). Total PA and PA types were entered as categorical variables in the separate models.

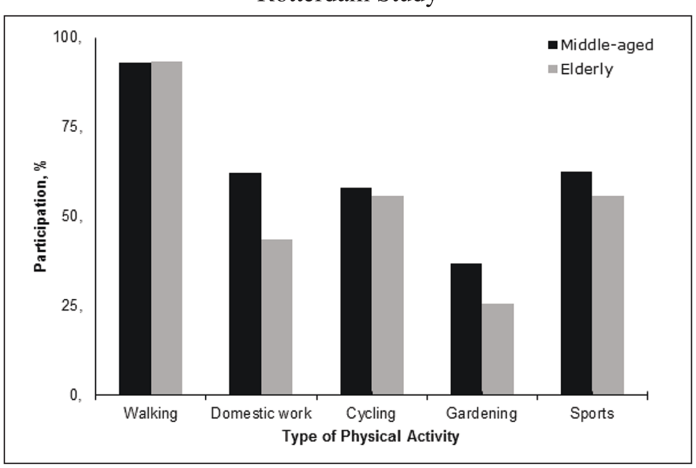
Given prior work, we conducted a sensitivity analysis using stratified models by sex (11). Moreover, 24.6% (n=1,364) was employed at baseline, but we did not collect information on occupational PA. Therefore, we repeated our analyses in non-workers. Finally, we repeated the analysis in participants with and without comorbidity to evaluate whether the association is driven by individuals who are less healthy.

Our data contained 15.2% missing data for alcohol consumption and all other covariates had less than 5% missing data. We used multiple imputation (n=5 imputations) by the Expectation Maximization method. All analyses were conducted using SPSS software version 20 (IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp) and R (3.0.1).

Results

Middle-aged adults participated more often in cycling, domestic work, gardening and sports than elderly adults (Figure 1). Additionally, middle-aged adults reported fewer problems with mobility, self-care and daily activities (Table 1). The number of participants in each group of every PA type is presented in Supplementary Table S1.

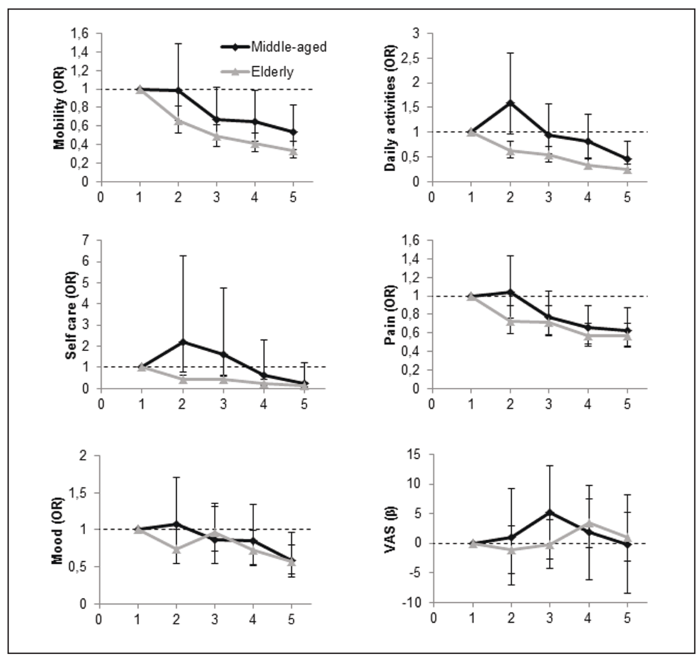
Figure 1
Proportion of participants by physical activity type for the Rotterdam Study



The median (range) of the 5 categories of total PA are 1) 6.0 (<12.0) MET·hours·week-1; 2) 18.8 (12.1-27.5) MET·hours·week-1; 3) 39.3 (27.6-53.0) MET·hours·week-1; 4) 68.2 (53.1-88.8) MET·hours·week-1; 5) 119.9 (>88.8) MET·hours·week-1. The median levels of total PA across categories are therefore equivalent to 13, 40, 84, 146 and 257 minutes per day of total physical activity of 4 METs. There were no associations found with the VAS for any PA variable (Supplementary Table S2).

In both middle-aged and elderly adults, higher total PA was associated with lower odds of having problems with mobility, daily activities and mood (i.e. being anxious or depressed) and with lower odds of having pain (Figure 2). Additionally, total PA was associated with lower odds of having problems with self-care in the elderly. The ORs (95%CI) of the associations between the highest level of total PA, compared to the lowest level of total PA, and having mobility problems were 0.54 (0.35, 0.83) and 0.33 (0.26, 0.43) in middle-aged and elderly adults, respectively. For problems with mood the ORs (95%CI) for the highest level of total PA were 0.59 (0.36, 0.96) and 0.57 (0.41, 0.8) for the middle-aged and elderly, respectively.

Figure 2
Associations between total physical activity groups with quality of life measures in middle aged (≤65 years) and elderly adults (age >65 years)



Abbreviations: OR, odds ratio; VAS, visual analogue scale. Association between five total PA categories and six measures of health-related quality of life. The x-axis represents the 5 levels of total physical activity The median (range) are 1) 6.0 (<12.0) MET·hours·week-1; 2) 18.8 (12.1-27.5) MET·hours·week-1; 3) 39.3 (27.6-53.0) MET·hours·week-1; 4) 68.2 (53.1-88.8) MET·hours·week-1; 5) 119.9 (>88.8) MET·hours·week-1. The median levels of total physical activity across categories are therefore equivalent to 13, 40, 84, 146 and 257minutes per day of total physical activity of 4 metabolic equivalents. The y-axis represents odds ratios (OR) and 95% confidence intervals (95%CIs) of having problems with a quality of life domain, and beta coefficients and their 95%CI for the visual analogue scale. The first total physical activity category is the reference category (i.e. OR = 1 and β=0). Models are adjusted for age, sex, marital status, smoking, alcohol consumption, education, job status, and comorbidity.

Table 1
Baseline Participant Characteristics per Age Group (n=5,554)

	Middle-aged (≤ 65 years)	Elderly (>65 years)
Participants, no	1,819	3,735
Female, no. (%)	1,055 (58.0)	2,143 (57.4)
Age	59.2 (3.7)	74.0 (6.4)
Educational level		
Primary education, no. (%)	122 (6.7)	323 (8.6)
Lower education , no. (%)	573 (31.5)	1,635 (43.8)
Intermediate education, no. (%)	553 (30.4)	1,112 (29.8)
Higher education, no. (%)	571 (31.4)	665 (17.8)
Living with partner, no. (%)	1,455 (80.0)	2,489 (66.6)
Employed, no. (%)	1,134 (62.3)	232 (6.2)
Smoking		
Never, no. (%)	637 (35.0)	1,297 (34.7)
Former, no. (%)	886 (48.7)	2,095 (56.1)
Current, no. (%)	296 (16.3)	343 (9.2)
Alcohol, grams/day	13.3 (14.7)	11.1 (14.1)
BMI		
Underweight (<18.5 kg/m^2), no. (%)	49 (2.7)	60 (1.6)
Normal weight (18.5 – 25.0 kg/m^2), no. (%)	539 (29.6)	980 (26.2)
Overweight (25 – 30 kg/m^2), no. (%)	822 (45.2)	1,825 (48.9)
Obese (≥30 kg/m^2), no. (%)	409 (22.5)	870 (23.3)
Diabetes, no. (%)	166 (9.1)	649 (17.4)
Cancer, no. (%)	166 (9.1)	818 (21.9)
CHD, no. (%)	65 (3.6)	400 (10.7)
Stroke, no. (%)	17 (0.9)	148 (4.0)
Groups of physical activity		
Very low, no. (%)	305 (16.8)	822 (22.0)
Low, no. (%)	350 (19.2)	740 (19.8)
Medium, no. (%)	417 (22.9)	698 (18.7)
High, no. (%)	393 (21.6)	719 (19.3)
Very high, no. (%)	354 (19.5)	756 (20.2)
Total PA, MET·hours·week^{-1}	55.9 (52.1)	54.1 (55.0)
Walking, MET·hours·week^{-1}	11.3 (15.0)	12.2 (14.1)
Cycling, MET·hours·week^{-1}	5.5 (10.5)	4.2 (9.0)
Domestic work, MET·hours·week-1	20.8 (31.3)	20.0 (28.9)
Gardening, MET·hours·week^{-1}	3.7 (10.7)	3.8 (11.5)
Sports, MET·hours·week-1	14.6 (23.8)	14.0 (28.9)
Any problems with mobility, no. (%)	278 (15.3)	967 (25.9)
Any problems with self-care, no. (%)	33 (1.8)	196 (5.2)
Any problems with daily activities, no. (%)	174 (9.6)	526 (14.1)
Any problems with pain, no. (%)	825 (45.4)	1,657 (44.4)
Any problems with mood, no. (%)	223 (12.3)	424 (11.4)
Visual analogue scale	82.1 (53.1)	80.4 (40.1)

Abbreviations: BMI, body mass index; no, number. Numbers are mean (SD), unless otherwise stated.

Regarding PA types, walking was not associated with any HRQL domain in middle-aged adults (Table 2), but with mobility, self-care, daily activities and pain in the elderly (Table 3). For example, in the elderly, the high walking category was associated with 43% lower odds of having problems with mobility (95%CI: 0.47, 0.69), compared to the low category.

Cycling was associated with HRQL in the elderly only (Table 3). Moreover, cycling was the PA type associated with the lowest ORs overall in elderly adults. Compared to low cycling, high cycling was associated with 37% (95%CI: 0.50, 0.78), 57% (95%CI: 0.24, 0.77), 58% (95%CI: 0.30, 0.59) and 33% (95%CI: 0.56, 0.80) lower odds of having problems with mobility, self-care, daily activities and pain, respectively.

We found domestic work to be associated with pain in middle-aged adults (Table 2) and with mobility, self-care, daily activities and pain in the elderly (Table 3). For example, in the middle-aged, medium domestic work was associated with 27% lower odds of having pain (95%CI: 0.57, 0.93), compared to the low category.

For gardening we found significant associations with HRQL domains in both middle-aged and elderly adults (Table 2-3). For example, high gardening was associated with 57% (95%CI: 0.21, 0.88) and 38% (95%CI: 0.41-0.92) lower odds of having problems with daily activities in middle-aged and elderly adults, respectively.

We found sports to be associated with better mobility and less pain in both age groups and with better self-care, daily activities and mood in middle-aged adults (Table 2). Moreover, it was the PA type with the most associations with HRQL domains in the middle-aged. In this age group, compared to low sports, high sports was associated with 41% (95%CI: 0.41, 0.85), 82% (95%CI: 0.04, 0.84), 60% (95%CI: 0.24, 0.66), 44% (95%CI: 0.43, 0.72) and 34% (95%CI: 0.45, 0.99) lower odds of having problems with mobility, self-care, daily activities, pain and mood, respectively (Table 2).

In our sensitivity analyses by gender, employment status and presence of comorbidity, our findings did not materially change (Supplementary Table S3 - S12).

Discussion

In this population-based cohort of middle-aged and elderly adults, we found a dose-response relation between total PA and better HRQL. Additionally, we found that sport was associated with better mobility, self-care, daily activities, mood and less pain in middle-aged adults, whereas cycling was associated strongest with these HRQL domains in the elderly.

Only a few studies have investigated the nature of the dose-response relation between PA and HRQL, and have reported conflicting results (2, 9-11). A systematic review among adults aged <65 years suggested that there might be optimal levels of PA, and any PA below or above this threshold might not have additional benefits on HRQL (2). In contrast, two

Table 2
Odds ratios and their 95% confidence intervals for quality of life scores in middle-aged adults (≤ 65 years) for all physical activity types, the Rotterdam Study, 2009-2014 (n= 1,819)

		Mobility		Self-care		Daily activities		Pain		Mood	
	Median MET·hours·week^{-1} (range)	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Walking[a]											
Low	2.3 (<4.5)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	7.9 (4.5-12.0)	0.91	(0.66, 1.25)	1.38	(0.61, 3.1)	0.95	(0.64, 1.41)	1.02	(0.82, 1.28)	0.95	(0.68, 1.33)
High	21.0 (≥12.1)	1.00	(0.72, 1.38)	0.55	(0.2, 1.54)	1.04	(0.69, 1.56)	0.88	(0.69, 1.12)	0.76	(0.53, 1.11)
Cycling[b]											
Low	0 (0)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	3.0 (0-6.0)	1.03	(0.76, 1.40)	1.11	(0.47, 2.63)	1.06	(0.73, 1.53)	1.03	(0.82, 1.29)	1.00	(0.71, 1.40)
High	12.0 (≥6.1)	0.81	(0.57, 1.14)	1.63	(0.65, 4.05)	0.68	(0.44, 1.06)	0.82	(0.64, 1.04)	0.93	(0.65, 1.35)
Domestic work[c]											
Low	0 (0)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	12.3 (0-26.9)	0.75	(0.53, 1.05)	0.99	(0.41, 2.39)	0.99	(0.65, 1.50)	0.73	(0.57, 0.93)	0.82	(0.56, 1.18)
High	45.9 (≥27.0)	0.74	(0.52, 1.05)	0.67	(0.24, 1.90)	1.15	(0.75, 1.77)	0.81	(0.63, 1.05)	0.81	(0.56, 1.18)
Gardening[d]											
Low	0 (0)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	4.0 (0-8.0)	0.63	(0.44, 0.89)	1.14	(0.48, 2.70)	0.80	(0.54, 1.20)	0.90	(0.72, 1.14)	1.05	(0.74, 1.49)
High	16.0 (≥8.1)	0.84	(0.54, 1.31)	0.31	(0.04, 2.36)	0.43	(0.21, 0.88)	1.08	(0.79, 1.48)	1.25	(0.79, 1.97)
Sports[e]											
Low	0 (0)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	7.6 (0-14.9)	0.94	(0.67, 1.31)	1.32	(0.56, 3.11)	1.15	(0.77, 1.72)	0.82	(0.64, 1.05)	0.96	(0.67, 1.39)
High	29.0 (≥15.0)	0.59	(0.41, 0.85)	0.18	(0.04, 0.84)	0.40	(0.24, 0.66)	0.56	(0.43, 0.72)	0.66	(0.45, 0.99)

Abbreviations: CI, confidence interval; OR, odds ratio; Ref, referent; Odds ratios below 0 indicate lower odds of having problems in that domain; Models are adjusted for age, sex, marital status, smoking, alcohol consumption, education, job status, comorbidity and the other physical activity types; a. Walking is equivalent to 3.0 METs. The median levels of walking across categories are therefore equivalent to 6, 23 and 60 minutes per day of walking; b. Cycling is equivalent to 4.0 METs. The median levels of walking across categories are therefore equivalent to 0, 6 and 26 minutes per day of walking; c. Average domestic work is equivalent to 3.5 METs.(16) The median levels of domestic work across categories are therefore equivalent to 0, 30 and 111 minutes per day of domestic work; d. Gardening is equivalent to 4.0 METs. The median levels of gardening across categories are therefore equivalent to 0, 9 and 34 minutes per day of gardening; e. Sports can consist of different intensities. The median levels of sports across categories are therefore equivalent to 0, 13 and 50 minutes per day of sports of 5 METs.

studies in middle-aged adults found a linear trend between PA and HRQL (10, 11). Finally, a study from the Australian Longitudinal Study on Women's Health, in middle-aged and elderly women (aged 50-81 years), found that improvements in HRQL were observed at very low levels of PA and continued up to higher levels, after which increases were less marked for some outcomes, like the physical component summary and physical functioning (9). In agreement with this study, we found that the odds of having problems with HRQL domains decreased with increasing total PA levels in both middle-aged and elderly adults. In the elderly, the decreases were observed at the lowest PA levels and continued up to the highest level, but were less marked. In middle-aged participants, the odds of having problems with HRQL domains declined less rapidly with increasing total PA levels. Due to the cross-sectional nature of the studies, we cannot comment on the direction of the association between PA and HRQL. It is unclear whether physically active individuals experience a better HRQL or that people with a better HRQL are more likely to be physically active. In this regard, it is plausible that lower odds of having pain lead to higher levels of sports participation, but it could also be that higher sports participation leads to lower odds of having pain problems. Data from randomized controlled trials indicate that exercise has a positive effect on quality of life in older adults with insomnia (24) and minor depression (25) and can reduce pain among individuals with osteoarthritis (26, 27). In addition, a recent randomized controlled trial in frail elderly adults indicated that an activity oriented intervention program (e.g. training of functions and skills) could aid in improving physical functioning and vitality, although these results did not reach significance (28). Moreover, longitudinal studies suggest that increases in PA levels are associated with improvements in physical functioning and vitality scores (9, 29), indicating that PA patterns are an important determinant of HRQL.

Our study included both middle-aged (≤65 years) and elderly adults (>65 years). In the Netherlands, 65 years is considered retirement age, and different PA patterns for these groups are therefore expected. We found that walking was associated with

Table 3
Odds ratios and their 95% confidence intervals for quality of life scores in elderly adults (> 65 years) for all physical activity types, the Rotterdam Study, 2009-2014 (n= 3,735)

		Mobility		Self-care		Daily activities		Pain		Mood	
	Median MET·hours·week^{-1} (range)	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Walking[a]											
Low	2.3 (<4.5)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	7.9 (4.5-12.0)	0.74	(0.61, 0.89)	0.48	(0.34, 0.69)	0.61	(0.48, 0.77)	0.87	(0.74, 1.03)	0.81	(0.63, 1.04)
High	21.0 (≥12.1)	0.57	(0.47, 0.69)	0.44	(0.31, 0.64)	0.55	(0.43, 0.70)	0.81	(0.69, 0.96)	0.83	(0.65, 1.06)
Cycling[b]											
Low	0 (0)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	3.0 (0-6.0)	0.61	(0.49, 0.76)	0.34	(0.19, 0.60)	0.4	(0.29, 0.54)	0.71	(0.60, 0.85)	0.82	(0.62, 1.08)
High	12.0 (≥6.1)	0.63	(0.50, 0.78)	0.43	(0.24, 0.77)	0.42	(0.30, 0.59)	0.67	(0.56, 0.80)	0.80	(0.60, 1.08)
Domestic work[c]											
Low	0 (0)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	14.5 (0-26.9)	0.84	(0.68, 1.02)	0.93	(0.63, 1.37)	0.99	(0.76, 1.27)	0.82	(0.69, 0.98)	0.94	(0.71, 1.22)
High	47.2 (≥27.0)	0.65	(0.53, 0.80)	0.60	(0.38, 0.96)	0.61	(0.46, 0.81)	0.79	(0.67, 0.94)	0.80	(0.61, 1.04)
Gardening[d]											
Low	0 (0)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	4.0 (0-8.0)	0.81	(0.62, 1.05)	0.57	(0.30, 1.08)	0.58	(0.40, 0.85)	0.78	(0.64, 0.97)	1.16	(0.85, 1.58)
High	17.8 (≥8.1)	0.86	(0.66, 1.13)	0.46	(0.21, 1.00)	0.62	(0.41, 0.92)	1.13	(0.92, 1.40)	0.77	(0.53, 1.11)
Sports[e]											
Low	0 (0)	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Moderate	6.8 (0-14.9)	0.97	(0.79, 1.18)	1.09	(0.73, 1.64)	1.17	(0.91, 1.51)	0.89	(0.75, 1.06)	0.91	(0.70, 1.19)
High	30.5 (≥15.0)	0.68	(0.54, 0.87)	1.10	(0.64, 1.89)	0.75	(0.53, 1.05)	0.71	(0.59, 0.86)	0.77	(0.56, 1.04)

Abbreviations: CI, confidence interval; OR, odds ratio; Ref, referent; Odds ratios below 0 indicate lower odds of having problems in that domain; Models are adjusted for age, sex, marital status, smoking, alcohol consumption, education, job status, comorbidity and the other physical activity types; a. Walking is equivalent to 3.0 METs. The median levels of walking across categories are therefore equivalent to 6, 23 and 60 minutes per day of walking; b. Cycling is equivalent to 4.0 METs. The median levels of walking across categories are therefore equivalent to 0, 6 and 26 minutes per day of walking; c. Average domestic work is equivalent to 3.5 METs.(16) The median levels of domestic work across categories are therefore equivalent to 0, 35 and 114 minutes per day of domestic work; d. Gardening is equivalent to 4.0 METs. The median levels of gardening across categories are therefore equivalent to 0, 9 and 38 minutes per day of gardening; e. Sports can consist of different intensities. The median levels of sports across categories are therefore equivalent to 0, 12 and 52 minutes per day of sports of 5 METs.

lower odds of having problems with mobility, self-care, daily activities and pain in elderly participants, but not in the middle-aged. This resembles results from a recent study, that found stronger associations of walking with the mental component summary, physical functioning, mental health and vitality in older compared to middle-aged women (9). Another study in adults aged 75 years and older reported that older persons who attained recommended levels of walking had better results in most aspects of HRQL (30). Moreover, a walking intervention among older individuals has shown beneficial effects on physical and mental HRQL (31). The fact that in the current study walking was only associated with HRQL in the elderly participants might be explained by the relative importance of this activity type among the elderly, whereas they participated less in other PA types (32).

We found that a high level of cycling was associated with fewer problems with daily activities, mobility, self-care and pain in the elderly, but not in middle-aged adults. We are not aware of another study evaluating the association between cycling and HRQL in elderly adults. Even so, a study in Australian men, aged 18-55 years, found a beneficial association between cycling frequency and psychological well-being (6). The fact that we found no association between cycling and HRQL in middle-aged adults might be explained by the fact that in contrast to Australia, cycling is a common way of commuting in the Netherlands, instead of a solely a form of sports. Indeed, a large proportion of participants in our study participated in cycling on a weekly basis (57.5% of middle-aged and 39.8% of elderly).

We found an association between gardening and HRQL that has not been reported before. Since gardening can be considered a relaxing activity, this might explain the positive association. Moreover, being outside might contribute to the effect as well. It is possible that sunlight exposure during gardening increased vitamin D levels, which consequently improved quality of life (33). Furthermore, in literature, the association between domestic work and HRQL remains unclear. A study in younger adults reported an inverse association (34), whereas domestic work was positively related to HRQL in university students (5). Our study indicates that domestic work is associated with better HRQL in middle-aged and elderly adults.

Sports is an activity type that has been reported to be associated with HRQL in middle-aged adults (4). In our study, we found that it was associated with lower odds of having problems with all HRQL-aspects in middle-aged adults, whereas it was only associated with better mobility and less pain in elderly adults. Probably, elderly adults engage in different kinds of sports than their middle-aged counterparts. Indeed, we found that younger adults engage more in high intensity activities like tennis and jogging, whereas elderly participated more in gymnastics, bowls and billiards (data not shown). Additionally, sports made up 20% of the total MET·hours·week^{-1} in middle-aged adults and 15% of the MET·hours·week^{-1} in the elderly.

Major strengths of our study were the use of a large community-based cohort and the categorization of participants into broad range of PA categories, to facilitate the examination of dose-response relationships. Furthermore, we included a number of different activities while adjusting for the remaining activities, which enabled us to examine their independent associations with HRQL. However, our study has some limitations worth mentioning: because of the cross-sectional design, the influence of PA on HRQL could not be determined. It is possible that PA influenced HRQL, but it is also possible that people with lower HRQL are less likely to engage in PA. Second, it may be hypothesized that people in poor health participate in PA less than others, creating the opportunity for reverse causation. Although we did not find that results were influenced by comorbidity. Furthermore, we had data on cancer, cardiovascular disease and diabetes up to 2012, whereas we collected data on PA and HRQL for RS-III (n=1,893) between 2012 and 2014. It is possible that part of the observed associations might be explained presence of comorbidities that presented after 2012. Therefore, we cannot fully exclude the possibility of residual confounding by comorbidities. Another limitation is that our results are based on self-reported PA and HRQL. Although our questionnaires have shown to be valid and reliable (15, 35) potential recall bias and social desirability cannot be excluded.

In summary, sport was the PA type with most associations with HRQL in middle-aged adults, whereas activities with lower intensity, like walking, cycling and domestic work, were more important in elderly adults. These results suggest that different activities could be promoted to different age groups, to improve HRQL. Future research, involving trials or studies with longitudinal designs, could provide more insight about the characteristics of specific PA types beneficially related with HRQL in different populations.

Acknowledgements: CK, KD, FvR, JS, OHF and AH participated actively in each of the following aspects for this article: conception and design or analysis and interpretation of data; drafting the article or revising it critically for important intellectual content and final approval of the version to be published. The Rotterdam Study is funded by Erasmus MC and Erasmus University, Rotterdam, the Netherlands; the Netherlands Organisation for Scientific Research (NWO); the Netherlands Organisation for the Health Research and Development (ZonMw); the Research Institute for Diseases in the Elderly (RIDE); the Ministry of Education, Culture and Science; the Ministry for Health, Welfare and Sports; the European Commission (DG XII) and the Municipality of Rotterdam. OHF works in ErasmusAGE, a centre for aging research across the life course funded by Nestlé Nutrition (Nestec Ltd); Metagenics Inc and AXA. Nestlé Nutrition (Nested Ltd), Metagenics Inc and AXA had no role in design and conduct of the study; collection, management, analysis and interpretation of the data and preparation, review or approval of the manuscript. The authors gratefully acknowledge the study participants, the staff from the Rotterdam Study and the participating general practitioners and pharmacists of the Ommoord district.

Conflict of interest: none declared.

Ethical standard: The study protocol was approved by the medical ethics committee according to the Wet Bevolkingsonderzoek ERGO (Population Study Act Rotterdam Study), executed by the Ministry of Health, Welfare and Sport of The Netherlands.

References

1. Vagetti GC, Barbosa Filho VC, Moreira NB, Oliveira V, Mazzardo O, Campos W. Association between physical activity and quality of life in the elderly: a systematic review, 2000-2012. Rev Bras Psiquiatr. 2014 Jan-Mar;36(1):76-88.
2. Bize R, Johnson JA, Plotnikoff RC. Physical activity level and health-related quality of life in the general adult population: a systematic review. Prev Med. 2007 Dec;45(6):401-415.
3. Berzon R, Hays RD, Shumaker SA. International use, application and performance of health-related quality of life instruments. Qual Life Res. 1993 Dec;2(6):367-368.
4. Kim I, Choi H, Davis AH. Health-related quality of life by the type of physical activity in Korea. J Community Health Nurs. 2010 Apr;27(2):96-106.
5. Pedisic Z, Rakovac M, Titze S, Jurakic D, Oja P. Domain-specific physical activity and health-related quality of life in university students. Eur J Sport Sci. 2014;14(5):492-499.
6. Crane M, Rissel C, Standen C, Greaves S. Associations between the frequency of cycling and domains of quality of life. Health Promot J Austr. 2014 Dec;25(3):182-185.
7. Sun F, Norman IJ, While AE. Physical activity in older people: a systematic review. BMC Public Health. 2013;13:449.
8. Dong L, Block G, Mandel S. Activities Contributing to Total Energy Expenditure in the United States: Results from the NHAPS Study. Int J Behav Nutr Phys Act. 2004 Feb 12;1(1):4.
9. Heesch KC, van Uffelen JG, van Gellecum YR, Brown WJ. Dose-response relationships between physical activity, walking and health-related quality of life in mid-age and older women. J Epidemiol Community Health. 2012 Aug;66(8):670-677.
10. Vuillemin A, Boini S, Bertrais S, et al. Leisure time physical activity and health-related quality of life. Prev Med. 2005 Aug;41(2):562-569.
11. Wendel-Vos GC, Schuit AJ, Tijhuis MA, Kromhout D. Leisure time physical activity and health-related quality of life: cross-sectional and longitudinal associations. Qual Life Res. 2004 Apr;13(3):667-677.
12. Koolhaas CM, Dhana K, Golubic R, et al. Physical Activity Types and Coronary Heart Disease Risk in Middle-Aged and Elderly Persons: The Rotterdam Study. Am J Epidemiol. 2016 Apr 15;183(8):729-738.
13. Hofman A, Brusselle GG, Darwish Murad S, et al. The Rotterdam Study: 2016 objectives and design update. Eur J Epidemiol. 2015 Aug;30(8):661-708.
14. Hofman A, Darwish Murad S, van Duijn CM, et al. The Rotterdam Study: 2014 objectives and design update. Eur J Epidemiol. 2013 Nov;28(11):889-926.
15. Stel VS, Smit JH, Pluijm SM, Visser M, Deeg DJ, Lips P. Comparison of the LASA Physical Activity Questionnaire with a 7-day diary and pedometer. J Clin Epidemiol. 2004 Mar;57(3):252-258.
16. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc. 2011 Aug;43(8):1575-1581.
17. Kavousi M, Elias-Smale S, Rutten JH, et al. Evaluation of newer risk markers for coronary heart disease risk classification: a cohort study. Ann Intern Med. 2012 Mar 20;156(6):438-444.
18. Koller MT, Leening MJ, Wolbers M, et al. Development and validation of a coronary risk prediction model for older U.S. and European persons in the Cardiovascular Health Study and the Rotterdam Study. Ann Intern Med. 2012 Sep 18;157(6):389-397.
19. United Nations Educational SaCOUISCoEI. 1976.
20. Brazier JE, Walters SJ, Nicholl JP, Kohler B. Using the SF-36 and Euroqol on an elderly population. Quality of Life Research. [journal article]. 1996;5(2):195-204.
21. EuroQol G. EuroQol--a new facility for the measurement of health-related quality of life. Health Policy. 1990 Dec;16(3):199-208.
22. Brooks R. EuroQol: the current state of play. Health Policy. 1996 Jul;37(1):53-72.
23. Sabia S, Dugravot A, Kivimaki M, Brunner E, Shipley MJ, Singh-Manoux A. Effect

of intensity and type of physical activity on mortality: results from the Whitehall II cohort study. Am J Public Health. 2012 Apr;102(4):698-704.
24. Reid KJ, Baron KG, Lu B, Naylor E, Wolfe L, Zee PC. Aerobic exercise improves self-reported sleep and quality of life in older adults with insomnia. Sleep Med. 2010 Oct;11(9):934-940.
25. Singh NA, Clements KM, Fiatarone MA. A randomized controlled trial of the effect of exercise on sleep. Sleep. 1997 Feb;20(2):95-101.
26. Gina B, Pierre G, Pierre-Michel R, et al. Comparison of a Group- versus a Home-Based Exercise Program in Osteopenic Women. Journal of Aging and Physical Activity. 1996;4(2):151-164.
27. Rejeski WJ, Ettinger WH, Jr., Martin K, Morgan T. Treating disability in knee osteoarthritis with exercise therapy: a central role for self-efficacy and pain. Arthritis Care Res. 1998 Apr;11(2):94-101.
28. De Vriendt P, Peersman W, Florus A, Verbeke M, Van de Velde D. Improving Health Related Quality of Life and Independence in Community Dwelling Frail Older Adults through a Client-Centred and Activity-Oriented Program. A Pragmatic Randomized Controlled Trial. J Nutr Health Aging. 2016 Jan;20(1):35-40.
29. Wolin KY, Glynn RJ, Colditz GA, Lee IM, Kawachi I. Long-term physical activity patterns and health-related quality of life in U.S. women. Am J Prev Med. 2007 Jun;32(6):490-499.
30. Horder H, Skoog I, Frandin K. Health-related quality of life in relation to walking habits and fitness: a population-based study of 75-year-olds. Qual Life Res. 2013 Aug;22(6):1213-1223.
31. Okamoto N, Nakatani T, Morita N, Saeki K, Kurumatani N. Home-based walking improves cardiopulmonary function and health-related QOL in community-dwelling adults. Int J Sports Med. 2007 Dec;28(12):1040-1045.
32. Shephard RJ. What is the optimal type of physical activity to enhance health? Br J Sports Med. 1997 Dec;31(4):277-284.
33. Tepper S, Dabush Y, Shahar DR, Endevelt R, Geva D, Ish-Shalom S. Vitamin D Status and Quality of Life in Healthy Male High-Tech Employees. Nutrients. 2016 Jun 15;8(6).
34. Jurakic D, Pedisic Z, Greblo Z. Physical activity in different domains and health-related quality of life: a population-based study. Qual Life Res. 2010 Nov;19(9):1303-1309.
35. Uyl-de Groot CA, Rutten FF, Bonsel GJ. Measurement and valuation of quality of life in economic appraisal of cancer treatment. Eur J Cancer. 1994;30A(1):111-117.