Physical Activity Levels, Correlates, and All-Cause Mortality Risk in People Living With Different Health Conditions

Marks-Vieveen, Jenny M; Uijtdewilligen, Léonie; Motazedi, Ehsan; Stijnman, Dominique P M; van den Akker-Scheek, Inge; Bouma, Adrie J; Buffart, Laurien M; de Groot, Vincent; de Hollander, Ellen; Jelsma, Judith G M

Published in:
Journal of Physical Activity and Health

DOI:
10.1123/jpah.2023-0387

Journal of Physical Activity and Health, 2024, 21, 394-404
https://doi.org/10.1123/jpah.2023-0387

Human Kinetics
ORIGINAL RESEARCH

Physical Activity Levels, Correlates, and All-Cause Mortality Risk in People Living With Different Health Conditions

Jenny M. Marks-Vieveen,[1,2,3] Léonie Uijtdewilligen,[1,2] Ehsan Motazedi,[1,2] Dominique P.M. Stijnman,[4] Inge van den Akker-Scheek,[5] Adrie J. Bouma,[6] Laurien M. Buffart,[7] Vincent de Groot,[8] Ellen de Hollander,[9] Judith G.M. Jelsma,[1,2] Johan de Jong,[10,11] Helco G. van Keeken,[11] Leonie A. Krops,[6] Marike van der Leeden,[8] Stephan A. Loer,[3] Willem van Mechelen,[1,2] Femke van Nassau,[1,2] Joske Nauta,[1,2] Evert Verhagen,[1] Wanda Wendel-Vos,[9] Lucas H.V. van der Woude,[11] Johannes Zwerver,[11,12] Rienk Dekker,[6] and Hidde P. van der Ploeg[1,2]

[1]Department of Public and Occupational Health, Amsterdam UMC, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands; [2]Amsterdam Public Health Research Institute, Amsterdam, The Netherlands; [3]Department of Anesthesiology, Amsterdam UMC, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands; [4]Department of Geriatrics, Research Institute for Medical Innovation, Radboud University Medical Center, Nijmegen, The Netherlands; [5]Department of Orthopedics, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; [6]Department of Rehabilitation, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; [7]Department of Medical BioSciences, Research Institute for Medical Innovation, Radboud University Medical Center, Nijmegen, The Netherlands; [8]Department of Rehabilitation Medicine and Amsterdam Movement Sciences, Amsterdam UMC, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands; [9]National Institute for Public Health and the Environment, Bilthoven, The Netherlands; [10]School of Sport Studies, Hanze University of Applied Sciences, Groningen, The Netherlands; [11]Department of Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; [12]Department of Sports Medicine, Gelderse Vallei Hospital, Ede, The Netherlands

Background: To better understand physical activity behavior and its health benefits in people living with health conditions, we studied people with and without 20 different self-reported health conditions with regard to (1) their physical activity levels, (2) factors correlated with these physical activity levels, and (3) the association between physical activity and all-cause mortality. ***Methods:*** We used a subsample (n = 88,659) of the Lifelines cohort study from the Netherlands. For people living with and without 20 different self-reported health conditions, we studied the aforementioned factors in relation to physical activity. Physical activity was assessed with the Short Questionnaire to Assess Health-Enhancing Physical Activity Questionnaire, and mortality data were obtained from the Dutch death register. ***Results:*** People with a reported health condition were less likely to meet physical activity guidelines than people without a reported health condition (odds ratios ranging from 0.55 to 0.89). Higher body mass index and sitting time, and lower self-rated health, physical functioning, and education levels were associated with lower odds of meeting physical activity guidelines across most health conditions. Finally, we found a protective association between physical activity and all-cause mortality in both people living with and without different health conditions. ***Conclusion:*** People living with different health conditions are generally less physically active compared with people living without a health condition. Both people living with and without self-reported health conditions share a number of key factors associated with physical activity levels. We also observed the expected protective association between physical activity and all-cause mortality.

Keywords: chronic disease, physical (in)activity, sedentariness, preventive care

Lack of physical activity is one of the greatest public health challenges of our time. An inactive lifestyle increases the risk of numerous lifestyle-related noncommunicable diseases, including obesity, diabetes, cardiovascular diseases osteoarthritis, and several forms of cancer.[1] An estimated 6% to 10% of all deaths from major noncommunicable diseases are due to physical inactivity.[2] Compared with the healthy population, less is known about the levels, correlates, and health benefits of physical activity in people living with a health condition.

When the World Health Organization[3] updated its global guidelines on physical activity and sedentary behavior in 2020, for the first time, they specifically included guidelines for adults living with chronic conditions, as well as for people living with disability.[4] However, one of the conclusions from the guidelines committee was that the evidence base for people living with a chronic disease and/or disability is relatively narrow, and much of the guidelines is based on extrapolation from the evidence from general, population-based cohort studies. The latest Lancet special issue[5] on physical activity also showed a lack of high-quality research on physical activity in people living with disabilities. Since people living with disabilities often suffer from underlying chronic diseases, it is even more important to focus on this research gap.[4,6] This is especially true since a physically active lifestyle is likely to have health benefits for people living with chronic

van der Ploeg https://orcid.org/0000-0002-3719-5249
Marks-Vieveen (jenny.vieveen@amsterdamumc.nl) is corresponding author, https://orcid.org/0000-0002-6556-8962

conditions, though at the same time, there are more barriers to be expected. A physically active lifestyle not only helps to prevent the worsening of disease, but can also improve daily functioning and quality of life, and is associated with improved mental well-being and attributes to manage the existing health condition.[7]

As the number of people with chronic diseases continues to grow, the challenges we face to take care of this population puts a massive strain on our health care system, globally.[8,9] For example, while in the 1970s 1 out of 12 working people in the Netherlands held a job in health care, nowadays the number is 2 out of 10. And if the way we approach health care will not change, in 2060 one-third of our workforce will need to be employed in health care to treat all patients.[10] Not only will we need more professionals working in health care, but we will also be confronted with loss of productivity through absenteeism and presentism due to chronic diseases. Taking all the aforementioned challenges into account, it is of high importance that we not only focus on preventing people from developing chronic diseases but also on keeping people suffering from chronic diseases as healthy as possible. With its broad range of (health) benefits, physical activity has an important role in keeping people living with different health conditions relatively healthy and participating in society.

To better understand physical activity behavior and its health benefits in people living with chronic diseases, we studied participants with 20 different health conditions from the large prospective cohort Lifelines study. Our aim was to study people living with or without different health conditions with regard to (1) their physical activity levels, (2) the factors correlated with these physical activity levels, and (3) the association between physical activity and all-cause mortality.

Methods

Design

The current study is a secondary analysis of the Lifelines prospective cohort study. Lifelines is a multidisciplinary prospective population-based cohort study examining in a unique 3-generation design the health and health-related behaviors of 167,729 persons living in the North of the Netherlands. It employs a broad range of investigative procedures in assessing the biomedical, sociodemographic, behavioral, physical, and psychological factors that contribute to the health and disease of the general population, with a special focus on multimorbidity and complex genetics.[11] The Lifelines cohort study was set up to gain insight into the etiology of healthy aging.[12] Participants were recruited by their general practitioners. Exclusion criteria were having a terminal illness with a life expectancy below 5 years, having a severe mental illness through which participants were not fully capable of making rational decisions, not being able to visit the general practitioner, not being able to fill in questionnaires, and not being able to understand the Dutch language. For our analyses, we only included adults (18 y or older). All participants provided written informed consent before enrollment into the Lifelines cohort study. The Lifelines study protocol was approved by the Medical Ethical Review Committee of the University Medical Center Groningen (reference number 2007/152).[13]

Measurements

The Lifelines baseline assessment was performed between 2007 and 2013. The second assessment, on average 46 months after the baseline assessment, was performed between 2014 and 2017. At both the baseline and second assessment, participants filled in multiple questionnaires and were seen at a location of the participant's preference, for in-person measurements, including anthropometrics.[14]

Physical Activity and Sitting Time

Physical activity levels were measured with the validated Short Questionnaire to Assess Health-Enhancing Physical Activity (SQUASH).[15] Using SQUASH, participants were asked about their habitual physical activity (frequency, duration, and intensity) addressing the main domains of physical activity (commuting, leisure time, household, and education/work). SQUASH was used to assess total physical activity levels expressed as minutes of moderate to vigorous physical activity in minutes per week, as well as reaching the Dutch physical activity guidelines (yes/no). These Dutch physical activity guidelines promote for adults 150 minutes of moderate to vigorous physical activity per week, 2 times a week muscle and bone strengthening activities, and for elderly people add balance exercises, which were all taken into consideration for the calculation of meeting the guidelines from the SQUASH questionnaire. The Dutch recommendation also emphasizes the more you move, the better, and to avoid long periods of sitting.[16,17] Total sitting time (in minutes per day) was measured using the validated Marshall Sitting Questionnaire.[18] Because sitting time was only measured at the second Lifelines assessment, we only examined cross-sectional associations between physical activity and sitting time data from the second assessment. This resulted in the use of data from 88,659 people of the 101,373 people who completed the second assessment of the Lifelines study.

Health Conditions

Health conditions were self-reported by participants who were prompted for different health conditions if they were present or not. These health conditions included the majority of prevailing diseases that consume the lion's share of health care resources.[12] For our analysis, we used the 20 most prevalent health conditions, and the less frequently prevalent health conditions were grouped as "other." These prevalent health conditions are summarized in Table 1. Participants were defined as healthy if they had none of these health conditions. The questionnaire clustered some health conditions with general denominators, so that lung emphysema and chronic bronchitis were included in Chronic Obstructive Pulmonary Disease (COPD), and heart failure, heart attack/infarct, and (open) bypass grafting or balloon procedures were included in heart disease. In the osteoarthritis group, people were also included with arthrosis. Mortality data were obtained from the Dutch death registry on September 7, 2021, which was linked to the data of the Lifelines participants to cover the period between the completion of the second assessment for each participant and the sensor date.

Anthropometrics, Quality of Life, and Demographics

Body height was measured to the nearest 0.1 cm standing upright with the back against a stadiometer. Body weight was measured light-clothed without shoes to the nearest 0.1 kg on a standard weighing scale. Body mass index (BMI) in kilograms per meter square was calculated from body height and body weight measured during the second assessment. At baseline, the RAND-36 questionnaire[19] was used to measure health-related quality of life. For our analyses, we only used self-rated general health (using a 5-point scale) and RAND-physical functioning subscore (using a

Table 1 Population Characteristics

	Total, N (column % per variable)	Moderate to vigorous physical activity min/wk, n (row %)				
		0	1–149	150–299	300–599	600+
All participants	88,659 (100%)	1677 (1.89%)	6762 (7.63%)	11,912 (13.44%)	23,253 (26.23%)	45,055 (50.82%)
Gender						
Man	36,241 (40.88%)	551 (1.52%)	2005 (5.53%)	3815 (10.53%)	8619 (23.78%)	21,251(58.64%)
Woman	52,416 (59.12%)	1126 (2.15%)	4756 (9.07%)	8097 (15.45%)	14,634 (27.92%)	23,803 (45.41%)
Unknown	<10					
Age, mean (SD), y	50.18 (12.58)	58.22 (14.6)	49.58 (12.63)	49.09 (12.26)	49.26 (12.3)	50.503 (12.61)
18–34	11,112 (12.53%)	101 (0.91%)	855 (7.69%)	1602 (14.42%)	2990 (26.91%)	5564 (50.07%)
35–49	32,623 (36.8%)	396 (1.21%)	2648 (8.12%)	4752 (14.57%)	8902 (27.29%)	15,925 (48.81%)
50–64	32,516 (36.67%)	597 (1.84%)	2363 (7.23%)	4208 (12.94%)	8513 (26.18%)	16,835 (51.77%)
65+	12,408 (14%)	583 (4.7%)	896 (7.22%)	1350 (10.88%)	2848 (22.95%)	6731 (54.25%)
Education level						
Low	26,191 (29.54%)	874 (3.34%)	2032 (7.76%)	2833 (10.82%)	5771 (22.03%)	14,681 (56.05%)
Middle	34,116 (38.48%)	453 (1.33%)	2310 (6.77%)	4199 (12.31%)	8489 (24.88%)	18,665 (54.71%)
High	26,763 (30.19%)	303 (1.13%)	2297 (8.58%)	4679 (17.48%)	8618 (32.2%)	10,866 (40.6%)
Unknown	1589 (1.79%)	47 (2.96%)	123 (7.74%)	201 (12.65%)	375 (23.6%)	843 (53.05%)
BMI, mean (SD), kg/m^2	25.99 (4.2)	28.08 (5.35)	26.37 (4.68)	25.82 (4.29)	25.97 (4.15)	26 (4.04)
Underweight, <18.5	598 (0.67%)	13 (2.17%)	56 (9.36%)	96 (16.05%)	163 (27.26%)	270 (45.15%)
Normal weight, 18.5–24.9	39,267 (44.29%)	484 (1.23%)	2843 (7.24%)	5579 (14.21%)	10,867 (27.67%)	19,494 (49.64%)
Overweight, 25–29.9	35,695 (40.26%)	668 (1.87%)	2614 (7.32%)	4463 (12.5%)	9042 (25.33%)	18,908 (52.97%)
Obese, 30+	13,075 (14.75%)	506 (3.87 %)	1243 (9.51%)	1772 (13.55%)	3178 (24.31%)	6376 (48.76%)
Unknown	24 (0.03%)	<10	<10	<10	<10	<10
Smoking status						
Never smoker	40,433 (45.6%)	652 (1.61%)	3079 (7.41%)	5765 (14.26%)	11,125 (27.51%)	19,812 (49%)
Ex-smoker	30,571 (34.48%)	604 (1.98%)	2206 (7.22%)	3885 (12.71%)	7885 (25.79%)	15,991 (52.31%)
Current smoker	16,392 (18.49%)	386 (2.35%)	1372 (8.37%)	2092 (12.76%)	3927 (23.96%)	8615 (52.56%)
Unknown	1263 (1.42%)	35 (2.77%)	105 (8.31%)	170 (13.46%)	316 (25.02%)	637 (50.43%)
Self-rated health						
Poor–mediocre	9925 (11.19%)	553 (5.57%)	1267 (12.77%)	1545 (15.57%)	2402 (24.2%)	4158 (41.89%)
Good–excellent	78,594 (88.65%)	1114 (1.42%)	5482 (6.97%)	10,353 (13.17%)	20,816 (26.48%)	40,829 (51.95%)
Unknown	140 (0.16%)	10 (7.14%)	13 (2.29%)	14 (10%)	35 (25%)	68 (48.57%)
Health condition						
Healthy	56,595 (63.83%)	695 (1.23%)	4031 (7.12%)	7653 (13.52%)	15,225 (26.9%)	28,991 (51.22%)
ADHD	268 (0.30%)	<10	<10	36 (13.43%)	49 (18.28%)	158 (58.96%)
Anxiety	2660 (3%)	78 (2.93%)	243 (9.13%)	442 (16.62%)	679 (25.53%)	1218 (45.79%)
COPD	4576 (5.16%)	182 (3.98%)	391 (8.54%)	512 (11.19%)	1080 (23.6%)	2411 (52.69%)
Chronic fatigue syndrome	349 (0.39%)	<10	<10	52 (14.9%)	100 (28.65%)	164 (46.99%)
Crohn disease	160 (0.18%)	<10	<10	24 (15%)	47 (29.38%)	71 (44.38%)

(continued)

Table 1 *(continued)*

	Total, N (column % per variable)	Moderate to vigorous physical activity min/wk, n (row %)				
		0	1–149	150–299	300–599	600+
Depression	7044 (7.94%)	160 (2.27%)	698 (9.91%)	1062 (15.08%)	1797 (25.51%)	3327 (47.23%)
Diabetes type 1	136 (0.15%)	<10	<10	19 (14%)	39 (28.68%)	66 (48.53%)
Diabetes type 2	1734 (1.96%)	94 (5.42%)	151 (8.71%)	225 (12.98%)	444 (25.61%)	820 (47.29%)
Epilepsy	586 (0.66%)	<10	<10	79 (13.48%)	152 (25.94%)	307 (52.39%)
Fibromyalgia	1935 (2.18%)	65 (3.36%)	210 (10.85%)	285 (14.73%)	491 (25.37%)	884 (45.68%)
Heart disease	1566 (1.77%)	64 (4.09%)	117 (7.47%)	162 (10.34%)	316 (20.18%)	907 (57.92%)
Manic-depressive disorder	71 (0.08%)	<10	<10	<10	29 (40.85%)	24 (33.80%)
Multiple sclerosis	128 (0.14%)	13 (10.16%)	13 (10.16%)	27 (21.1%)	40 (31.25%)	35 (27.34%)
Osteoarthritis	6800 (7.67%)	188 (2.76%)	434 (6.38%)	789 (11.6%)	1703 (25.04%)	3686 (54.21%)
Osteoporosis	634 (0.71%)	20 (3.15%)	64 (10.09%)	87 (13.72%)	164 (25.87%)	299 (47.16%)
Parkinson disease	41 (0.05%)	<10	<10	<10	<15	18 (43.90%)
Panic disorder	885 (1.0%)	<10	<10	134 (15.14%)	264 (29.83%)	400 (45.20%)
Rheumatoid arthritis	808 (0.91%)	20 (2.47%)	73 (9.03%)	100 (12.38%)	213 (26.36%)	402 (49.75%)
Schizophrenia	26 (0.03%)	<10	<10	<10	<10	15 (57.69%)
Stroke	354 (0.4%)	17 (4.8%)	27 (7.63%)	42 (11.86%)	79 (22.32%)	189 (53.39%)
Other, including unknown	1303 (1.47%)	44 (3.38%)	107 (8.21%)	163 (12.51%)	326 (25.02%)	663 (50.88%)

Abbreviations: BMI, body mass index; COPD, Chronic Obstructive Pulmonary Disease.

100-point scale). Demographics such as gender, age, and education level were assessed using questionnaires.

Statistical Analysis

We used covariate-adjusted linear and logistic regression analyses to examine physical activity (ie, meeting the Dutch physical activity guidelines, and time spent in minutes per week moderate- and vigorous-intensity physical activity) and its correlates for people living with and without different health conditions. In our study, we used the second Lifelines wave to examine cross-sectional levels and associations for physical activity. Some categories were merged if the number of people in a category was smaller than 50. Per Lifelines policy, categories with <10 people cannot be presented or calculated; hence, some small numbers are presented as <X. For health conditions with low numbers, only descriptive statistics were calculated and no regression analyses were performed.

To examine the relationship between all-cause mortality and physical activity, we used Cox regression with total moderate to vigorous physical activity time assessed during the second wave as an independent variable, adjusted for age, gender, education, BMI, and smoking. In 2 different additional sensitivity analyses, we excluded the first 3 years of deaths and added an adjustment for self-reported health, respectively.

In all analyses, we excluded participants when they had missing data for variables in a model. We considered a statistical significance level of $\alpha = .05$ and presented 95% confidence intervals (CIs). The statistical analyses were performed in SPSS Statistics (version 26) and in R.

Results

Population Description

The total number of participants included in our analyses was 88,659. The number of women participating in our subsample of the Lifelines study exceeded the number of men (59.1% vs 40.9%; Table 1). The mean age was 50.2 years (SD 12.6) with the largest number of participants in the 35 to 49 age group (36.8%) and the 50 to 64 (36.7%) age group. Most participants were in the middle category for their highest completed level of education (38.84%). The mean BMI in the total population was 26 kg/m^2, and 14.8% of the population was classified as obese with a BMI of 30 kg/m^2 or higher. Current smokers represented 18.5%. Participants rated their general health as good to excellent (88.7%) with only a small group rating it as poor to mediocre. Most participants were classified as healthy (63.8%) as they did not self-report any of the studied health conditions. Depression was the most commonly self-reported disease (7.9%) and self-reported stroke was the least common (0.4%).

Supplementary Table S1 (available online) shows the personal characteristics by health condition. Participants with self-reported heart disease were the oldest group (62.83 y mean, 11.86 SD), and the self-reported anxiety group was the youngest (48.38 y, SD 11.76). Self-reported type 2 diabetes patients had the highest BMI

Table 2 Physical Activity Levels in People With and Without a Health Condition

	Moderate- and vigorous-intensity physical activity, min/wk		Meeting Dutch physical activity guidelines[a]	
	Median (IQR)	β (95% CI) (corrected for age and gender)	n (%)	OR (95% CI) (corrected for age and gender)
Healthy population	600 (844)	Reference	30,037 (52.9%)	1.00 (reference)
ADHD	700 (1065)	119.08 (58.19 to 179.97)	312 (50.2%)	0.89 (0.76 to 1.04)
Anxiety disorder	530 (790)	–51.05 (–80.86 to –21.25)	1329 (49.9%)	0.87 (0.80 to 0.94)
Chronic fatigue syndrome	495 (824)	–76.04 (–123.32 to –28.77)	464 (45.0%)	0.72 (0.64 to 0.82)
COPD	630 (900)	26.65 (3.55 to –49.75)	2219 (46.6%)	0.80 (0.75 to 0.85)
Crohn disease	525 (748)	–100.04 (–186.91 to –13.17)	142 (47.2%)	0.79 (0.63 to 0.99)
Depression	540 (800)	–48.93 (–66.27 to –31.59)	4162 (48.0%)	0.81 (0.78 to 0.85)
Diabetes type 1	540 (810)	–94.16 (–197.86 to –9.55)	104 (49.3%)	0.87 (0.66 to 1.14)
Diabetes type 2	540 (840)	–91.88 (–124.86 to –58.90)	934 (41.1%)	0.65 (0.60 to 0.71)
Epilepsy	645 (810)	3.46 (–43.48 to 50.41)	522 (49.9%)	0.89 (0.79 to 1.01)
Fibromyalgia	480 (750)	–60.93 (–88.81 to –33.04)	1380 (43.7%)	0.68 (0.63 to 0.73)
Heart disease	660 (920)	–27.61 (–60.40 to 5.17)	1107 (47.1%)	0.86 (0.79–0.93)
Manic-depressive disorder	520 (680)	–89.19 (–183.07 to 4.68)	140 (54.3%)	1.06 (0.83 to 1.35)
MS	330 (490)	–296.70 (–401.13 to –192.27)	80 (38.5%)	0.55 (0.41 to 0.72)
Osteoarthritis	610 (840)	23.97 (6.80 to –41.14)	5089 (48.3%)	0.87 (0.83 to 0.91)
Osteoporosis	518 (730)	–68.65 (–104.54 to –32.76)	868 (44.7%)	0.74 (0.67 to 0.81)
Panic disorder	530 (795)	–49.39 (–77.84 to –20.94)	1461 (49.8%)	0.86 (0.80 to 0.93)
Parkinson disease	510 (765)	–138.76 (–293.54 to 16.01)	41 (43.2%)	0.73 (0.49 to 1.10)
Rheumatoid arthritis	540 (810)	–57.82 (–91.38 to –24.26)	969 (45.3%)	0.76 (0.69 to 0.83)
Schizophrenia	560 (835)	–87.00 (–260.83 to 86.84)	44 (58.7%)	1.28 (0.81 to 2.03)
Stroke	580 (820)	–89.48 (–145.19 to –33.78)	355 (47.3%)	0.84 (0.73 to 0.97)

Abbreviations: CI, confidence interval; MS, multiple sclerosis; OR, odds ratio; IQR, interquartile range.
[a]Dutch physical activity guidelines for adults: at least 150 minutes of moderate to vigorous physical activity per week, and muscle and bone strengthening activities twice per week (combined with balance exercises for elderly people).

(mean 30.01 kg/m^2; SD 4.81) and patients with osteoporosis had the lowest (25.0 kg/m^2; SD 3.76).

Physical Activity by Health Condition

Table 2 presents the amount of self-reported moderate to vigorous physical activity and the number of participants who met the physical activity guidelines, separated per health condition. More than half of the healthy population (52.9%) met the physical activity guidelines. People with a self-reported health condition were less likely to meet the guidelines compared with people without a self-reported health condition, with lower odds of meeting the guidelines varying from 11% in attention deficit hyperactivity disorder (ADHD) and epilepsy patients to 45% in patients with multiple sclerosis. Overall, moderate- to vigorous-intensity physical activity levels showed similar physical activity patterns, with people reporting health conditions generally having lower physical activity levels compared with people without a health condition.

Factors Correlated With Meeting the Physical Activity Guidelines

Table 3 shows the associations between meeting the physical activity guidelines and age, gender, BMI, self-rated health, total sitting time, physical functioning, and education level for people living with and without self-reported health conditions. Being overweight or obese was associated with lower odds of meeting the guidelines, which was consistent across people with and without different self-reported health conditions. However, not all associations were significant. In the COPD, epilepsy, osteoarthritis, osteoporosis, rheumatoid arthritis, and stroke groups, younger people were more likely to meet the guidelines than people of 65 years and older, while the healthy population showed an inverse pattern. Gender differences were relatively small and generally not significant. People rating their general health as poor to mediocre were between 20% (COPD) and 58% (stroke) less likely to meet guidelines compared with people with at least good self-rated health. Sitting >8 hours a day was also associated with lower physical activity, up to 32% for the rheumatoid patients. In all groups, a lower level of physical functioning was related to lower odds of meeting guidelines, especially for fibromyalgia (odds ratios = 0.32) and diseases affecting joints (rheumatoid arthritis: odds ratios = 0.40; CI, 0.20–0.80; and osteoarthritis: odds ratios = 0.38; CI, 0.26–0.56). Overall, both in the healthy and in the chronic disease population, higher education was associated with higher odds of meeting guidelines.

In summary, higher BMI and sitting time as well as lower self-rated health, physical functioning, and education levels were generally associated with a lower odds of meeting physical activity guidelines for both people with and without different health conditions. However, findings were not always consistent for all health conditions. Associations for age and gender were less clear.

Supplementary Table S2 (available online) shows the descriptive associations for all health conditions for which the sample size was too small to run the multivariable model. Similar patterns were observed within these health conditions.

Physical Activity and All-Cause Mortality

During an average follow-up time of 6.29 years (SD 0.98), 1364 deaths occurred in 557,744 person-years. Table 4 shows the dose–response association between moderate to vigorous physical activity and all-cause mortality. Due to the small number of deaths in several subgroups, we could only run the analyses on 4 health condition groups and on the group including people without a self-reported health condition. All 5 groups showed a protective association for physical activity against all-cause mortality. Supplementary Table S3 (available online) presents the additional sensitivity analyses, which excluded the first 3 years of deaths. Supplementary Table S4 (available online) presents the sensitivity analyses, which additionally corrected for self-reported health. These sensitivity analyses generally showed similar dose–response associations between physical activity levels and all-cause mortality.

Discussion

We used data from a large prospective cohort to study physical activity in people with a self-reported health condition as well as in healthy people. We showed that people having a health condition are less physically active than people living without a health condition. Differences in physical activity levels between different health conditions were substantial. The patients with the most self-reported physical activity minutes were patients with mental (schizophrenia, attention deficit hyperactivity disorder, and manic-depressive disorder) health conditions rather than with self-reported physical health conditions, although these groups consisted of small numbers. The least physically active group was people living with multiple sclerosis, which is in line with the natural progression of the disease. A higher BMI and sitting time as well as lower self-rated health, physical functioning, and education levels were shown to be associated with a lower odds of meeting physical activity guidelines for both people with and without different health conditions. However, findings were not consistent for all health conditions. Associations for age and gender were less clear. Finally, we showed that physical activity has a protective association with all-cause mortality for people living with and without health conditions.

Our finding on the lower physical activity levels in people living with a health condition is in line with the study of Martin Ginis et al,[5] who reported that people living with disabilities in high-income countries are 16% to 62% less likely to meet physical activity guidelines compared with their healthy counterparts. These results are similar to the findings of De Hollander,[20] who showed 11.9% to 49.8% of lower physical activity in adults with disabilities. Though our study focused on health conditions instead of disabilities, our results show less pronounced differences in physical activity levels between people living with and without a health condition. This might be a result of selection bias. The Lifelines study excludes severely ill people, and people living with a health condition are generally underrepresented in Lifelines.[11–14] Given the inverse relationship that we found between self-rated health and physical activity, this potential selection bias could have resulted in an overestimation of physical activity levels in people living with a health condition. When it comes to the factors that were associated with physical activity, results between people living with and without different health conditions were overall quite similar and generally in line with results from the healthy population.[21] For example, prior studies have shown that a BMI $\geq$ 25 kg/m^2 is associated with lower levels of moderate and vigorous activity in a healthy population.[22,23] More surprisingly were the less clear associations between age and gender with physical activity levels, which are in contrast to studies in the healthy population that often report lower physical activity levels in women and older people.[21,24]

Table 3 Factors Associated With Meeting the Dutch Physical Activity Guidelines for People With and Without Different Health Conditions

N in multivariate model	Healthy population		Anxiety disorder		Chronic fatigue syndrome		COPD		Depression		Diabetes type 2		Epilepsy	
	29,740		1303		509		2382		4403		1122		547	
	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)
Age, y														
18–35	5476 (55.4%)	0.91 (0.82–1.00)	217 (50.9%)	1.05 (0.65–1.70)	53 (42.1%)	0.76[b] (0.43–1.35)	171 (57.6%)	2.23 (1.47–3.40)	546 (52.4%)	0.88 (0.67–1.16)	<10 (60.0%)	0.87[b] (0.59–1.30)	44 (46.3%)	1.24[b] (0.70–2.19)
36–50	12,946 (52.5%)	0.86 (0.79–0.93)	543 (49.2%)	0.87 (0.59–1.30)	179 (47.2%)		768 (48.7%)	1.13 (0.89–1.43)	1671 (47.3%)	0.82 (0.66–1.02)	<150 (41.9%)		219 (50.9%)	
51–64	8852 (52.0%)	0.88 (0.81–0.96)	452 (50.6%)	1.04 (0.70–1.55)	174 (43.7%)	0.67 (0.38–1.19)	848 (47.8%)	1.28 (1.03–1.59)	1536 (47.5%)	0.82 (0.66–1.01)	370 (41.5%)	0.93 (0.71–1.22)	205 (53.1%)	1.48 (0.84–2.61)
≥65	2763 (53.7%)	1.00	117 (48.3%)	1.00	58 (45.0%)	1.00	432 (39.0%)	1.00	409 (47.6%)	1.00	411 (40.1%)	1.00	54 (40.0%)	1.00
Gender														
Man	12,834 (51.2%)	1.00	367 (49.9%)	1.00	157 (47.3%)	1.00	953 (48.7%)	1.00	1226 (48.4%)	1.00	484 (43.1%)	1.00	199 (45.9%)	1.00
Woman	17,203 (54.3%)	1.12 (1.06–1.17)	962 (49.8%)	0.98 (0.76–1.26)	307 (43.9%)	0.81 (0.55–1.21)	1266 (45.2%)	1.00 (0.85–1.19)	2936 (47.9%)	0.99 (0.86–1.13)	450 (39.1%)	1.09 (0.85–1.40)	323 (52.8%)	1.40 (0.98–2.01)
BMI, kg/m^2														
<25	15,277 (57.5%)	1.00	618 (53.5%)	1.00	226 (53.1%)	1.00	807 (50.8%)	1.00	1903 (53.4%)	1.00	150 (53.4%)	1.00	230 (57.8%)	1.00
25–30	11,276 (50.9%)	0.81 (0.77–0.85)	498 (51.2%)	1.04 (0.81–1.33)	154 (42.2%)	0.69 (0.45–1.04)	921 (48.1%)	0.85 (0.71–1.03)	1521 (46.9%)	0.77 (0.67–0.88)	431 (43.3%)	0.60 (0.42–0.87)	201 (48.6%)	0.73 (0.50–1.08)
≥30	3046 (42.8%)	0.62 (0.58–0.67)	189 (39.3%)	0.80 (0.57–1.10)	78 (35.1%)	0.46 (0.28–0.76)	448 (38.6%)	0.57 (0.45–0.71)	665 (39.0%)	0.72 (0.60–0.84)	338 (35.7%)	0.53 (0.36–0.77)	85 (39.7%)	0.73 (0.44–1.20)
Self-rated health														
At least good	28,640 (53.7%)	1.00	1073 (53.6%)	1.00	272 (52.6%)	1.00	1782 (49.3%)	1.00	3241 (51.0%)	1.00	766 (45.2%)	1.00	447 (51.8%)	1.00
Poor/mediocre	1365 (41.6%)	0.68 (0.61–0.76)	253 (38.5%)	0.63 (0.47–0.84)	192 (37.4%)	0.59 (0.40–0.87)	431 (38.3%)	0.80 (0.64–1.00)	914 (39.7%)	0.73 (0.63–0.85)	168 (29.1%)	0.67 (0.49–0.92)	73 (40.8%)	0.65 (0.39–1.08)
Total sitting, h/d														
<8	7141 (56.1%)	1.00	326 (53.1%)	1.00	117 (50.2%)	1.00	533 (49.3%)	1.00	965 (50.5%)	1.00	224 (40.8%)	1.00	126 (52.5%)	1.00
≥8	9459 (52.1%)	0.86 (0.82–0.90)	363 (47.6%)	0.82 (0.66–1.03)	141 (45.6%)	0.77 (0.53–1.12)	678 (46.2%)	0.84 (0.71–0.99)	1267 (47.0%)	0.88 (0.78–1.00)	325 (46.0%)	1.35 (1.05–1.73)	165 (49.7%)	0.91 (0.64–1.30)
Physical functioning[d]														
0–33	29,020 (53.5%)	1.00	1202 (52.8%)	1.00	346 (50.7%)	1.00	1890 (50.2%)	1.00	3709 (50.5%)	1.00	767 (46.1%)	1.00	465 (51.6%)	1.00
34–66	489 (39.5%)	0.61 (0.52–0.72)	78 (31.1%)		95 (38.3%)		234 (35.6%)	0.72 (0.56–0.93)	329 (34.9%)	0.64 (0.52–0.79)	103 (30.4%)		36 (41.4%)	0.81[c]

(continued)

Table 3 *(continued)*

N in multivariate model	Healthy population 29,740		Anxiety disorder 1303		Chronic fatigue syndrome 509		COPD 2382		Depression 4403		Diabetes type 2 1122		Epilepsy 547	
	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)
67–100	52 (32.9%)	0.46 (0.27–0.78)	13 (27.1%)	0.55[c] (0.37–0.80)	10 (16.9%)	0.75[c] (0.49–1.15)	31 (23.0%)	0.58 (0.32–1.04)	38 (25.2%)	0.49 (0.30–0.80)	14 (19.2%)	0.60[c] (0.42–0.85)	<10 (33.3%)	(0.45–1.47)
Education level														
Low	6933 (49.2%)	1.00	413 (46.2%)	1.00	148 (40.3%)	1.00	800 (40.7%)	1.00	1157 (43.1%)	1.00	430 (36.6%)	1.00	149 (42.6%)	1.00
Medium	12,182 (53.7%)	1.17 (1.10–1.24)	546 (50.7%)	1.03 (0.79–1.35)	197 (48.9%)	1.12 (0.73–1.73)	824 (50.8%)	1.15 (0.94–1.40)	1731 (48.8%)	1.11 (0.96–1.29)	286 (45.0%)	1.30 (0.98–1.72)	214 (52.2%)	1.22 (0.80–1.85)
High	10,417 (54.7%)	1.20 (1.13–1.28)	354 (53.6%)	0.98 (0.72–1.34)	112 (47.1%)	0.87 (0.53–1.44)	551 (52.1%)	1.10 (0.88–1.36)	1207 (52.6%)	1.19 (1.01–1.40)	192 (49.1%)	1.28 (0.93–1.76)	148 (55.0%)	1.59 (1.00–2.54)

N in multivariate model	Fibromyalgia 1579		Heart disease 1198		Osteoarthritis 5780		Osteoporosis 1002		Panic disorder 1429		Rheumatoid arthritis 1092		Stroke 351	
	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)
Age, y														
18–35	84 (50.0%)	2.14 (1.18–3.86)	18 (47.4%)	0.82[b] (0.57–1.18)	58 (56.3%)	1.03[b] (0.87–1.22)	10 (50.0%)	1.10[b] (0.70–1.75)	249 (49.0%)	0.86 (0.53–1.40)	47 (58.8%)	1.47[b] (1.04–2.07)	14 (70.0%)	1.35[b] (0.72–2.55)
36–50	505 (45.5%)	0.90 (0.65–1.24)	163 (49.2%)	0.90 (0.69–1.17)	898 (51.8%)	1.05 (0.93–1.18)	94 (50.5%)	1.02 (0.77–1.35)	659 (50.2%)	0.85 (0.56–1.31)	257 (50.2%)	1.35 (1.00–1.83)	69 (50.7%)	1.42 (0.86–2.34)
51–64	569 (41.7%)	0.88 (0.66–1.18)	376 (48.1%)	1.00	2400 (49.1%)	1.00	333 (46.4%)	1.00	460 (50.6%)	1.02 (0.67–1.57)	392 (45.4%)	1.00	144 (50.3%)	1.00
≥65	222 (42.8%)	1.00	550 (45.9%)		1733 (45.5%)		431 (42.3%)		93 (45.4%)	1.00	273 (39.9%)		128 (41.6%)	
Gender														
Man	133 (43.8%)	1.00	768 (49.7%)	1.00	1661 (50.0%)	1.00	122 (46.2%)	1.00	386 (49.2%)	1.00	330 (46.6%)	1.00	169 (47.1%)	1.00
Woman	1247 (43.7%)	1.01 (0.71–1.44)	339 (42.2%)	0.92 (0.71–1.19)	3428 (47.5%)	0.93 (0.83–1.04)	746 (44.5%)	0.85 (0.57–1.24)	1075 50.0%)	0.99 (0.78–1.27)	639 (44.6%)	1.02 (0.79–1.33)	186 (47.6%)	1.22 (0.78–1.92)
BMI, kg/m^2														
<25	458 (48.0%)	1.00	316 (55.1%)	1.00	1858 (56.6%)	1.00	420 (52.7%)	1.00	674 (54.1%)	1.00	352 (50.0%)	1.00	108 (51.9%)	1.00
25–30	553 (44.7%)	0.89 (0.70–1.14)	558 (48.1%)	0.78 (0.59–1.03)	2212 (48.2%)	0.75 (0.67–0.85)	339 (44.3%)	0.72 (0.54–0.95)	543 (49.8%)	0.89 (0.70–1.13)	423 (47.1%)	1.05 (0.80–1.39)	166 (48.4%)	0.88 (0.53–1.49)
≥30	341 (38.0%)	0.77 (0.59–1.01)	211 (37.3%)	0.68 (0.48–0.96)	952 (38.2%)	0.60 (0.52–0.70)	100 (28.9%)	0.43 (0.29–0.65)	217 (39.7%)	0.66 (0.48–0.89)	176 (35.5%)	0.68 (0.48–0.96)	73 (39.5%)	0.71 (0.38–1.32)

(continued)

Table 3 *(continued)*

N in multivariate model	Fibromyalgia		Heart disease		Osteoarthritis		Osteoporosis		Panic disorder		Rheumatoid arthritis		Stroke	
	1579		1198		5780		1002		1429		1092		351	
	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)	n (%)[a]	OR (95% CI)
Self-rated health														
At least good	915 (49.7%)	1.00	895 (51.6%)	1.00	4203 (51.2%)	1.00	685 (49.4%)	1.00	1108 52.3%)	1.00	724 (49.1%)	1.00	291 (53.4%)	1.00
Poor/mediocre	463 (35.3%)	0.70 (0.56–0.88)	211 (34.8%)	0.67 (0.50–0.90)	875 (38.0%)	0.77 (0.67–0.88)	181 (33.0%)	0.62 (0.45–0.86)	352 (43.3%)	0.79 (0.61–1.02)	244 (34.4%)	0.69 (0.51–0.93)	64 (31.5%)	0.42 (0.24–0.73)
Total sitting, h/d														
<8	339 (45.3%)	1.00	346 (52.1%)	1.00	1614 (51.5%)	1.00	291 (48.4%)	1.00	322 (54.4%)	1.00	288 (48.2%)	1.00	111 (54.7%)	1.00
≥8	401 (43.6%)	0.95 (0.78–1.17)	331 (49.3%)	0.90 (0.71–1.14)	1532 (49.8%)	0.93 (0.84–1.04)	225 (44.8%)	0.80 (0.61–1.04)	444 (49.7%)	0.80 (0.64–0.99)	269 (44.5%)	0.68 (0.53–0.88)	109 (54.0%)	0.82 (0.52–1.27)
Physical functioning[d]														
0–33	970 (48.8%)	1.00	890 (51.4%)	1.00	4143 (52.5%)	1.00	696 (51.3%)	1.00	1326 (51.9%)	1.00	732 (50.8%)	1.00	281 (52.9%)	1.00
34–66	341 (37.8%)	0.56 (0.44–0.71)	135 (38.9%)	0.67[c] (0.48–0.93)	706 (39.1%)	0.68 (0.58–0.79)	107 (31.4%)		97 (35.4%)		164 (40.1%)	0.65 (0.47–0.91)	48 (43.6%)	
67–100	27 (17.6%)	0.32 (0.17–0.58)	17 (23.3%)		65 (22.0%)	0.38 (0.26–0.56)	15 (17.4%)	0.55[c] (0.39–0.79)	18 (36.0%)	0.56[c] (0.40–0.80)	19 (17.8%)	0.40 (0.20–0.80)	5 (15.6%)	0.72[c] (0.39–1.30)
Education level														
Low	555 (40.0%)	1.00	454 (40.8%)	1.00	2106 (43.5%)	1.00	415 (39.5%)	1.00	427 (46.6%)	1.00	385 (41.0%)	1.00	142 (40.0%)	1.00
Medium	583 (47.1%)	1.10 (0.88–1.39)	356 (51.7%)	1.11 (0.84–1.46)	1630 (50.6%)	1.17 (1.04–1.33)	238 (48.6%)	1.31 (0.95–1.80)	584 (49.3%)	1.06 (0.82–1.37)	329 (46.7%)	0.98 (0.73–1.31)	111 (51.4%)	0.87 (0.52–1.48)
High	215 (45.2%)	1.10 (0.81–1.49)	275 (46.6%)	1.17 (0.86–1.58)	1239 (55.4%)	1.28 (1.12–1.47)	189 (54.2%)	1.44 (1.03–2.01)	422 (53.8%)	1.15 (0.86–1.52)	238 (52.5%)	1.18 (0.85–1.63)	94 (57.7%)	1.55 (0.87–2.74)

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio.

[a]N (%) includes all participants with valid data for each individual variable, the multivariate model only includes participants with valid data for all variables in the model. [b]18–50 years as an aggregated group because the groups 18–35 years and 36–50 years were too small. [c]34–100 as an aggregated group because the individual groups 34–66 and 67–100 were too small. [d]Higher score corresponds to a lower level of physical functioning.

Table 4 The Association Between Moderate to Vigorous Physical Activity and All-Cause Mortality

		Moderate to vigorous physical activity, min/wk				
	Total	0	1–149	150–299	300–599	600+
All participants						
Person-years	557,744	10,479	42,569	74,883	146,280	283,533
No of deaths	1364	103	125	168	325	643
Hazard ratio (95% CI)		1.00 (reference)	0.80 (0.61–1.05)	0.70 (0.54–0.91)	0.68 (0.53–0.86)	0.59 (0.47–0.74)
Healthy						
Person-years	356,131	4385	25,425	48,099	95,644	182,578
No of deaths	572	27	46	78	139	282
Hazard ratio (95% CI)		1.00 (reference)	0.77 (0.46–1.29)	0.72 (0.45–1.15)	0.66 (0.42–1.04)	0.58 (0.37–0.90)
COPD						
Person-years	28,862	1105	2447	3274	6836	15,201
No of deaths	160	23	19	13	34	71
Hazard ratio (95% CI)		1.00 (reference)	0.88 (0.48–1.60)	0.38 (0.19–0.79)	0.50 (0.28–0.87)	0.48 (0.29–0.79)
Diabetes type 2						
Person-years	10,698	550	909	1388	2782	5069
No of deaths	93	16	≤10	≤10	21	39
Hazard ratio (95% CI)		1.00 (reference)	0.53 (0.27–1.07)	0.32 (0.14–0.70)	0.44 (0.25–0.80)	0.44 (0.26–0.75)
Heart disease						
Person-years	9590	379	698	1011	1937	5566
No of deaths	89	<10	<10	<10	22	43
Hazard ratio (95% CI)		1.00 (reference)	0.47 (0.24–0.94)	0.35 (0.17–0.73)	0.62 (0.36–1.06)	0.41 (0.25–0.69)
Osteoarthritis						
Person-years	42,632	1188	2747	4956	10,704	23,037
No of deaths	154	10	13	22	33	76
Hazard ratio (95% CI)		1.00 (reference)	0.85 (0.51–1.42)	0.81 (0.49–1.33)	0.84 (0.54–1.30)	0.64 (0.41–0.98)

Abbreviations: BMI, body mass index; CI, confidence interval; COPD, Chronic Obstructive Pulmonary Disease. Note: Hazard ratio adjusted for age, gender, education, BMI, and smoking.

The consistent protective association between physical activity and all-cause mortality across the different health conditions and healthy groups is promising and in line with physical activity guidelines.[24] Interestingly, physically active people with COPD, type 2 diabetes, and cardiovascular disease had substantially lower all-cause mortality odds. It is difficult to interpret this finding due to the small number of deaths in these groups and the ensuing uncertainty in our effect estimates. This low statistical power also makes it difficult to further investigate potential reverse causality, where, for example, less healthy people could be less active as a result of their disease and have a higher risk of mortality. In additional sensitivity analyses, which excluded the first 3 years of deaths, we found similar association estimates with even wider CIs. When correcting for self-reported health in other sensitivity analyses, we also found similar results and even wider CIs with some attenuation in some of the association estimates, which suggests there might have been some reverse causality. However, the dose–response association between physical activity levels and all-cause mortality remained clear in all sensitivity analyses.

Besides the potential limitations around selection bias, selective missing data, reverse causality, and residual confounding, another limitation was the self-reported assessment of physical activity. Although the SQUASH questionnaire has been validated, it does tend to substantially overestimate physical activity levels, which is illustrated by the high levels of moderate to vigorous physical activity that we reported. Hence, the interpretation of absolute physical activity levels and dose–response associations with all-cause mortality is not recommended. However, the questionnaire has been shown to be suited for studying the associations with relative physical activity levels that we carried out in this study.[15] Furthermore, in the calculation for meeting the guidelines or not, this overestimation of physical activity is taken into account, which makes estimates more realistic. Another limitation was the small sample size for several health conditions, which was mostly limited in our mortality analyses that could only be run for 4 health conditions. This small sample size limitation is illustrative of the difficulties we face in studying physical activity in people living with health conditions. Even in a large general population cohort such as Lifelines, data on people with health conditions are scarcely available. This is partly due to the low prevalence of some of the diseases in the general population and partly to the underrepresentation of people who live with a health condition due to selection bias and specific exclusion criteria for people with health conditions.

Our study gave important insights into the prevalence, correlates, and associations with mortality of physical activity in people with 20 different health conditions. Physical activity in people with health conditions is important but underresearched, and more research is necessary to study physical activity in more depth across different health conditions to better inform practice, guidelines, and strategies to improve physical activity levels among people living with a health condition.

Acknowledgments

Funding: The Lifelines initiative has been made possible by a subsidy from the Dutch Ministry of Health, Welfare and Sport, the Dutch Ministry of Economic Affairs, the University Medical Center Groningen (UMCG), Groningen University, and the Provinces in the North of the Netherlands (Drenthe, Friesland, Groningen). The current paper was also supported by ZonMw (grant number: 546001002). **Author Contributions:** *Study conceptualization*: Bouma, van Keeken, Krops, van Nassau, Nauta, Dekker, van der Ploeg. *Analyses*: Uijtdewilligen, Stijnman, Motazedi, Marks-Vieveen, van der Ploeg. *Drafting of the manuscript*: Marks-Vieveen, Uijtdewilligen, Stijnman, van der Ploeg. *Editing of the manuscript and approval of the final version*: All authors.

References

1. Hallal PC, Bauman AE, Heath GW, Kohl HW 3rd, Lee IM, Pratt M. Physical activity: more of the same is not enough. *Lancet*. 2012; 380(9838):190–191. doi:10.1016/S0140-6736(12)61027-7
2. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*. 2012;380(9838):219–229. doi:10.1016/S0140-6736(12)61031-9
3. Global action plan on physical activity 2018-2030, More active people for a healthier World. 2018. https://apps.who.int/iris/bitstream/handle/10665/272722/9789241514187-eng.pdf
4. Dempsey PC, Friedenreich CM, Leitzmann MF, et al. Global public health guidelines on physical activity and sedentary behavior for people living with chronic conditions: a call to action. *J Phys Act Health*. 2021; 18:76–85. doi:10.1123/jpah.2020-0525
5. Martin Ginis KA, van der Ploeg HP, Foster C, et al. Participation of people living with disabilities in physical activity: a global perspective. *Lancet*. 2021;398(10298):443–455. doi:10.1016/S0140-6736(21)01164-8
6. Carty C, van der Ploeg HP, Biddle SJH, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021;18(1):86–93. doi:10.1123/jpah.2020-0629
7. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. 2020;54(24):1451–1462. doi:10.1136/bjsports-2020-102955
8. Ansah JP, Chiu CT. Projecting the chronic disease burden among the adult population in the United States using a multi-state population model. *Front Public Health*. 2023;10:1082183. doi:10.3389/fpubh.2022.1082183
9. Global status report on noncommunicable diseases 2010. 2010. https://apps.who.int/iris/handle/10665/44579
10. Regeringsbeleid WRvh: Kiezen voor houdbare zorg, Mensen, middelen en maatschappelijk draagvlak. 2021. https://www.wrr.nl/publicaties/rapporten/2021/09/15/kiezen-voor-houdbare-zorg
11. Scholtens S, Smidt N, Swertz MA, et al. Cohort Profile: LifeLines, a three-generation cohort study and biobank. *Int J Epidemiol*. 2015; 44(4):1172–1180. doi:10.1093/ije/dyu229
12. Stolk RP, Rosmalen JG, Postma DS, et al. Universal risk factors for multifactorial diseases: LifeLines: a three-generation population-based study. *Eur J Epidemiol*. 2008;23(1):67–74. doi:10.1007/s10654-007-9204-4
13. Lifelines https://www.lifelines.nl/
14. Klijs B, Scholtens S, Mandemakers JJ, Snieder H, Stolk RP, Smidt N. Representativeness of the LifeLines Cohort Study. *PLoS One*. 2015; 10(9):e0137203. doi:10.1371/journal.pone.0137203
15. Wendel-Vos GC, Schuit AJ, Saris WH, Kromhout D. Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity. *J Clin Epidemiol*. 2003;56(12):1163–1169. doi:10.1016/S0895-4356(03)00220-8
16. Beweegrichtlijnen RIVM. https://www.sportenbewegenincijfers.nl/kernindicatoren/beweegrichtlijnen
17. Physical activity and risk of chronic diseases. 2017. https://www.healthcouncil.nl/documents/advisory-reports/2017/08/22/physical-activity-guidelines-2017
18. Marshall AL, Miller YD, Burton NW, Brown WJ. Measuring total and domain-specific sitting: a study of reliability and validity. *Med Sci Sports Exerc*. 2010;42(6):1094–1102. doi:10.1249/MSS.0b013e3181c5ec18
19. Hays RD, Morales LS. The RAND-36 measure of health-related quality of life. *Ann Med*. 2001;33(5):350–357. doi:10.3109/07853890109002089
20. de Hollander EL, Proper KI. Physical activity levels of adults with various physical disabilities. *Prev Med Rep*. 2018;10:370–376. doi:10.1016/j.pmedr.2018.04.017
21. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet*. 2012;380(9838):258–271. doi:10.1016/S0140-6736(12)60735-1
22. Ekelund U, Kolle E, Steene-Johannessen J, et al. Objectively measured sedentary time and physical activity and associations with body weight gain: does body weight determine a decline in moderate and vigorous intensity physical activity? *Int J Obes*. 2017;41(12):1769–1774. doi:10.1038/ijo.2017.186
23. Sagelv EH, Ekelund U, Hopstock LA, et al. The bidirectional associations between leisure time physical activity change and body mass index gain. The Tromsø Study 1974–2016. *Int J Obes*. 2021;45(8):1830–1843. doi:10.1038/s41366-021-00853-y
24. Shin CN, Lee YS, Belyea M. Physical activity, benefits, and barriers across the aging continuum. *Appl Nurs Res*. 2018;44:107–112. doi:10.1016/j.apnr.2018.10.003