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Determinants of physical activity among older adults in Germany – a nationwide cohort study

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Manuscripts

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3 **1 Determinants of physical activity among older adults in Germany – a nationwide cohort**
4 **2 study**

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2
3 15 **Abstract**
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6 16 **Objectives**
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8 17 To investigate individual, interpersonal and environmental determinants of regular aerobic physical
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10 18 activity (PA) participation among older adults in Germany.

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12 19 **Design**
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14 20 Population-based cohort study.

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16 21 **Setting**
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18 22 Cluster-randomized general population sample selected based on population registry address
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20 23 information from 130 nationally distributed sample points collected from 1997-1999 and re-
21
22 24 evaluated 12 years later from 2008-2011.

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24 25 **Participants**
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26 26 1184 adults, aged 65 years or older at follow-up with complete data at baseline and follow-up were
27
28 27 included in the final study sample.

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30 31 **Outcome measure**
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33 29 Regular 'aerobic PA \geq 1 day/week' assessed based on self-reported information.

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35 30 **Results**
36

37 31 At follow-up, 53.2 % of the participants engaged in aerobic PA \geq 1 day/week. Participants aged 50 to
38
39 32 60 years at baseline were more likely to engage in aerobic PA \geq 1 day/week than participants aged 61
40
41 33 to 78 years; odds ratio (OR): 1.88, 95% CI: 1.46-2.40. Participants with middle and high
42
43 34 socioeconomic status (SES) were more likely to engage in aerobic PA \geq 1 day/week than participants
44
45 35 with low SES; OR middle SES: 2.08, 1.33-3.25; high SES 3.44, 2.11-5.60. Participants with high social
46
47 36 support were more likely to engage in aerobic PA \geq 1 day/week at follow up than participants with
48
49 37 low social support; OR 1.98, 1.26-3.12. Furthermore, participants who engaged in leisure-time PA at
50
51 38 least once per week at baseline were more likely to engage in aerobic PA \geq 1 day/week at follow up
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53 39 than those who engaged less than once per week; OR 1.95, 1.46-2.60.
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3 41 **Conclusions**

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5 42 Several influencing factors assessed at middle age predicted regular aerobic PA participation twelve
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7 43 years later. These factors should be considered when planning interventions to prevent physical
8
9 44 inactivity in older adults. There is great potential to increase aerobic PA participation in older adults
10
11 45 in Germany, in particular among those with low SES and low social support.
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15 47 **Keywords**

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18 48 Physical activity, determinants, healthy aging, older people, Germany
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24 50 **Strengths and limitations of this study**

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27 51 • This study pairs some of the advantages of a nationwide, population-based survey with a
28
29 52 cohort study design
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31 53 • Another strength is the long average follow-up period of 12 years
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33 54 • A limitation is the assessment of the outcome indicators with self-reports on physical activity
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35 55 level that are prone to recall and social desirability bias
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37 56 • The study sample size of 1184 persons is appropriate to conduct analysis based on the whole
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39 57 sample but limited to conduct sub-group analysis
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58 **Background**

59 In Germany, 50 % of adults aged 65 years and older suffer from at least three chronic diseases [1].
60 Physical activity (PA) can play a major role to prevent multimorbidity in this age group because of the
61 wide range of health conditions which can be positively influenced by PA [2]. Regular PA in older
62 adults contributes to a variety of health benefits such as lower risks of cardiovascular diseases [3],
63 functional limitations [4], dementia [5] and all-cause mortality [6] as well as a better psychological
64 wellbeing [3]. Furthermore, PA plays an important role in the treatment and management of many
65 chronic diseases and conditions such as hypertension, hyperlipidemia, type 2 diabetes and obesity
66 [3]. Low intensity PA can improve the health status of the sedentary elderly and moderate and
67 vigorous intensity aerobic PAs may be even more beneficial [4, 7, 8]. The World Health Organization
68 (WHO) recommends that older adults engage in moderate intensity aerobic PA of at least 150
69 minutes per week or vigorous intensity aerobic PA of at least 75 minutes per week [9]. However, in
70 many countries the majority of the elderly population does not achieve the WHO recommendation
71 [10]. In Germany, three fourths of women and three fifths of men aged 65 years and older engage in
72 less than 150 minutes of aerobic PA per week and half of them engage in less than one day per week
73 of aerobic PA [11]. In the context of population ageing, this observation demonstrates the potential
74 of PA promotion to support healthy ageing, which is defined by the WHO as 'developing and
75 maintaining the functional ability that enables well-being in older age' [2]. Therefore, to effectively
76 promote PA and plan interventions, further knowledge is needed about factors influencing PA in
77 older adults and groups at risk for an inactive lifestyle. Ecological models are commonly used to
78 select and structure determinants of PA behaviour [12]. These models imply that factors from
79 multiple levels (e.g. individual, interpersonal, environment, policy and global) influence PA. PA
80 behaviour of older adults is structured in a similar way, with multiple levels of influencing factors:
81 individual factors, e.g. age, sex and physical health [13, 14], interpersonal factors, e.g. living with a
82 spouse and social support [14] and environmental factors, e.g. the built environment [13, 15].

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83 However, the evidence in the literature on determinants of regular PA in older adults based on
84 cohort study data is limited [13].

85 This study aimed to investigate determinants of regular aerobic PA among older adults living in
86 Germany using data from a nationwide, population-based cohort study.

87 **Methods**

88 **Study design and participants**

89 Data from the German National Health Interview and Examination Survey for adults 1997-99
90 (GNHIES98) baseline survey and its first follow-up wave 2008-11 (DEGS1) were used. GNHIES98 and
91 DEGS1 are components of the national German Federal Health Monitoring programme, operated by
92 the Robert Koch Institute, which monitors the health status and health behaviour of adults 18 years
93 and older in Germany. The survey study design is described in detail elsewhere [16, 17]. In summary,
94 GNHIES98 and DEGS1 are both nationwide, population-based health examination surveys. Individuals
95 of the general adult population were randomly selected in 130 nationally distributed sample points
96 using a two-stage clustered sampling procedure: initially communities were sampled (primary sample
97 unit) and within these communities address information was randomly drawn from local population
98 registries. Institutionalized persons were excluded from the study sample. The GNHIES98 sample was
99 comprised of 7124 participants between the ages of 18 and 79 years and the DEGS1 sample of 8152
100 participants between the ages of 18 and 91 years [18, 19]. Interviews, examinations and tests were
101 carried out in both surveys. GNHIES98 data collection was conducted from October 1997 to March
102 1999 and DEGS1 data collection was conducted from November 2008 to December 2011. GNHIES98
103 was approved by the Board of the Federal Commissioner for Data Protection Berlin. DEGS1 was
104 approved by the Federal and State Commissioners for Data Protection and by the ethics committee
105 of the Charité – University Medicine Berlin (No. EA2/047/08). All participants provided informed
106 written consent.

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3 107 The response rates were 61 % for GNHIES98 and 62 % for DEGS1 [18, 19]. All GNHIES98 participants
4
5 108 were invited to participate in the DEGS1 follow-up survey. To improve the re-participation rate,
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7 109 participants who moved away or were not willing or able to visit the examination centre had the
8
9 110 opportunity to take part in an interview programme. GNHIES98 participants were enrolled in DEGS1
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11 111 between 10 and 15 years after GNHIES98 participation; 91 % participated 11 to 13 years after
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13 112 GNHIES98. The age range of the study sample for analysis was defined as participants aged 65 years
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15 113 or older at follow-up (DEGS1). This included persons who were aged 50 years or above at baseline
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17 114 (GNHIES98). A flow chart of participants is shown in Figure 1. 50.5 % (n = 1501) of GNHIES98
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19 115 participants, aged 65 years or older at follow-up, participated in DEGS1. Of the 49.5 % non-
20
21 116 participants, 19.3 % (n = 575) had died during the follow-up period. A lower re-participation rate was
22
23 117 observed for men, older participants, participants with lower socioeconomic status (SES),
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25 118 participants with chronic disease as well as those with lower leisure time PA level (Additional file 1).
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27 119 The final study sample included 1184 participants after exclusion of participants who were younger
28
29 120 than 65 years at follow-up (n = 220) and participants with missing data for the PA outcome variable
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31 121 (n = 97). The multivariate analysis was conducted based on a complete-case sample (n = 1143); thus
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33 122 an additional 41 participants were excluded due to missing data for at least one of the covariates
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35 123 used.

39 124 **Definition of variables**

40 125 *Outcome variable*

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42 126 The participants were asked at follow-up about the number of days and the duration on an average
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44 127 day they engage in physical activities which make her or him sweat or get out of breath in an average
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46 128 week. The reference period was the last three months. A dichotomous variable was constructed with
47
48 129 the categories: 'aerobic PA ≥ 1 day per week'; Yes/No. This cut-off point was chosen because regular
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50 130 aerobic PA on a weekly basis is associated with substantial health benefits [3].
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3 131 *Predictor variables*
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5 132 The information used for constructing the exposure variables was assessed in the baseline survey
6
7 133 (GNHIES98) with self-administered questionnaires, physician-administered computer-assisted
8
9 134 personal interviews (CAPI) or physical examinations. The variables were selected based on theories
10
11 135 and evidence available in the literature [12, 20]. According to the ecological model, individual
12
13 136 (demographic variables, health status), interpersonal (living with a spouse, social support), health
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15 137 behavioural (LTPA, participation in a health behaviour change programme, smoking status) and
16
17 138 environmental (size of and satisfaction with the living area) factors were included in the analysis.
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21 139 Individual factors
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24 140 Participant SES was assessed using an index based on the educational level, household income and
25
26 141 occupational status of the participants which has been described in detail elsewhere [21]. The
27
28 142 prevalence of chronic diseases was assessed during the CAPI. Participants were defined as 'having a
29
30 143 chronic disease' if they indicated diagnosis by a physician of at least one of the following diseases:
31
32 144 coronary heart disease, stroke, diabetes, respiratory disease or cancer. Participant body mass index
33
34 145 (BMI) was calculated using measured participant weight and height. According to the guidelines of
35
36 146 the WHO, obesity was defined as BMI ≥ 30 kg/m² [22].
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39 147 Interpersonal factors
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42 148 Participants were defined as 'living with a spouse' if they indicated marriage or co-habitation with
43
44 149 their spouse. The question 'How many people are so close to you that you can count on them if you
45
46 150 have serious personal problems?' derived from the Oslo-3 Social Support Scale [23] was used as
47
48 151 proxy variable for social support. Two categories were constructed: 'low social support' (1 person or
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50 152 none) and 'high social support' (at least 2 persons).
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53 153 Behavioural factors
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3 154 'Leisure time physical activity' (LTPA) was assessed with the question, 'On average, how often do you
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5 155 do sports activities or other physical activities in your leisure time, which make you sweat or out of
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7 156 breath?'. The five answer categories were summarised into 2 categories: 'weekly LTPA' (daily/3 to 6
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9 157 times a week/1 to 2 times a week) and 'no weekly LTPA' (once a month/never). 'Participation in at
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11 158 least one health behaviour change programme' (abbreviated as 'at least one health programme') was
12
13 159 defined if participants reported participation in a programme with the topic 'weight reduction',
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15 160 'healthy nutrition', 'back training' or 'stress management' during the last twelve months [24]. The
16
17 161 variable should be an indicator for health oriented behaviour. Participants were defined as 'smoker'
18
19 162 if they reported that they currently smoke and were defined as 'non-smoker' if they identified as a
20
21 163 former smoker or as having never smoked.

24 164 Environmental factors

26
27 165 A 'residential area size' variable was constructed with four categories: 'rural area' (< 5000
28
29 166 inhabitants); 'small-sized city' (5000 - < 20,000 inhabitants); 'medium-sized city' (20,000 - < 100,000
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31 167 inhabitants); 'metropolitan city' (\geq 100,000 inhabitants). For a subjective estimation of the
32
33 168 environment, participants were asked to rate the 'satisfaction with their living area' on a 7-point
34
35 169 scale (from 1 'very unsatisfied' to 7 'very satisfied'). A dichotomous variable was constructed with the
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37 170 categories 'not satisfied' (points 1-5) and 'satisfied' (points 6 and 7).

40 171 **Statistical analyses**

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43 172 All statistical analyses were performed with the survey design procedure of Stata 14.1 to adjust for
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45 173 cluster design. P-values less than 0.05 were defined as statistically significant. Determinants of
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47 174 aerobic PA \geq 1 day/week were investigated in two steps: first, bivariate analyses were performed and,
48
49 175 second, exposure variables that were significantly associated with the outcome in the bivariate
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51 176 analysis ($p < .05$) were included in a stepwise logistic regression analysis. Bivariate associations
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53 177 between the exposure and outcome variables were analysed with the Pearson's chi-squared test
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55 178 with Rao-Scott correction. In the logistic regression, odds ratios (OR) and 95 % confidence intervals

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3 179 (CI) were estimated to examine the associations between baseline exposure variables and
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5 180 participation in aerobic PA ≥ 1 day/week at follow-up. During the stepwise analysis three models
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7 181 were investigated: Model 1 included individual factors (sex, age, SES, chronic disease and obesity), in
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9 182 Model 2 the interpersonal factors living with a spouse and social support were added, in Model 3 the
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11 183 behavioural variables were added (LTPA, at least one health programme). To detect multicollinearity
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13 184 between the covariates, variance inflation factors (VIF) were calculated. All VIFs were less than 1.5
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15 185 and thus clearly lower than the common threshold for multicollinearity of 10 [25]. To investigate
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17 186 whether the determinants of aerobic PA ≥ 1 day/week differ between men and women and between
18
19 187 different age groups, age and sex interaction analyses were performed for all associations presented
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21 188 in the Model 3.

189 **Results**

190 **Participants**

191 52.5 % (n = 622) of the participants were women. The mean age of the participants at baseline was
192 60 years (range 50-78 years) and at follow-up 72 years (range 65-91 years). 60.2 % (n = 713) were in
193 the age group '50 -60 years' at baseline and 39.8 % (n = 471) in the age group '61-78 years'. The
194 description of the participants according to socio-demographic, health-related, interpersonal,
195 behavioural and environmental variables at baseline is presented in Table 1. When comparing
196 participants from the older age group (61-78 years) to participants from the younger age group (50-
197 60 years) at baseline, older participants had high SES less often, had a chronic disease more often,
198 lived with a spouse less often, participated in LTPA less often, participated in a health programme less
199 often and smoked less often than younger participants (each $p < .05$).

200 **Aerobic PA ≥ 1 day/week**

201 53.2 % of the participants engaged in aerobic PA ≥ 1 day/week at follow up. No significant difference
202 was observed between men and women (55.3 % vs 51.3 %; $p = .158$). The prevalence of engaging in

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3 203 aerobic PA ≥ 1 day/week (41.2 %) was lower at baseline among the 61-78 year age group than among
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5 204 the 50-60 year age group, where prevalence was 61.2 % ($p < .001$). The prevalence of aerobic PA ≥ 1
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7 205 day/week according to baseline socio-demographic, health-related, behavioural, social and
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9 206 environmental variables is shown in Table 2.

11 207 **Determinants of engaging in aerobic PA ≥ 1 day/week**

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14 208 Binary analyses showed (Table 2) that age, SES, chronic disease, obesity, living with a spouse, social
15
16 209 support, LTPA and participation in at least one health programme at baseline were significantly
17
18 210 associated with aerobic PA ≥ 1 day/week at follow-up.

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21 211 Multivariate analyses showed that age, SES, social support and LTPA were predictors for aerobic PA
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23 212 ≥ 1 day/week at follow-up (Table 3). The results of Model 3 (all binary significant variables included)
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25 213 indicated that participants aged 50 to 60 years were more likely to engage in aerobic PA ≥ 1 day/week
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27 214 than participants aged 61 to 78 years, with an OR of 1.88 (95% CI, 1.46-2.40). Participants with
28
29 215 middle or high SES were more likely to engage in aerobic PA ≥ 1 day/week than participants with low
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31 216 SES, with an OR of 2.08 (1.33-3.25) for middle SES and 3.44 (2.11-5.60) for high SES. Participants with
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33 217 high social support were more likely to engage in aerobic PA ≥ 1 day/week at follow up than
34
35 218 participants with a low social support, with an OR of 1.98 (1.26-3.12). Furthermore, participants who
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37 219 participate in LTPA every week at baseline were more likely to engage in aerobic PA ≥ 1 day/week at
38
39 220 follow up than inactive participants, with an OR of 1.95 (1.46-2.60).

41 221 **Subgroup analyses**

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44 222 The interaction analyses showed that age was an effect modifier for the association between SES and
45
46 223 aerobic PA ≥ 1 day/week and for the association between social support and aerobic PA ≥ 1 day/week
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48 224 (interaction term age*middle SES: $p = .033$; age*high SES: $p < .001$; age*social support: $p < .001$).

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51 225 Subgroup analyses showed that SES was a significant determinant of aerobic PA ≥ 1 day/week only in
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53 226 the age group 65 to 72 years but not in the age group 73 to 91 years. Participants in this age group
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55 227 with middle or high SES were more likely to engage in aerobic PA ≥ 1 day/week than participants with

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3 228 low SES (middle SES: 3.02, 1.70-5.37; high SES: 6.62, 3.74-11.72). Furthermore, social support was
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5 229 only a significant determinant of aerobic PA ≥ 1 day/week among participants 65 to 72 years.
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7 230 Participants in this age group with higher social support were more likely to engage in aerobic PA ≥ 1
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9 231 day/week, with an OR of 3.31 (1.76-6.21). Sex was not an effect modifier for any of the presented
10
11 232 associations.

14 233 **Discussion**

17 234 In this nationwide, population-based cohort study, it was observed that half of the older adults 65+
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19 235 years in Germany did not engage in aerobic PA at least one day per week. The multivariate analyses
20
21 236 showed that the groups at high risk for having an inactive lifestyle at age 65+ years were those who,
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23 237 12 years earlier, were in the older age groups, those with low socio-economic position, low social
24
25 238 support and low previous levels of PA. Several additional determinants of aerobic PA identified in
26
27 239 binary analyses were no longer associated with the outcome after multivariate adjustment.

30 240 **Individual factors**

33 241 Sex was not a determinant for aerobic PA ≥ 1 day/week in older adults in the present study. Other
34
35 242 studies with older adults showed mixed results with a tendency to report a higher PA level for men
36
37 243 [10, 13, 14]. A time trend analysis on the prevalence of physical inactivity among German adults aged
38
39 244 25 to 69 years over an observation period of 20 years demonstrated that gender differences
40
41 245 observed in the first 1990-92 survey diminished over time so that women were no longer more
42
43 246 inactive than men in the 2008-2011 survey [26]. The higher proportion of women than men aged 65
44
45 247 years and older living in Germany participating in PA courses as part of primary prevention
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47 248 programmes [24] might explain the similar PA prevalence in this study.

51 249 The observed lower odds for participation in aerobic PA ≥ 1 day/week with higher age in the present
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53 250 study are consistent with other studies [10, 13, 14, 27]. The loss of physical function as well as the
54
55 251 fear of injuries and falling may play a role in the reduction of the PA level with progression of age

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3 252 [28]. A qualitative study showed that older adults still believe that PA is inappropriate for older
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5 253 people and might be even harmful [28, 29]. Furthermore, a cohort effect might explain, at least
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7 254 partly, the differences between age groups. Beginning in the 1970s, the number of recreational sport
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9 255 offers started to increase in Germany [30], thus the younger age group in the previously mentioned
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11 256 study (22-32 years old at the year 1970) might have benefited more than the older age group.

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14 257 Consistent with the findings reported in other studies, older adults with higher SES participated more
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16 258 often in aerobic PA ≥ 1 day/week later in life than persons with low SES [14, 27, 31]. More social and
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18 259 material resources and more PA friendly neighbourhoods may partly explain the higher activity level
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20 260 of older adults with a higher SES [31, 32]. Another important factor might be the difference in PA
21
22 261 behaviour earlier in life. Adults with higher levels of education are more physically active in leisure
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24 262 time, perhaps to compensate for work-related inactivity, whereas adults with lower levels of
25
26 263 education may have higher PA level during their work time [33, 34]. With age and retirement it is
27
28 264 likely that adults who participate in leisure time PA continue these activities, whereas adults who had
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30 265 only experienced work-related activity may become inactive.

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32
33 266 The results of this study suggest that chronic disease developed earlier in life is not a predictor of
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35 267 aerobic PA ≥ 1 day/week in older adults. A cross-sectional study [31] also observed no relationship
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37 268 between diabetes and hypertension and PA in older adults. However, other prospective studies
38
39 269 showed that older adults with poor health status were less likely to be physically active [13, 14, 35].
40
41 270 Prescribed PA is part of the therapy of several chronic diseases like heart disease and diabetes. Thus,
42
43 271 chronic diseases can act as both barriers to or motivations for PA, which may blur the association
44
45 272 over time. It is possible that such a blurring of the association between chronic disease and PA may
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47 273 have occurred in our study. Moreover, participants with chronic diseases had a lower probability of
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49 274 re-participation (see Additional File 1), reducing the possibility to rigorously investigate the long-term
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51 275 association between chronic diseases and aerobic PA ≥ 1 day/week in our study sample.
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3 276 Furthermore, obesity was not a predictor of the outcome aerobic PA ≥ 1 day/week. Results of
4
5 277 prospective studies investigating the influence of obesity on PA in elderly are inconsistent. The
6
7 278 authors of a review concluded that the influence of obesity on PA is weak [14], whereas the results of
8
9 279 the English Longitudinal Study of Aging observed that obesity is associated with a lower likelihood of
10
11 280 being persistently active [27]. Similar to chronic diseases, obesity may, on the one hand, result in a
12
13 281 lower PA level or, on the other hand, as part of a therapy may encourage an increase in activity level.
14
15 282 The different directions of this association make it difficult to evaluate the effect of obesity on PA.

18 283 **Interpersonal factors**

20
21 284 The results of this study suggest that interpersonal factors are important determinants of engaging in
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23 285 aerobic PA ≥ 1 day/week in older adults. Participants with higher social support were more likely to
24
25 286 participate in aerobic PA ≥ 1 day/week. Social networks could promote physical activity among older
26
27 287 adults by providing information, connecting older adults to resources, such as transport services, and
28
29 288 providing encouragement [28, 32]. The results are in line with a cross-sectional study which observed
30
31 289 that in elderly people social isolation is related to negative health behaviour like physical inactivity
32
33 290 [36, 37]. Living with a spouse was not a significant predictor in this analysis but older adults with a
34
35 291 partner tended to be more physical active. Further studies observed that older adults who are
36
37 292 married are more likely to participate in physical activities later in life [14].

41 293 **Behavioural factors**

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43
44 294 In the current study, former weekly LTPA was a predictor of aerobic PA ≥ 1 day/week in older adults.
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46 295 Several studies observed that PA participation earlier in life is an important determinant of physical
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48 296 behaviour among older adults, in line with our observations [29, 38]. Experiences about physical
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50 297 competence as well as a positive attitude towards PA could explain the tracking of PA behaviour later
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52 298 in life [29].

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55 299 Participation in at least one PA related health programme was not a significant predictor of aerobic
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57 300 PA ≥ 1 day/week twelve years later. It could be that programmes such as back training and stress

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3 301 management, did not prioritize the promotion of aerobic PA and thus that participation in these
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5 302 programmes had no positive effect on aerobic PA ≥ 1 day/week. It could also be that the programmes
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7 303 increased PA level in short-term but there were no long-term effects on aerobic PA level twelve years
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9 304 later.

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12 305 In this study, smoking was not associated with aerobic PA ≥ 1 day/week later in life, contrary to
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14 306 studies demonstrating that health risk behaviour like smoking and physical inactivity often cluster
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16 307 [14, 27]. Due to the high proportion of adults aged 65 years and older living in Germany who quit
17
18 308 smoking [39], an explanation for no association between smoking and PA later in life might be that
19
20 309 many participants quit smoking during the follow-up period.

21 22 23 310 **Environmental factors**

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26 311 The environmental factors investigated in the current study did not predict aerobic PA ≥ 1 day/week
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28 312 in older adults. Environmental characteristics such as urbanization and satisfaction with the living
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30 313 area are probably long-term characteristics, for which the impact on individual PA behaviour may
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32 314 already has appeared earlier in life. Also after adjustment for intermediate variables, like PA at
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34 315 baseline, the additional contribution seems small. Furthermore, participants might have moved to
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36 316 another residential area so that the former residential area has minor influence on the activity
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38 317 behaviour twelve years later. Two reviews investigated the relationship between the environmental
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40 318 factors within the neighbourhood and PA in older adults and came up with contradictory findings.
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42 319 The authors of one review [40] concluded that the majority of studies reviewed observed no
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44 320 relationship between environmental factors (objectively and subjectively measured) and PA
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46 321 behaviour of older adults. The authors of the other review [15] determined that characteristics of the
47
48 322 built environment (objectively measured) are associated with the PA of older adults. Differences in
49
50 323 the assessment of environmental characteristics as well as PA could be reasons for the differing
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52 324 results.

53 54 55 56 325 **Age interactions**

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3 326 SES and social support were not significant predictors of aerobic PA ≥ 1 day/week in the older age
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5 327 group but were significant predictors in the younger age group. One explanation for this could be
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7 328 decline in the prevalence of aerobic PA with increasing age leading to weaker influence of the
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9 329 predictors. A lower PA prevalence also leads to a lower statistical power to determine significant
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11 330 associations.

14 331 **Strengths and limitations**

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17 332 This study pairs some of the advantages of a nationwide, population-based survey with a high degree
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19 333 of representativeness and a cohort study design which gives stronger information on causal
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21 334 inference. High efforts were undertaken at all stages of conducting GNHIES89 and DEGS1 to reduce
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23 335 potential sources of bias [16, 17]. This comprised measures such as internal and external quality
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25 336 control during field work, anonymous data collection and record keeping, data quality assurance and
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27 337 use of accurate instruments. However, self-reports on PA level are prone to recall and social
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29 338 desirability bias [41]. Thus we cannot exclude the possibility that aerobic PA ≥ 1 day/week was over-
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31 339 reported. Also, most of the independent variables were based on self-reports involving the potential
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33 340 of reporting bias. Selection bias could have appeared at different stages (selection of individuals into
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35 341 the study, loss to follow-up, item non response). This may have influenced the results and may
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37 342 compromise the generalizability of the findings. For instance, we were not able to consider
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39 343 information of participants who had died during the follow-up period. Non-response analysis
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41 344 indicates that the non-responders were older, they had on average a lower level of LTPA and SES and
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43 345 more often chronic diseases and obesity compared to the responders. This suggests that the
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45 346 responders are a healthier and fitter group than the non-responders and that the prevalence of
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47 347 aerobic PA ≥ 1 day/week at follow-up might be overestimated. In addition, the study results might
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49 348 not apply to elderly individuals living in a nursing home who were not eligible for inclusion into the
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51 349 study sample.

55 350 **Conclusion**

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3 351 Despite limitations, we conclude that several influencing factors assessed at middle age predicted
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5 352 regular aerobic PA participation twelve years later. These factors should be considered when
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7 353 planning interventions to prevent physical inactivity in older adults. Aerobic PA has many benefits for
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9 354 aging people and can improve their life in many ways. There is a great potential to increase aerobic
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11 355 PA participation in older adults in Germany. Low PA levels among older adults indicate the need for
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13 356 PA promotion interventions tailored for this age group. Measures promoting a physically active
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15 357 lifestyle during middle age, e.g. through workplace interventions, may have positive long-term
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17 358 effects on PA level at older age due to the strong tracking of PA behaviour. Target groups for PA
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19 359 interventions at middle age should be people with low SES and low social support to prevent low PA
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21 360 levels later in life.
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3 361 **Additional material**
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6 362 Additional File 1: DEGS1 unit nonresponse analysis, differences in selected baseline characteristics
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8 363 between DEGS1 non-respondents and respondents.
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11 364 **Abbreviations**
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14 365 BMI – body mass index; CAPI – physician-administered computer assisted personal interview; DEGS –
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16 366 German Health Interview and Examination Survey for Adults 2008-11; GNHIES98 – German National
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18 367 Health Interview and Examination Survey 1997-99; OR – odds ratio; PA – physical activity; SES –
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20 368 socioeconomic status; WHO – World Health Organization
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24 369 **Declarations**
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27 370 **Ethics approval and consent to participate**
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29
30 371 The study GNHIES98 was approved by the Board of the Federal Commissioner Data Protection Berlin.
31
32 372 DEGS1 was approved by the Federal and State Commissioners for Data Protection and by the Charité
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34 373 – University Medicine Berlin ethic committee (No. EA2/047/08). All participants provided informed
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36 374 written consent.
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39 375 **Consent for publication**
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42 376 Not applicable.
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45 377 **Competing interests**
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48 378 The authors declare that they do have no competing interests.
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51 379 **Availability of data and materials**
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3 380 Datasets of GNHIES98 and DEGS1 are available via Public Use File
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5 381 (http://www.rki.de/DE/Content/Gesundheitsmonitoring/Forschungsdatenzentrum/informationen_a
6
7 382 [ntrag/info_antrag_node.html](http://www.rki.de/DE/Content/Gesundheitsmonitoring/Forschungsdatenzentrum/informationen_a_ntrag/info_antrag_node.html)).
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9

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16 385 **Authors' contributions**

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19 386 GBMM was involved in the design and conduct of GNHIES98 and DEGS1 in particular for the physical
20
21 387 activity questions. SK and KM conceptualized the current study. KM conducted the present analysis
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23 388 and GBMM, SJ, AS and JDF contributed to the analysis plan and interpretation of the results. KM
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25 389 drafted the manuscript and GBMM, SJ, AS, SK and JDF critically revised it. JDF contributed to writing
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27 390 the manuscript. All authors read and approved the final manuscript.
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3 506 **Figures**

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5 507 Figure 1: Flow diagram of participants

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509 Tables

Table 1: Baseline characteristics of the study sample (n = 1184)

	Missing	Age at baseline				Total	p-value	
		%	95% CI	%	95% CI			
1 Individual factors								
Sex	0							
Women (n=622)		53.0	(49.5-56.5)	51.8	(48.2-55.3)	52.5	(49.8-55.3)	0.600
Men (n=562)		47.0	(43.5-50.5)	48.2	(44.7-51.8)	47.5	(44.7-50.2)	
Socioeconomic status	14							
Low (n=151)		11.4	(8.9-14.4)	15.2	(11.9-19.2)	12.9	(10.6-15.7)	< 0.001
Middle (n=712)		57.5	(53.5-61.3)	66.0	(61.6-70.1)	60.9	(57.8-63.8)	
High (n=307)		31.2	(27.3-35.3)	18.8	(15.0-23.3)	26.2	(23.0-29.7)	
Chronic disease	3							
No (n=869)		78.5	(75.4-81.4)	66.0	(61.6-70.2)	73.6	(70.8-76.2)	< 0.001
Yes (n=312)		21.5	(18.6-24.6)	34.0	(29.8-38.4)	26.4	(23.8-29.2)	
Obesity	3							
Yes (n=297)		24.5	(20.8-28.5)	26.2	(22.3-30.4)	25.1	(22.2-28.4)	0.504
No (n=884)		75.5	(71.5-79.2)	73.8	(69.6-77.7)	74.9	(71.6-77.8)	
2 Interpersonal factors								
Living with a spouse	16							
No (n=216)		16.7	(14.0-19.7)	21.2	(17.7-25.3)	18.5	(16.2-21.1)	0.035
Yes (n=952)		83.3	(80.3-86.0)	78.8	(74.7-82.3)	81.5	(78.9-83.8)	
Social support	21							
Low (n=100)		7.6	(5.7-10.0)	10.2	(7.8-13.1)	8.6	(7.0-10.5)	0.110
High (n=1,063)		92.4	(90.0-94.3)	89.8	(86.9-92.2)	91.4	(89.5-93.0)	
3 Behavioural factors								
Leisure time physical activity	26							
Every week (n=784)		72.1	(67.9-76.0)	61.0	(56.8-65.1)	67.7	(64.4-70.9)	< 0.001
Not every week (n=374)		27.9	(24.0-32.1)	39.0	(34.9-43.2)	32.3	(29.1-35.6)	
At least one health programme	0							
Yes (n=124)		12.6	(10.4-15.3)	7.2	(5.2-10.0)	10.5	(8.8-12.5)	0.002
No (n=1,060)		87.4	(84.7-89.6)	92.8	(90.0-94.8)	89.5	(87.5-91.2)	
Smoking status	11							
Smoker (n=188)		20.0	(17.2-23.0)	10.1	(7.5-13.3)	16.0	(14.0-18.2)	< 0.001
Non-smoker (n=985)		80.0	(77.0-82.8)	89.9	(86.7-92.5)	84.0	(81.8-86.0)	
4 Environmental factors								
Residential area size	0							
Rural (n=249)		20.3	(13.5-29.4)	22.1	(14.4-32.2)	21	(14.2-30.0)	0.601
Small-sized city (n=247)		20.1	(13.3-29.1)	22.1	(14.4-32.3)	20.9	(14.0-30.0)	
Medium-sized city (n=318)		26.9	(19.0-36.7)	26.8	(18.5-37.0)	26.9	(19.1-36.3)	
Metropolitan city (n=370)		32.7	(23.7-43.1)	29.1	(20.4-39.7)	31.3	(22.7-41.4)	

Satisfaction with residential area	21							
Not satisfied (n=308)	26.1	(22.9-29.7)	27.0	(23.3-31.0)	26.5	(23.9-29.2)	0.733	
Satisfied (n=855)	73.9	(70.3-77.1)	73.0	(69.0-76.7)	73.5	(70.8-76.1)		

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Table 2: Bivariate associations between aerobic physical activity \geq 1 day/week and potential predictor variables

		Aerobic physical activity \geq 1 day/week				p-value*
		No		Yes		
		%	95% CI	%	95% CI	
1	Sex					
	Women (n=622)	48.7	(44.7-52.7)	51.3	(47.3-55.3)	0.158
	Men (n=562)	44.7	(40.1-49.4)	55.3	(50.6-59.9)	
	Age group					
	50-60 years (n=713)	38.8	(35.1-42.8)	61.2	(57.2-64.9)	< 0.001
	61-78 years (n=471)	58.8	(54.1-63.4)	41.2	(36.6-45.9)	
	Socioeconomic status					
	Low (n=151)	70.2	(62.0-77.3)	29.8	(22.7-38.0)	< 0.001
	Middle (n=712)	47.9	(43.8-52.0)	52.1	(48.0-56.2)	
	High (n=307)	31.9	(27.0-37.3)	68.1	(62.7-73.0)	
	Chronic disease					
	No (n=869)	44.1	(40.5-47.7)	55.9	(52.3-59.5)	0.006
	Yes (n=312)	53.8	(47.6-60.0)	46.2	(40.0-52.4)	
	Obesity					
	Yes (n=297)	53.5	(47.4-59.5)	46.5	(40.5-52.6)	0.005
	No (n=884)	44.6	(41.2-48.0)	55.4	(52.0-58.8)	
2	Living with a spouse					
	No (n=216)	57.4	(51.1-63.4)	42.6	(36.6-48.9)	< 0.001
	Yes (n=952)	44.1	(40.5-47.8)	55.9	(52.2-59.5)	
	Social support					
	Low (n=100)	65.0	(55.4-73.5)	35.0	(26.5-44.6)	< 0.001
	High (n=1,063)	44.9	(41.6-48.2)	55.1	(51.8-58.4)	
3	Leisure time physical activity					
	Every week (n=784)	38.6	(34.8-42.6)	61.4	(57.4-65.2)	< 0.001
	Not every week (n=374)	62.8	(57.6-67.8)	37.2	(32.2-42.4)	
	At least one health programme					
	Yes (n=124)	34.7	(26.7-43.6)	65.3	(56.4-73.3)	0.005
	No (n=1,060)	48.2	(44.8-51.7)	51.8	(48.3-55.2)	
	Smoking status					
	Smoker (n=188)	49.5	(41.7-57.3)	50.5	(42.7-58.3)	0.406
	Non-smoker (n=985)	46.0	(42.5-49.5)	54.0	(50.5-57.5)	
4	Residential area size					
	Rural (n=249)	48.6	(42.1-55.1)	51.4	(44.9-57.9)	0.873
	Small-sized city (n=247)	48.2	(39.4-57.1)	51.8	(42.9-60.6)	
	Medium-sized city (n=318)	45.9	(39.6-52.4)	54.1	(47.6-60.4)	

Metropolitan city (n=370)	45.4	(40.5-50.4)	54.6	(49.6-59.5)	
Satisfaction with residential area					0.711
Not satisfied (n=308)	47.1	(42.0-52.2)	52.9	(47.8-58.0)	
Satisfied (n=855)	46.0	(42.2-49.7)	54.0	(50.3-57.8)	

*Pearson's chi-squared test with Rao-Scott correction

1: Individual factors; 2: Interpersonal factors; 3: Behavioural factors; 4: Environmental factors

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Table 3: Stepwise adjusted odds ratios of aerobic physical activity at follow-up by baseline predictor variables, adults aged 65 years or older

Baseline variables	Aerobic physical activity ≥ 1 day/week					
	Model 1		Model 2		Model 3	
	OR	95 % CI	OR	95 % CI	OR	95 % CI
Sex						
Women	0.95	(0.73 - 1.23)	1.01	(0.78 - 1.32)	1.05	(0.80 - 1.38)
Men	1.00	-	1.00	-	1.00	-
Age group						
50-60 years	2.00	(1.56 - 2.56)	1.97	(1.53 - 2.52)	1.88	(1.46 - 2.40)
61-78 years	1.00	-	1.00	-	1.00	-
Socioeconomic status						
Low	1.00	-	1.00	-	1.00	-
Middle	2.48	(1.61 - 3.84)	2.39	(1.54 - 3.70)	2.08	(1.33 - 3.25)
High	4.52	(2.83 - 7.23)	4.29	(2.67 - 6.90)	3.44	(2.11 - 5.60)
Chronic disease						
No	1.25	(0.92 - 1.69)	1.24	(0.91 - 1.69)	1.21	(0.89 - 1.66)
Yes	1.00	-	1.00	-	1.00	-
Obesity						
No	1.23	(0.93 - 1.62)	1.24	(0.94 - 1.63)	1.14	(0.86 - 1.52)
Yes	1.00	-	1.00	-	1.00	-
Living with a spouse						
Yes			1.36	(1.00 - 1.84)	1.31	(0.96 - 1.79)
No			1.00	-	1.00	-
Social support						
High			2.11	(1.35 - 3.30)	1.98	(1.26 - 3.12)
Low			1.00	-	1.00	-
Leisure time physical activity						
Every week					1.95	(1.46 - 2.60)
Not every week					1.00	-
At least one health programme						
Yes					1.36	(0.88 - 2.10)
No					1.00	-

Bold: $p < 0.05$; OR = Odds Ratio; Model 1: Individual factors; Model 2: + interpersonal factors; Model 3: + behavioural factors

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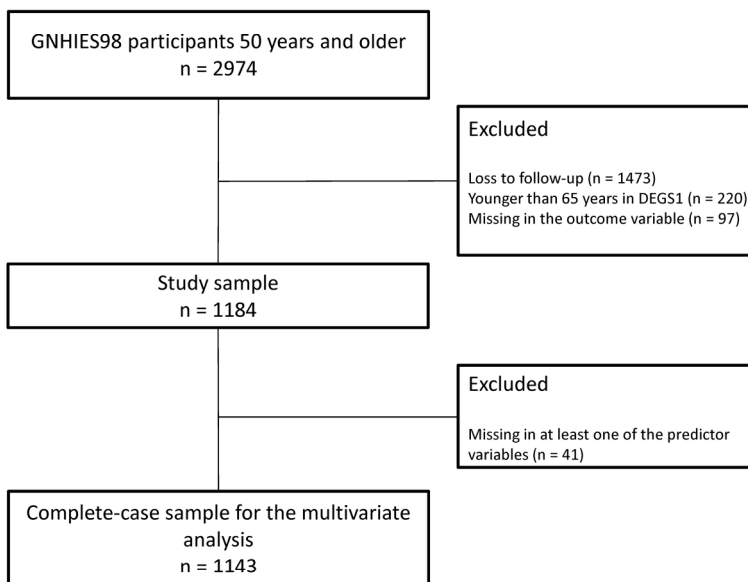


Figure 1: Flow diagram of participants

190x142mm (300 x 300 DPI)

Additional File 1 – DEGS1 unit non-response analysis

Table 1: Differences in selected baseline characteristics between DEGS1 respondents, non-respondents and deceased

	Responder		Non-responder		Deceased	
	%	95% CI	%	95% CI	%	95% CI
Total (n=2974)	50.5	(48.3-52.6)	30.2	(28.3-32.1)	19.3	(17.9-20.9)
Sex						
Women (n=1,567)	52.6	(50.2-55.0)	59.2	(56.0-62.5)	42.6	(39.0-46.3)
Men (n=1,407)	47.4	(45.0-49.8)	40.8	(37.5-44.0)	57.4	(53.7-61.0)
Age						
50-60 years (n=1,492)	65.2	(62.6-67.7)	43.2	(39.9-46.5)	21.7	(18.5-25.3)
61-78 years (n=1,482)	34.8	(32.3-37.4)	56.8	(53.5-60.1)	78.3	(74.7-81.5)
Socioeconomic status						
Low (n=566)	13.1	(10.9-15.6)	26.6	(23.0-30.6)	26.5	(22.6-30.7)
Middle (n=1,709)	60.3	(57.5-63.0)	59.4	(55.7-63.0)	55.9	(51.9-59.8)
High (n=611)	26.6	(23.6-30.0)	14.0	(11.3-17.0)	17.6	(14.2-21.6)
Chronic disease						
No (n=1,984)	74.7	(72.5-76.9)	67.0	(64.1-69.8)	46.4	(42.1-50.8)
Yes (n=980)	25.3	(23.1-27.5)	33.0	(30.2-35.9)	53.6	(49.2-57.9)
Obesity						
Yes (n=860)	26.1	(23.3-29.1)	34.0	(30.6-37.6)	29.8	(25.8-34.1)
No (n=2,087)	73.9	(70.9-76.7)	66.0	(62.4-69.4)	70.2	(65.9-74.2)
Living with a spouse						
Yes (n=2,273)	85.1	(83.1-86.8)	74.0	(70.5-77.2)	72.3	(68.1-76.2)
No (n=589)	14.9	(13.2-16.9)	26.0	(22.8-29.5)	27.7	(23.8-31.9)
Leisure time physical activity						
Every week (n=1,624)	67.6	(64.7-70.4)	46.5	(42.5-50.5)	43.8	(39.1-48.6)
Not every week (n=1,231)	32.4	(29.6-35.3)	53.5	(49.5-57.5)	56.2	(51.4-60.9)

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Reported on page
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5-6
		(b) For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	15
Study size	10	Explain how the study size was arrived at	5 (see cited study protocol papers)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9
		(b) Describe any methods used to examine subgroups and interactions	9
		(c) Explain how missing data were addressed	6
		(d) If applicable, explain how loss to follow-up was addressed	Additional file 1
		(e) Describe any sensitivity analyses	15, Additional file 1
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for	6, Fig. 1

		eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	Additional file 1
		(c) Consider use of a flow diagram	Fig. 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, Tab. 1
		(b) Indicate number of participants with missing data for each variable of interest	Tab. 1
		(c) Summarise follow-up time (eg, average and total amount)	6
Outcome data	15*	Report numbers of outcome events or summary measures over time	9-10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10, Tab. 2, 3
		(b) Report category boundaries when continuous variables were categorized	6-8
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

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Predictors of physical activity among older adults in Germany – a nationwide cohort study

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3 **1 Predictors of physical activity among older adults in Germany – a nationwide cohort study**

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5 2

6
7 3 Kristin Manz¹, Gert B. M. Mensink¹, Susanne Jordan¹, Anja Schienkiewitz¹, Susanne Krug¹, Jonas D.
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19 13 13302 Berlin, Germany

1
2
3 14 **Abstract**
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5
6 15 **Objectives**
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8 16 To investigate individual, interpersonal and environmental baseline factors predicting regular aerobic
9
10 17 physical activity (PA) participation among older adults in Germany at follow-up 12 years later.

11
12 18 **Design**
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14 19 Population-based cohort study.

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16 20 **Setting**
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18 21 Cluster-randomized general population sample selected based on population registry address
19
20 22 information from 130 nationally distributed sample points collected from 1997-1999 and re-
21
22 23 evaluated 12 years later from 2008-2011.

24 24 **Participants**
25

26 25 1184 adults, aged 65 years or older at follow-up with complete data at baseline and follow-up were
27
28 26 included in the final study sample.

29
30 31 **Outcome measure**
32

33 32 Regular 'aerobic PA \geq 1 day/week' assessed based on self-reported information.

34
35 35 **Results**
36

37 30 At follow-up, 53.2 % of the participants engaged in aerobic PA \geq 1 day/week. Participants aged 50 to
38
39 31 60 years at baseline were more likely to engage in aerobic PA \geq 1 day/week than participants aged 61
40
41 32 to 78 years; odds ratio (OR): 1.88, 95% CI: 1.46-2.40. Participants with middle and high
42
43 33 socioeconomic status (SES) were more likely to engage in aerobic PA \geq 1 day/week than participants
44
45 34 with low SES; OR middle SES: 2.08, 1.33-3.25; high SES 3.44, 2.11-5.60. Participants with high social
46
47 35 support were more likely to engage in aerobic PA \geq 1 day/week at follow up than participants with
48
49 36 low social support; OR 1.98, 1.26-3.12. Furthermore, participants who engaged in leisure-time PA at
50
51 37 least once per week at baseline were more likely to engage in aerobic PA \geq 1 day/week at follow up
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53 38 than those who engaged less than once per week; OR 1.95, 1.46-2.60.
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40 **Conclusions**

41 Several influencing factors assessed at baseline predicted regular aerobic PA participation twelve
42 years later. These factors should be considered when planning interventions to prevent physical
43 inactivity in older adults. There is great potential to increase aerobic PA participation in older adults
44 in Germany, in particular among those with low SES and low social support.

46 **Keywords**

47 Physical activity, determinants, healthy aging, older people, Germany

49 **Strengths and limitations of this study**

- 50 • This study pairs some of the advantages of a nationwide, population-based survey with a
51 cohort study design
- 52 • Another strength is the long average follow-up period of 12 years
- 53 • A limitation is the assessment of the outcome indicators with self-reports on physical activity
54 level that are prone to recall and social desirability bias
- 55 • The study sample size of 1184 persons is appropriate to conduct analysis based on the whole
56 sample but limited to conduct sub-group analysis

57 **Background**

58 In Germany 50 % of adults aged 65 years and older suffer from at least three chronic diseases [1].
59 Physical activity (PA) can play a major role in preventing multimorbidity in this age group because of
60 the wide range of health conditions which can be positively influenced by PA [2]. Regular PA in older
61 adults contributes to a variety of health benefits such as lower risks of cardiovascular diseases [3],
62 functional limitations [4], dementia [5] and all-cause mortality [6] as well as better psychological
63 wellbeing [3]. Furthermore, PA plays an important role in the treatment and management of many
64 chronic diseases and conditions such as hypertension, hyperlipidemia, type 2 diabetes and obesity
65 [3]. Low intensity PA can improve the health status of the sedentary elderly and moderate and
66 vigorous intensity aerobic PAs may be even more beneficial [4, 7, 8]. The World Health Organization
67 (WHO) recommends that older adults engage in moderate intensity aerobic PA of at least 150
68 minutes per week or vigorous intensity aerobic PA of at least 75 minutes per week [9]. However, in
69 many countries the majority of the elderly population does not achieve the WHO recommendation
70 [10]. In Germany, three quarters of women and three fifths of men aged 65 years and older engage
71 in less than 150 minutes of aerobic PA per week and half of them engage in less than one day per
72 week of aerobic PA [11]. In the context of population ageing, this observation demonstrates the
73 potential of PA promotion to support healthy ageing, which is defined by the WHO as 'developing
74 and maintaining the functional ability that enables well-being in older age' [2]. Therefore, to
75 effectively promote PA and plan interventions, further knowledge is needed about factors
76 influencing PA in older adults and groups at risk for an inactive lifestyle. Ecological models are
77 commonly used to select and structure determinants of PA behaviour [12]. These models imply that
78 factors from multiple levels (e.g. individual, interpersonal, environment, policy and global) influence
79 PA. PA behaviour of older adults is structured in a similar way, with multiple levels of influencing
80 factors: individual factors, e.g. age, sex and physical health [13, 14], interpersonal factors, e.g. living
81 with a spouse and social support [14] and environmental factors, e.g. the built environment [13, 15].

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82 However, the evidence in the literature on determinants of regular PA in older adults based on
83 cohort study data is limited [13].

84 This study aimed to investigate predictors of regular aerobic PA among older adults living in Germany
85 using data from a nationwide, population-based cohort study.

86 **Methods**

87 **Study design and participants**

88 Data from the German National Health Interview and Examination Survey for adults 1997-99
89 (GNHIES98) baseline survey and its first follow-up wave 2008-11 (DEGS1) were used. GNHIES98 and
90 DEGS1 are components of the national German Federal Health Monitoring programme, operated by
91 the Robert Koch Institute, which monitors the health status and health behaviour of adults 18 years
92 and older in Germany. The survey study design is described in detail elsewhere [16, 17]. In summary,
93 GNHIES98 and DEGS1 are both nationwide, population-based health examination surveys. Individuals
94 from the general adult population were randomly selected in 130 nationally distributed sample
95 points using a two-stage clustered sampling procedure: initially communities were sampled (primary
96 sample unit) and within these communities address information was randomly drawn from local
97 population registries. Institutionalized persons were excluded from the study sample. The GNHIES98
98 sample was comprised of 7124 participants between the ages of 18 and 79 years and the DEGS1
99 sample of 8152 participants between the ages of 18 and 91 years [18, 19]. Interviews, examinations
100 and tests were carried out in both surveys. GNHIES98 data collection was conducted from October
101 1997 to March 1999 and DEGS1 data collection was conducted from November 2008 to December
102 2011. GNHIES98 was approved by the Board of the Federal Commissioner for Data Protection Berlin.
103 DEGS1 was approved by the Federal and State Commissioners for Data Protection and by the ethics
104 committee of the Charité – University Medicine Berlin (No. EA2/047/08). All participants provided
105 informed written consent.

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3 106 The response rates were 61 % for GNHIES98 and 62 % for DEGS1 [18, 19]. All GNHIES98 participants
4
5 107 were invited to participate in the DEGS1 follow-up survey. To improve the re-participation rate
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7 108 participants who moved away or were not willing or able to visit the examination centre had the
8
9 109 opportunity to take part in an interview programme. GNHIES98 participants were enrolled in DEGS1
10
11 110 between 10 and 15 years after GNHIES98 participation; 91 % participated 11 to 13 years after
12
13 111 GNHIES98. The age range of the study sample for analysis was defined as participants aged 65 years
14
15 112 or older at follow-up (DEGS1). This included persons who were aged 50 years or above at baseline
16
17 113 (GNHIES98). A flow chart of participants is shown in Figure 1. 50.5 % (n = 1501) of GNHIES98
18
19 114 participants, aged 65 years or older at follow-up, participated in DEGS1. Of the 49.5 % non-
20
21 115 participants, 19.3 % (n = 575) had died during the follow-up period. A lower re-participation rate was
22
23 116 observed for men, older participants, participants with lower socioeconomic status (SES),
24
25 117 participants with chronic disease as well as those with lower leisure time PA level (Additional file 1).
26
27 118 The final study sample included 1184 participants after the exclusion of participants who were
28
29 119 younger than 65 years at follow-up (n = 220) and participants with missing data for the PA outcome
30
31 120 variable (n = 97). The multivariate analysis was conducted based on a complete-case sample (n =
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33 121 1143); thus an additional 41 participants were excluded due to missing data for at least one of the
34
35 122 covariates used.

39 123 **Patient and public involvement**

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42 124 Patients or public were not involved.

43 44 45 125 **Definition of variables**

46 47 48 126 *Outcome variable*

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51 127 The participants were asked at follow-up about the number of days and the duration on an average
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53 128 day they engaged in physical activities which made them sweat or get out of breath in an average
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55 129 week. The reference period was the last three months. A dichotomous variable was constructed with

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3 130 the categories: 'aerobic PA ≥ 1 day per week'; Yes/No. This cut-off point was chosen because regular
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5 131 aerobic PA on a weekly basis is associated with substantial health benefits [3].
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8 132 *Predictor variables*
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10 133 The information used for constructing the exposure variables was assessed in the baseline survey
11
12 134 (GNHIES98) with self-administered questionnaires, physician-administered computer-assisted
13
14 135 personal interviews (CAPI) or physical examinations. The variables were selected based on theories
15
16 136 and evidence available in the literature [12, 20]. According to the ecological model, individual
17
18 137 (demographic variables, health status), interpersonal (living with a spouse, social support), health
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20 138 behavioural (LTPA, participation in a health behaviour change programme, smoking status) and
21
22 139 environmental (size of and satisfaction with the living area) factors were included in the analysis.
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26 140 Individual factors
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29 141 Participant SES was assessed using an index based on the educational level, household income and
30
31 142 occupational status of the participants which has been described in detail elsewhere [21]. The
32
33 143 prevalence of chronic diseases was assessed during the CAPI. Participants were defined as 'having a
34
35 144 chronic disease' if they indicated diagnosis by a physician of at least one of the following diseases:
36
37 145 coronary heart disease, stroke, diabetes, respiratory disease or cancer. Participant body mass index
38
39 146 (BMI) was calculated using measured participant weight and height. According to the guidelines of
40
41 147 the WHO, obesity was defined as BMI ≥ 30 kg/m² [22].
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44 148 Interpersonal factors
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47 149 Participants were defined as 'living with a spouse' if they indicated marriage or co-habitation with
48
49 150 their spouse. The question 'How many people are so close to you that you can count on them if you
50
51 151 have serious personal problems?' derived from the Oslo-3 Social Support Scale [23] was used as
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53 152 proxy variable for social support. Two categories were constructed: 'low social support' (1 person or
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55 153 none) and 'high social support' (at least 2 persons).
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3 154 Behavioural factors
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6 155 'Leisure time physical activity' (LTPA) was assessed with the question, 'On average, how often do you
7
8 156 do sports activities or other physical activities in your leisure time, which make you sweat or out of
9
10 157 breath?'. The five answer categories were summarised into 2 categories: 'weekly LTPA' (daily/3 to 6
11
12 158 times a week/1 to 2 times a week) and 'no weekly LTPA' (once a month/never). 'Participation in at
13
14 159 least one health behaviour change programme' (abbreviated as 'at least one health programme') was
15
16 160 defined if participants reported participation in a programme with the topic 'weight reduction',
17
18 161 'healthy nutrition', 'back training' or 'stress management' during the last twelve months [24]. The
19
20 162 variable should be an indicator for health oriented behaviour. Participants were defined as 'smoker'
21
22 163 if they reported that they currently smoke and were defined as 'non-smoker' if they identified as a
23
24 164 former smoker or as having never smoked.
25

26
27 165 Environmental factors
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29
30 166 A 'residential area size' variable was constructed with four categories: 'rural area' (< 5000
31
32 167 inhabitants); 'small-sized city' (5000 - < 20,000 inhabitants); 'medium-sized city' (20,000 - < 100,000
33
34 168 inhabitants); 'metropolitan city' (\geq 100,000 inhabitants). For a subjective estimation of the
35
36 169 environment, participants were asked to rate 'satisfaction with their living area' on a 7-point scale
37
38 170 (from 1 'very unsatisfied' to 7 'very satisfied'). A dichotomous variable was constructed with the
39
40 171 categories 'not satisfied' (points 1-5) and 'satisfied' (points 6 and 7).
41
42

43
44 172 **Statistical analyses**
45

46
47 173 All statistical analyses were performed with the survey design procedure of Stata 14.1 to adjust for
48
49 174 cluster design. P-values less than 0.05 were defined as statistically significant. Predictors of aerobic
50
51 175 PA \geq 1 day/week were investigated in two steps: first, bivariate analyses were performed and,
52
53 176 second, exposure variables that were significantly associated with the outcome in the bivariate
54
55 177 analysis ($p < .05$) were included in a stepwise logistic regression analysis. Bivariate associations
56
57 178 between the exposure and outcome variables were analysed with the Pearson's chi-squared test
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2
3 179 with Rao-Scott correction. In the logistic regression, odds ratios (OR) and 95 % confidence intervals
4
5 180 (CI) were estimated to examine the associations between baseline exposure variables and
6
7 181 participation in aerobic PA ≥ 1 day/week at follow-up. During the stepwise analysis three models
8
9 182 were investigated: Model 1 included individual factors (sex, age, SES, chronic disease and obesity), in
10
11 183 Model 2 the interpersonal factors living with a spouse and social support were added, in Model 3 the
12
13 184 behavioural variables were added (LTPA, at least one health programme). To detect multicollinearity
14
15 185 between the covariates, variance inflation factors (VIF) were calculated. All VIFs were less than 1.5
16
17 186 and thus clearly lower than the common threshold for multicollinearity of 10 [25]. To investigate
18
19 187 whether the predictors of aerobic PA ≥ 1 day/week differ between men and women and between
20
21 188 different age groups, age and sex interaction analyses were performed for all associations presented
22
23 189 in Model 3.

190 **Results**

191 **Participants**

192 52.5 % (n = 622) of the participants were women. The mean age of the participants at baseline was
193 60 years (range 50-78 years) and at follow-up 72 years (range 65-91 years). 60.2 % (n = 713) were in
194 the age group '50-60 years' at baseline and 39.8 % (n = 471) in the age group '61-78 years'. The
195 description of the participants according to socio-demographic, health-related, interpersonal,
196 behavioural and environmental variables at baseline is presented in Table 1. When comparing
197 participants from the older age group (61-78 years) to participants from the younger age group (50-
198 60 years) at baseline, older participants had high SES less often, had a chronic disease more often,
199 lived with a spouse less often, participated in LTPA less often, participated in a health programme
200 less often and smoked less often than younger participants (each p < .05).

201 **Aerobic PA ≥ 1 day/week**

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2
3 202 53.2 % of the participants engaged in aerobic PA ≥ 1 day/week at follow up. No significant difference
4
5 203 was observed between men and women (55.3 % vs 51.3 %; $p = .158$). The prevalence of engaging in
6
7 204 aerobic PA ≥ 1 day/week (41.2 %) was lower at baseline among the 61-78 year age group than among
8
9 205 the 50-60 year age group, where prevalence was 61.2 % ($p < .001$). The prevalence of aerobic PA ≥ 1
10
11 206 day/week according to baseline socio-demographic, health-related, behavioural, social and
12
13 207 environmental variables is shown in Table 2.

16 208 **Predictors of engaging in aerobic PA ≥ 1 day/week**

18
19 209 Binary analyses showed (Table 2) that age, SES, chronic disease, obesity, living with a spouse, social
20
21 210 support, LTPA and participation in at least one health programme at baseline were significantly
22
23 211 associated with aerobic PA ≥ 1 day/week at follow-up.

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25
26 212 Multivariate analyses showed that age, SES, social support and LTPA were predictors for aerobic PA
27
28 213 ≥ 1 day/week at follow-up (Table 3). The results of Model 3 (all binary significant variables included)
29
30 214 indicated that participants aged 50 to 60 years were more likely to engage in aerobic PA ≥ 1 day/week
31
32 215 than participants aged 61 to 78 years, with an OR of 1.88 (95% CI, 1.46-2.40). Participants with
33
34 216 middle or high SES were more likely to engage in aerobic PA ≥ 1 day/week than participants with low
35
36 217 SES, with an OR of 2.08 (1.33-3.25) for middle SES and 3.44 (2.11-5.60) for high SES. Participants with
37
38 218 high social support were more likely to engage in aerobic PA ≥ 1 day/week at follow up than
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40 219 participants with a low social support, with an OR of 1.98 (1.26-3.12). Furthermore, participants who
41
42 220 participate in LTPA every week at baseline were more likely to engage in aerobic PA ≥ 1 day/week at
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44 221 follow up than inactive participants, with an OR of 1.95 (1.46-2.60).

48 222 **Subgroup analyses**

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51 223 The interaction analyses showed that age was an effect modifier for the association between SES and
52
53 224 aerobic PA ≥ 1 day/week and for the association between social support and aerobic PA ≥ 1 day/week
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55 225 (interaction term age*middle SES: $p = .033$; age*high SES: $p < .001$; age*social support: $p < .001$).

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57 226 Subgroup analyses showed that SES was a significant determinant of aerobic PA ≥ 1 day/week only in

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3 227 the age group 65 to 72 years but not in the age group 73 to 91 years. Participants in this age group
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5 228 with middle or high SES were more likely to engage in aerobic PA ≥ 1 day/week than participants with
6
7 229 low SES (middle SES: 3.02, 1.70-5.37; high SES: 6.62, 3.74-11.72). Furthermore, social support was
8
9 230 only a significant determinant of aerobic PA ≥ 1 day/week among participants 65 to 72 years.
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11 231 Participants in this age group with higher social support were more likely to engage in aerobic PA ≥ 1
12
13 232 day/week, with an OR of 3.31 (1.76-6.21). Sex was not an effect modifier for any of the presented
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15 233 associations.

18 234 **Discussion**

21 235 In this nationwide, population-based cohort study it was observed that half of the older adults 65+
22
23 236 years in Germany did not engage in aerobic PA at least one day per week. The multivariate analyses
24
25 237 showed that the groups at high risk for having an inactive lifestyle at age 65+ years were those who,
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27 238 12 years earlier, were in the older age groups, those with low socio-economic position, low social
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29 239 support and low previous levels of PA. Several additional determinants of aerobic PA identified in
30
31 240 binary analyses were no longer associated with the outcome after multivariate adjustment.

34 241 **Individual factors**

37 242 Sex was not a predictor for aerobic PA ≥ 1 day/week in older adults in the present study. Other
38
39 243 studies with older adults showed mixed results with a tendency to report a higher PA level for men
40
41 244 [10, 13, 14]. A time trend analysis on the prevalence of physical inactivity among German adults aged
42
43 245 25 to 69 years over an observation period of 20 years demonstrated that gender differences
44
45 246 observed in the first 1990-92 survey diminished over time so that women were no longer more
46
47 247 inactive than men in the 2008-2011 survey [26]. The higher proportion of women than men aged 65
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49 248 years and older living in Germany participating in PA courses as part of primary prevention
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51 249 programmes [24] might explain the similar PA prevalence in this study.

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3 250 The observed lower odds for participation in aerobic PA ≥ 1 day/week with higher age in the present
4
5 251 study are consistent with other studies [10, 13, 14, 27]. The loss of physical function as well as the
6
7 252 fear of injuries and falling may play a role in the reduction of the PA level with progression of age
8
9 253 [28]. A qualitative study showed that older adults still believe that PA is inappropriate for older
10
11 254 people and might be even harmful [28, 29]. Furthermore, a cohort effect might explain, at least
12
13 255 partly, the differences between age groups. Beginning in the 1970s, the number of recreational sport
14
15 256 offers started to increase in Germany [30], thus the younger age group in the previously mentioned
16
17 257 study (22-32 years old in 1970) might have benefited more than the older age group.
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20 258 Consistent with the findings reported in other studies, older adults with higher SES participated more
21
22 259 often in aerobic PA ≥ 1 day/week later in life than persons with low SES [14, 27, 31]. More social and
23
24 260 material resources and more PA friendly neighbourhoods may partly explain the higher activity level
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26 261 of older adults with a higher SES [31, 32]. Another important factor might be the difference in PA
27
28 262 behaviour earlier in life. Adults with higher levels of education are more physically active in leisure
29
30 263 time, perhaps to compensate for work-related inactivity, whereas adults with lower levels of
31
32 264 education may have higher PA level during their work time [33, 34]. With age and retirement it is
33
34 265 likely that adults who participate in leisure time PA continue these activities, whereas adults who had
35
36 266 only experienced work-related activity may become inactive.
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40 267 The results of this study suggest that chronic disease developed earlier in life is not a predictor of
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42 268 aerobic PA ≥ 1 day/week in older adults. A cross-sectional study [31] also observed no relationship
43
44 269 between diabetes and hypertension and PA in older adults. However, other prospective studies
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46 270 showed that older adults with poor health status were less likely to be physically active [13, 14, 35].
47
48 271 Prescribed PA is part of the therapy of several chronic diseases like heart disease and diabetes. Thus,
49
50 272 chronic diseases can act as both barriers to or motivations for PA, which may blur the association
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52 273 over time. It is possible that such a blurring of the association between chronic disease and PA may
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54 274 have occurred in our study. Moreover, participants with chronic diseases had a lower probability of
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3 275 re-participation (see Additional File 1), reducing the possibility of rigorously investigating the long-
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5 276 term association between chronic diseases and aerobic PA ≥ 1 day/week in our study sample.
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7
8 277 Furthermore, obesity was not a predictor of the outcome aerobic PA ≥ 1 day/week. Results of
9
10 278 prospective studies investigating the influence of obesity on PA in the elderly are inconsistent. The
11
12 279 authors of a review concluded that the influence of obesity on PA is weak [14], whereas the results of
13
14 280 the English Longitudinal Study of Aging observed that obesity is associated with a lower likelihood of
15
16 281 being persistently active [27]. Similar to chronic diseases, obesity may, on the one hand, result in a
17
18 282 lower PA level or, on the other hand, as part of a therapy may encourage an increase in activity level.
19
20 283 The different directions of this association make it difficult to evaluate the effect of obesity on PA.
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23 284 **Interpersonal factors**

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25
26 285 The results of this study suggest that interpersonal factors are important predictors of engaging in
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28 286 aerobic PA ≥ 1 day/week in older adults. Participants with higher social support were more likely to
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30 287 participate in aerobic PA ≥ 1 day/week. Social networks could promote physical activity among older
31
32 288 adults by providing information, connecting older adults to resources, such as transport services, and
33
34 289 providing encouragement [28, 32]. The results are in line with a cross-sectional study which observed
35
36 290 that in elderly people social isolation is related to negative health behaviour like physical inactivity
37
38 291 [36, 37]. Living with a spouse was not a significant predictor in this analysis but older adults with a
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40 292 partner tended to be more physical active. Further studies observed that older adults who are
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42 293 married are more likely to participate in physical activities later in life [14].
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46 294 **Behavioural factors**

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49 295 In the current study, former weekly LTPA was a predictor of aerobic PA ≥ 1 day/week in older adults.
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51 296 Several studies observed that PA participation earlier in life is an important determinant of physical
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53 297 behaviour among older adults, in line with our observations [29, 38]. Experiences about physical
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55 298 competence as well as a positive attitude towards PA could explain the tracking of PA behaviour later
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57 299 in life [29].
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3 300 Participation in at least one PA related health programme was not a significant predictor of aerobic
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5 301 PA ≥ 1 day/week twelve years later. It could be that programmes such as back training and stress
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7 302 management, did not prioritize the promotion of aerobic PA and thus that participation in these
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9 303 programmes had no positive effect on aerobic PA ≥ 1 day/week. It could also be that the programmes
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11 304 increased PA level in short-term but there were no long-term effects on aerobic PA level twelve years
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13 305 later.

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16 306 In this study, smoking was not associated with aerobic PA ≥ 1 day/week later in life, contrary to
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18 307 studies demonstrating that health risk behaviour like smoking and physical inactivity often cluster
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20 308 [14, 27]. Due to the high proportion of adults aged 65 years and older living in Germany who quit
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22 309 smoking [39], an explanation for the absence of an association between smoking and PA later in life
23
24 310 might be that many participants quit smoking during the follow-up period.

25 26 27 311 **Environmental factors**

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30 312 The environmental factors investigated in the current study did not predict aerobic PA ≥ 1 day/week
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32 313 in older adults. Environmental characteristics such as urbanization and satisfaction with the living
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34 314 area are probably long-term characteristics, for which the impact on individual PA behaviour may
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36 315 already have appeared earlier in life. Also, after adjustment for intermediate variables like PA at
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38 316 baseline, the additional contribution seems small. Furthermore, participants might have moved to
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40 317 another residential area so that the former residential area has minor influence on the activity
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42 318 behaviour twelve years later. Two reviews investigated the relationship between the environmental
43
44 319 factors within the neighbourhood and PA in older adults and came up with contradictory findings.
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46 320 The authors of one review [40] concluded that the majority of studies reviewed observed no
47
48 321 relationship between environmental factors (objectively and subjectively measured) and PA
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50 322 behaviour of older adults. The authors of the other review [15] determined that characteristics of the
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52 323 built environment (objectively measured) are associated with the PA of older adults. Differences in
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3 324 the assessment of environmental characteristics as well as PA could be reasons for the differing
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5 325 results.

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8 326 **Age interactions**

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10 327 SES and social support were not significant predictors of aerobic PA ≥ 1 day/week in the older age
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12 328 group but were significant predictors in the younger age group. One explanation for this could be a
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14 329 decline in the prevalence of aerobic PA with increasing age leading to weaker influence of the
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16 330 predictors. A lower PA prevalence also leads to a lower statistical power to determine significant
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18 331 associations.

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22 332 **Strengths and limitations**

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24 333 This study pairs some of the advantages of a nationwide, population-based survey with a high degree
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26 334 of representativeness and a cohort study design which provides stronger information on causal
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28 335 inference. Great efforts were made at all stages while conducting GNHIES89 and DEGS1 to reduce
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30 336 potential sources of bias [16, 17]. This comprised measures such as internal and external quality
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32 337 control during field work, anonymous data collection and record keeping, data quality assurance and
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34 338 use of accurate instruments. However, self-reports on PA level are prone to recall and social
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36 339 desirability bias [41]. Thus we cannot exclude the possibility that aerobic PA ≥ 1 day/week was over-
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38 340 reported. Also, most of the independent variables were based on self-reports involving the potential
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40 341 of reporting bias. Selection bias could have appeared at different stages (selection of individuals into
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42 342 the study, loss to follow-up, item non response). This may have influenced the results and may
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44 343 compromise the generalizability of the findings. For instance, we were not able to consider
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46 344 information from participants who had died during the follow-up period. Non-response analysis
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48 345 indicates that the non-responders were older, had a lower level of LTPA and SES on average and
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50 346 more often chronic diseases and obesity compared to the responders. This suggests that the
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52 347 responders are a healthier and fitter group than the non-responders and that the prevalence of
53
54 348 aerobic PA ≥ 1 day/week at follow-up might be overestimated. In addition, the study results might

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3 349 not apply to elderly individuals living in a nursing home who were not eligible for inclusion into the
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5 350 study sample.
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8 351 **Conclusion**
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10 352 Despite limitations, we conclude that several influencing factors assessed at baseline predicted
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12 353 regular aerobic PA participation twelve years later. These factors should be considered when
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14 354 planning interventions to prevent physical inactivity in older adults. Aerobic PA has many benefits for
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16 355 aging people and can improve their life in many ways. There is great potential for increasing aerobic
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18 356 PA participation in older adults in Germany. Low PA levels among older adults indicate the need for
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20 357 PA promotion interventions tailored for this age group. Measures promoting a physically active
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22 358 lifestyle during middle age, e.g. through workplace interventions, may have positive long-term
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24 359 effects on PA level at older age due to the strong tracking of PA behaviour. Target groups for PA
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26 360 interventions at middle age should be people with low SES and low social support to prevent low PA
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28 361 levels later in life.
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3 362 **Additional material**
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6 363 Additional File 1: DEGS1 unit nonresponse analysis, differences in selected baseline characteristics
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8 364 between DEGS1 non-respondents and respondents.
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11 365 **Abbreviations**
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14 366 BMI – body mass index; CAPI – physician-administered computer assisted personal interview; DEGS –
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16 367 German Health Interview and Examination Survey for Adults 2008-11; GNHIES98 – German National
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18 368 Health Interview and Examination Survey 1997-99; OR – odds ratio; PA – physical activity; SES –
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20 369 socioeconomic status; WHO – World Health Organization
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24 370 **Declarations**
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27 371 **Ethics approval and consent to participate**
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29
30 372 The study GNHIES98 was approved by the Board of the Federal Commissioner Data Protection Berlin.
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32 373 DEGS1 was approved by the Federal and State Commissioners for Data Protection and by the Charité
33
34 374 – University Medicine Berlin ethic committee (No. EA2/047/08). All participants provided informed
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36 375 written consent.
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39 376 **Consent for publication**
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42 377 Not applicable.
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45 378 **Competing interests**
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48 379 The authors declare that they have no competing interests.
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51 380 **Availability of data and materials**
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3 381 Datasets of GNHIES98 and DEGS1 are available via Public Use File
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5 382 (http://www.rki.de/DE/Content/Gesundheitsmonitoring/Forschungsdatenzentrum/informationen_a
6
7 383 [ntrag/info_antrag_node.html](http://www.rki.de/DE/Content/Gesundheitsmonitoring/Forschungsdatenzentrum/informationen_a_ntrag/info_antrag_node.html)).
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12
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16 386 **Authors' contributions**

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19 387 GBMM was involved in the design and conduct of GNHIES98 and DEGS1 in particular for the physical
20
21 388 activity questions. SK and KM conceptualized the current study. KM conducted the present analysis
22
23 389 and GBMM, SJ, AS and JDF contributed to the analysis plan and interpretation of the results. KM
24
25 390 drafted the manuscript and GBMM, SJ, AS, SK and JDF critically revised it. JDF contributed to writing
26
27 391 the manuscript. All authors contributed to interpretation of findings, reviewed, edited and approved
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29 392 the final manuscript.
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For peer review only

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3 508 **Figures**

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5 509 Figure 1: Flow diagram of participants

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511 Tables

Table 1: Baseline characteristics of the study sample (n = 1184)

	Missing	Age at baseline				Total	p-value	
		%	95% CI	%	95% CI			
1 Individual factors								
Sex	0							
Women (n=622)		53.0	(49.5-56.5)	51.8	(48.2-55.3)	52.5	(49.8-55.3)	0.600
Men (n=562)		47.0	(43.5-50.5)	48.2	(44.7-51.8)	47.5	(44.7-50.2)	
Socioeconomic status	14							
Low (n=151)		11.4	(8.9-14.4)	15.2	(11.9-19.2)	12.9	(10.6-15.7)	< 0.001
Middle (n=712)		57.5	(53.5-61.3)	66.0	(61.6-70.1)	60.9	(57.8-63.8)	
High (n=307)		31.2	(27.3-35.3)	18.8	(15.0-23.3)	26.2	(23.0-29.7)	
Chronic disease	3							
No (n=869)		78.5	(75.4-81.4)	66.0	(61.6-70.2)	73.6	(70.8-76.2)	< 0.001
Yes (n=312)		21.5	(18.6-24.6)	34.0	(29.8-38.4)	26.4	(23.8-29.2)	
Obesity	3							
Yes (n=297)		24.5	(20.8-28.5)	26.2	(22.3-30.4)	25.1	(22.2-28.4)	0.504
No (n=884)		75.5	(71.5-79.2)	73.8	(69.6-77.7)	74.9	(71.6-77.8)	
2 Interpersonal factors								
Living with a spouse	16							
No (n=216)		16.7	(14.0-19.7)	21.2	(17.7-25.3)	18.5	(16.2-21.1)	0.035
Yes (n=952)		83.3	(80.3-86.0)	78.8	(74.7-82.3)	81.5	(78.9-83.8)	
Social support	21							
Low (n=100)		7.6	(5.7-10.0)	10.2	(7.8-13.1)	8.6	(7.0-10.5)	0.110
High (n=1,063)		92.4	(90.0-94.3)	89.8	(86.9-92.2)	91.4	(89.5-93.0)	
3 Behavioural factors								
Leisure time physical activity	26							
Every week (n=784)		72.1	(67.9-76.0)	61.0	(56.8-65.1)	67.7	(64.4-70.9)	< 0.001
Not every week (n=374)		27.9	(24.0-32.1)	39.0	(34.9-43.2)	32.3	(29.1-35.6)	
At least one health programme	0							
Yes (n=124)		12.6	(10.4-15.3)	7.2	(5.2-10.0)	10.5	(8.8-12.5)	0.002
No (n=1,060)		87.4	(84.7-89.6)	92.8	(90.0-94.8)	89.5	(87.5-91.2)	
Smoking status	11							
Smoker (n=188)		20.0	(17.2-23.0)	10.1	(7.5-13.3)	16.0	(14.0-18.2)	< 0.001
Non-smoker (n=985)		80.0	(77.0-82.8)	89.9	(86.7-92.5)	84.0	(81.8-86.0)	
4 Environmental factors								
Residential area size	0							
Rural (n=249)		20.3	(13.5-29.4)	22.1	(14.4-32.2)	21	(14.2-30.0)	0.601
Small-sized city (n=247)		20.1	(13.3-29.1)	22.1	(14.4-32.3)	20.9	(14.0-30.0)	
Medium-sized city (n=318)		26.9	(19.0-36.7)	26.8	(18.5-37.0)	26.9	(19.1-36.3)	
Metropolitan city (n=370)		32.7	(23.7-43.1)	29.1	(20.4-39.7)	31.3	(22.7-41.4)	

Satisfaction with residential area	21							
Not satisfied (n=308)	26.1	(22.9-29.7)	27.0	(23.3-31.0)	26.5	(23.9-29.2)	0.733	
Satisfied (n=855)	73.9	(70.3-77.1)	73.0	(69.0-76.7)	73.5	(70.8-76.1)		

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Table 2: Bivariate associations between aerobic physical activity \geq 1 day/week and potential predictor variables

		Aerobic physical activity \geq 1 day/week				p-value*
		No		Yes		
		%	95% CI	%	95% CI	
1	Sex					
	Women (n=622)	48.7	(44.7-52.7)	51.3	(47.3-55.3)	0.158
	Men (n=562)	44.7	(40.1-49.4)	55.3	(50.6-59.9)	
	Age group					
	50-60 years (n=713)	38.8	(35.1-42.8)	61.2	(57.2-64.9)	< 0.001
	61-78 years (n=471)	58.8	(54.1-63.4)	41.2	(36.6-45.9)	
	Socioeconomic status					
	Low (n=151)	70.2	(62.0-77.3)	29.8	(22.7-38.0)	< 0.001
	Middle (n=712)	47.9	(43.8-52.0)	52.1	(48.0-56.2)	
	High (n=307)	31.9	(27.0-37.3)	68.1	(62.7-73.0)	
	Chronic disease					
	No (n=869)	44.1	(40.5-47.7)	55.9	(52.3-59.5)	0.006
	Yes (n=312)	53.8	(47.6-60.0)	46.2	(40.0-52.4)	
	Obesity					
	Yes (n=297)	53.5	(47.4-59.5)	46.5	(40.5-52.6)	0.005
	No (n=884)	44.6	(41.2-48.0)	55.4	(52.0-58.8)	
2	Living with a spouse					
	No (n=216)	57.4	(51.1-63.4)	42.6	(36.6-48.9)	< 0.001
	Yes (n=952)	44.1	(40.5-47.8)	55.9	(52.2-59.5)	
	Social support					
	Low (n=100)	65.0	(55.4-73.5)	35.0	(26.5-44.6)	< 0.001
	High (n=1,063)	44.9	(41.6-48.2)	55.1	(51.8-58.4)	
3	Leisure time physical activity					
	Every week (n=784)	38.6	(34.8-42.6)	61.4	(57.4-65.2)	< 0.001
	Not every week (n=374)	62.8	(57.6-67.8)	37.2	(32.2-42.4)	
	At least one health programme					
	Yes (n=124)	34.7	(26.7-43.6)	65.3	(56.4-73.3)	0.005
	No (n=1,060)	48.2	(44.8-51.7)	51.8	(48.3-55.2)	
	Smoking status					
	Smoker (n=188)	49.5	(41.7-57.3)	50.5	(42.7-58.3)	0.406
	Non-smoker (n=985)	46.0	(42.5-49.5)	54.0	(50.5-57.5)	
4	Residential area size					
	Rural (n=249)	48.6	(42.1-55.1)	51.4	(44.9-57.9)	0.873
	Small-sized city (n=247)	48.2	(39.4-57.1)	51.8	(42.9-60.6)	
	Medium-sized city (n=318)	45.9	(39.6-52.4)	54.1	(47.6-60.4)	

Metropolitan city (n=370)	45.4	(40.5-50.4)	54.6	(49.6-59.5)	
Satisfaction with residential area					0.711
Not satisfied (n=308)	47.1	(42.0-52.2)	52.9	(47.8-58.0)	
Satisfied (n=855)	46.0	(42.2-49.7)	54.0	(50.3-57.8)	

*Pearson's chi-squared test with Rao-Scott correction

1: Individual factors; 2: Interpersonal factors; 3: Behavioural factors; 4: Environmental factors

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Table 3: Stepwise adjusted odds ratios of aerobic physical activity at follow-up by baseline predictor variables, adults aged 65 years or older

Baseline variables	Aerobic physical activity ≥ 1 day/week					
	Model 1		Model 2		Model 3	
	OR	95 % CI	OR	95 % CI	OR	95 % CI
Sex						
Women	0.95	(0.73 - 1.23)	1.01	(0.78 - 1.32)	1.05	(0.80 - 1.38)
Men	1.00	-	1.00	-	1.00	-
Age group						
50-60 years	2.00	(1.56 - 2.56)	1.97	(1.53 - 2.52)	1.88	(1.46 - 2.40)
61-78 years	1.00	-	1.00	-	1.00	-
Socioeconomic status						
Low	1.00	-	1.00	-	1.00	-
Middle	2.48	(1.61 - 3.84)	2.39	(1.54 - 3.70)	2.08	(1.33 - 3.25)
High	4.52	(2.83 - 7.23)	4.29	(2.67 - 6.90)	3.44	(2.11 - 5.60)
Chronic disease						
No	1.25	(0.92 - 1.69)	1.24	(0.91 - 1.69)	1.21	(0.89 - 1.66)
Yes	1.00	-	1.00	-	1.00	-
Obesity						
No	1.23	(0.93 - 1.62)	1.24	(0.94 - 1.63)	1.14	(0.86 - 1.52)
Yes	1.00	-	1.00	-	1.00	-
Living with a spouse						
Yes			1.36	(1.00 - 1.84)	1.31	(0.96 - 1.79)
No			1.00	-	1.00	-
Social support						
High			2.11	(1.35 - 3.30)	1.98	(1.26 - 3.12)
Low			1.00	-	1.00	-
Leisure time physical activity						
Every week					1.95	(1.46 - 2.60)
Not every week					1.00	-
At least one health programme						
Yes					1.36	(0.88 - 2.10)
No					1.00	-

Bold: $p < 0.05$; OR = Odds Ratio; Model 1: Individual factors; Model 2: + interpersonal factors; Model 3: + behavioural factors

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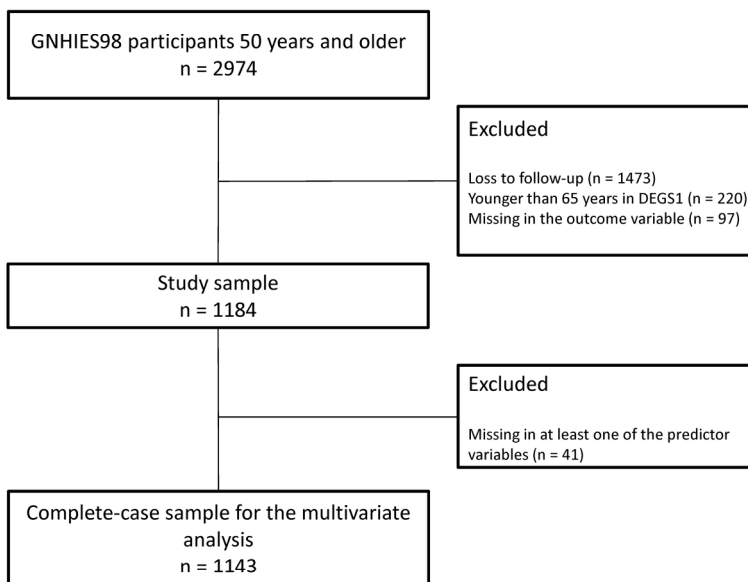


Figure 1: Flow diagram of participants

190x142mm (300 x 300 DPI)

Additional File 1 – DEGS1 unit non-response analysis

Table 1: Differences in selected baseline characteristics between DEGS1 respondents, non-respondents and deceased

	Responder		Non-responder		Deceased	
	%	95% CI	%	95% CI	%	95% CI
Total (n=2974)	50.5	(48.3-52.6)	30.2	(28.3-32.1)	19.3	(17.9-20.9)
Sex						
Women (n=1,567)	52.6	(50.2-55.0)	59.2	(56.0-62.5)	42.6	(39.0-46.3)
Men (n=1,407)	47.4	(45.0-49.8)	40.8	(37.5-44.0)	57.4	(53.7-61.0)
Age						
50-60 years (n=1,492)	65.2	(62.6-67.7)	43.2	(39.9-46.5)	21.7	(18.5-25.3)
61-78 years (n=1,482)	34.8	(32.3-37.4)	56.8	(53.5-60.1)	78.3	(74.7-81.5)
Socioeconomic status						
Low (n=566)	13.1	(10.9-15.6)	26.6	(23.0-30.6)	26.5	(22.6-30.7)
Middle (n=1,709)	60.3	(57.5-63.0)	59.4	(55.7-63.0)	55.9	(51.9-59.8)
High (n=611)	26.6	(23.6-30.0)	14.0	(11.3-17.0)	17.6	(14.2-21.6)
Chronical disease						
No (n=1,984)	74.7	(72.5-76.9)	67.0	(64.1-69.8)	46.4	(42.1-50.8)
Yes (n=980)	25.3	(23.1-27.5)	33.0	(30.2-35.9)	53.6	(49.2-57.9)
Obesity						
Yes (n=860)	26.1	(23.3-29.1)	34.0	(30.6-37.6)	29.8	(25.8-34.1)
No (n=2,087)	73.9	(70.9-76.7)	66.0	(62.4-69.4)	70.2	(65.9-74.2)
Living with a spouse						
Yes (n=2,273)	85.1	(83.1-86.8)	74.0	(70.5-77.2)	72.3	(68.1-76.2)
No (n=589)	14.9	(13.2-16.9)	26.0	(22.8-29.5)	27.7	(23.8-31.9)
Leisure time physical activity						
Every week (n=1,624)	67.6	(64.7-70.4)	46.5	(42.5-50.5)	43.8	(39.1-48.6)
Not every week (n=1,231)	32.4	(29.6-35.3)	53.5	(49.5-57.5)	56.2	(51.4-60.9)

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Reported on page
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5-6
		(b) For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	15
Study size	10	Explain how the study size was arrived at	5 (see cited study protocol papers)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9
		(b) Describe any methods used to examine subgroups and interactions	9
		(c) Explain how missing data were addressed	6
		(d) If applicable, explain how loss to follow-up was addressed	Additional file 1
		(e) Describe any sensitivity analyses	15, Additional file 1
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for	6, Fig. 1

		eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	Additional file 1
		(c) Consider use of a flow diagram	Fig. 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, Tab. 1
		(b) Indicate number of participants with missing data for each variable of interest	Tab. 1
		(c) Summarise follow-up time (eg, average and total amount)	6
Outcome data	15*	Report numbers of outcome events or summary measures over time	9-10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10, Tab. 2, 3
		(b) Report category boundaries when continuous variables were categorized	6-8
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.