This is an electronic reprint of the original article.
This reprint *may differ* from the original in pagination and typographic detail.

Author(s): von Bonsdorff, Mikaela; Rantanen, Taina; Leinonen, Raija; Kujala, Urho; Törmäkangas, Timo; Mänty, Minna; Heikkinen, Eino

Title: Physical activity history and end-of-life hospital and long-term care

Year: 2009

Version:

1 **Physical activity history and end-of-life hospital and long-term care**

2

3

4 Mikaela B von Bonsdorff, MSc,[1] Taina Rantanen, PhD,[1] Raija Leinonen, PhD,[2]

5 Urho M Kujala, MD, PhD,[3] Timo Törmäkangas, MSc,[1]

6 Minna Mänty, MSc,[1] Eino Heikkinen, MD, PhD[1]

7

8

9 [1]Finnish Centre for Interdisciplinary Gerontology, University of Jyväskylä, PO Box 35 (Viv),

10 40014 University of Jyväskylä, Finland

11 [2]GeroCenter Foundation for Research and Development, Kinkomaan sairaala, 40930 Kinkomaa,

12 Finland

13 [3]Department of Health Sciences, University of Jyväskylä, PO Box 35, 40014 University of

14 Jyväskylä, Finland

15

16

17 **Corresponding author and reprint requests:**

18 Mikaela von Bonsdorff

19 Finnish Centre for Interdisciplinary Gerontology

20 University of Jyväskylä

21 PO Box 35 (Viveca)

22 FIN-40014 University of Jyväskylä

23 Tel. +358 14 260 4596, Fax +358 14 260 4600, e-mail mikaela.bonsdorff@sport.jyu.fi

24

25 Word count of the paper: 2789

26 Word count of the abstract: 283

27 Tables and Figures: 3+2

28

29 **Keywords:** aging, physical activity, health care, chronic diseases, decedent population, disability

30

31 **Running head:** Physical activity and end-of-life care

32

33

34 **ABSTRACT**

35

36 **Background.** Little is known about the early predictors of need for care in late life. The purpose

37 of this study was to investigate whether physical activity from midlife onwards was associated

38 with hospital and long-term care in the last year of life.

39 **Methods.** We studied a decedent population of 846 persons aged 66-98 years at death, who on

40 average 5.8 years prior to death, had participated in an interview about their current and earlier

41 physical activity. Data on the use of care in the last year of life are register-based data and

42 complete.

43 **Results.** Men needed on average 96 days (SD 7.0) and women 138 days (SD 6.2) of in-patient

44 care in the last year of life. Among men, the risk for all-cause hospital care in the last year of life

45 was higher for those who had been sedentary since midlife (adjusted risk ratio [IRR] 1.98, 95%

46 confidence interval [CI] 1.14-3.42) compared to those who had been consistently physically active

47 while use of long-term care did not correlate with physical activity history. Among women, the

48 risk for long-term care was higher for those who had been sedentary (IRR 2.03, 95% CI 1.28-3.21)

49 or only occasionally physically active (IRR 1.60, 95% CI 1.06-2.43), than for those who had been

50 consistently active from midlife onwards, while use of hospital care did not correlate with physical

51 activity history.

52 **Conclusion.** People who had been physically active since midlife needed less end-of-life in-

53 patient care, but patterns differed between men and women.

54

55
56

57

58

59

INTRODUCTION

The need for health care increases with age and closeness to death (1,2), mainly because of increased need for nursing home care among very old frail persons (3,4). However, little is known about the early predictors of need for care in late life (5).

Compression of morbidity theory suggests that healthy life-styles may delay onset of morbidity and thus help compressing the period of disability and high health care costs to near the end of life. (6). Regular physical activity reduces the risk for chronic disabling diseases such as coronary heart disease (7-9) and diabetes (10). Physical activity may be an important factor in preventing disability in old age among people with chronic disease (11-15). Recent long-term studies have found that midlife and old age physical activity lowered the risk of late life mobility difficulties and dementia (16,17) and that former elite athletes had less need for hospital care during later life than age-matched controls (18). However, little is known about the association of physical activity earlier in life and need for in-patient care prior to death among people who die in old age. The longer life-span of physically active people may predispose them to more rather than less need of care at the end of life. On the other hand, persons who exercise regularly may suffer less from chronic diseases and disability in old age and thus need less health and social care services at the end of life than more sedentary people. We studied the association of self-reported physical activity participation from midlife to old age and all-cause hospital and long-term care in the last year of life. Analyses were stratified according to gender and age at death.

85 **METHODS**

86

87 **Participants and data collection**

88 In the year 1988, a random sample of 1600 community-dwelling residents of the City of Jyväskylä

89 in central Finland aged 65-84 years was drawn from the national Population Register as part of the

90 prospective cohort study called Evergreen study (described in detail elsewhere) (19). Participants

91 were interviewed face-to-face in 1988 and in 1996. 1224 people (77%) of the target group took

92 part in the first interview in 1988. From that population, we conducted a nested case study. Cases

93 consisted of 846 persons who had died during 1989-2004. Those who had died in 1988 and those

94 who were alive at the end of the follow-up in January 2005 were excluded, to allow for a one-year

95 follow-up of service use before death (Figure 1).

96

97 Data were collected in face-to-face interviews conducted at the participants' homes by trained

98 university undergraduates in 1988 and 1996. In order to shorten the distance from interview to last

99 year of life, the data collection wave more proximal to the last year of life was used. Thus, data

100 collected in 1988 were used for persons who died during 1989-1997 and data collected in 1996 for

101 those who died during 1998-2004, except for persons who had died during 1998-2004 but not

102 participated in the 1996 interview (6%) or were institutionalized by 1996 (3%). For these persons

103 the 1988 interview data were used. The length of time from interview to death ranged between 1-9

104 years for 91% and 10-16 years for 9% of the participants, average time from interview to death

105 being 5.8 years. The study was approved by the Ethical Committee of the Central Finland Health

106 Care District.

107

108

109

110 **Outcome data**

111 In Finland, university, central, and district hospitals offer specialized care. Health centre in-patient

112 wards and nursing homes (long-term care) provide mainly rehabilitation and palliative care. Data

113 on university hospital, central and district hospital and health centre ward care were drawn from

114 the National Research and Development Centre for Welfare and Health (Stakes) register. The

115 information consisted of dates on all-cause admissions and discharges and the exact public or

116 private institution in which care took place. Data on nursing home care were collected from the

117 local registers of nursing homes in the area. On the basis of the register data, we calculated the

118 exact number of in-patient days of hospital and long-term care in the last year of life. These data

119 were linked to the Evergreen study interview data. The number of hospital and long-term care

120 days in the last year of life were analyzed separately in the negative binomial regression models.

121

122 **Measures**

123 Present physical activity level and intensity was determined on a seven point scale: moving about

124 only minimally to carry out everyday chores; light physical activity 1-2 times/week; light physical

125 activity several times/week; exercise causing breathlessness and sweating 1-2 times/week;

126 exercise causing breathlessness and sweating several times/week; exercise causing breathlessness

127 and heavy sweating several times/week; and engaging in competitive sports several times/week

128 (20,21). Physical activity earlier in life was determined by asking retrospectively about

129 participation in recreational or competitive sports at the ages of 10-19, 20-39, 40-64, 65-74 years,

130 and 75 years and over (22). The disciplines typically included e.g. skiing, tract and field sports,

131 and gymnastics.

132

133 Physical activity was categorized according to self-report data from midlife to old age, because

134 physical activity from age 40 years and over has been found to predict activity in old age (22), and

135   because midlife physical activity has been observed to be related more closely to health and

136   functional capacity in old age than more distal physical activity behavior (16,17). Three exclusive

137   groups according to physical activity at 40-64 years, 65-74 years, 75 years and over, and present

138   physical activity were formed. The groups were 1) consistently physically active from midlife

139   onwards (consistent participation in recreational or competitive sports from 40 years onwards and

140   at the time of the interview at least light physical activity several times/week), 2) occasionally

141   physically active from midlife onwards (participation in sports at some point, but not consistently,

142   from 40 years onwards and at the time of the interview either active or sedentary), and 3)

143   consistently sedentary from midlife onwards (no engagement in sports from 40 years onwards and

144   at the time of the interview light physical activity 1-2 times/week at most).

145

146   Potential confounders included age at death (range 66-98), gender, full-time education (6 years or

147   less vs. more than 6 years), marital status (married or cohabiting/single, widowed, divorced),

148   current smoking (yes/no) and receiving formal home care during the previous year (yes/no).

149   Cognitive functioning was measured with Mini-D test (23), developed from the

150   neuropsychological test of Luria (24). Scores ranged from 0-43, with a higher score indicating

151   better cognitive functioning. Morbidity was assessed according to self-reported physician-

152   diagnosed chronic diseases lasting over three months and primary causes of death obtained from

153   the national Population Register. Causes of death were classified as diseases of the heart and

154   circulatory, nervous, respiratory, digestive, and genitourinary system, and cancer at any site, acute

155   infections, accidents and all other causes of death according to the International Classification of

156   Diseases, ninth version (ICD-9) (25). The time from interview to death was calculated (range 1-16

157   years) and used as a variable in the models. In addition, self-reported information on instrumental

158   activities of daily living (IADL) disability was collected with regard to ten IADL tasks: preparing

159 meals, washing clothes, shopping, coping with light and heavy housework, administering and

160 taking medications, using the telephone, using public transport, and handling finances (26,27).

161

162 **Statistical analyses**

163 Comparisons of discrete baseline characteristics were performed using chi-square tests. For

164 continuous variables, independent sample t-test and ANOVA were used. All tests were performed

165 as two-tailed in SPSS 14.0 with significance level $p < 0.05$.

166

167 We studied the association between physical activity from midlife onwards and hospital and long-

168 term care using negative binomial regression models, where the strength of an association is

169 measured as an Incidence Rate Ratio (IRR). IRRs are interpreted as relative risk estimates and

170 represent the risk for persons in the predictor variable groups relative to those in the reference

171 group. Hospital and long-term care outcomes were continuous variables with one day as a unit.

172 We estimated risk values (IRR) and their 95% confidence intervals (CI) by comparing those who

173 had been sedentary from midlife onwards and those who had been occasionally physically active

174 from midlife onwards with those who had been consistently physically active from midlife

175 onwards (reference group). The likelihood ratio test was used to assess the interaction effect

176 between gender and physical activity behavior. IRRs were calculated for men and women

177 separately for risk for hospital and long-term care in the last year of life. Modeling was performed

178 with STATA 9 software (29), with significance level set at $p < 0.05$ for all effects.

179

180

181

182

183

184 **RESULTS**

185

186 Of the 846 deaths, 26% occurred at the ages of 66-79, 53% at 80-88, and 21% at the ages of 89-98.

187 The mean age of death was 82 (SD 6.2) years for men and 84 (SD 6.1) years for women. 67% of

188 the participants were women. The most common causes of death were diseases of the heart and

189 circulatory system (54%), cancer at any site (19%), diseases of the nervous system e.g. dementia

190 (8%), and acute infections e.g. septicemia (4%). We observed a statistically significant gender

191 interaction for hospital (p=0.027) and long-term care (p=0.001), and thus analyzed care separately

192 for men and women.

193

194 Thirty-eight percent of men and 23 percent of women were categorized as physically active from

195 midlife onwards. They suffered less from IADL disability, used less formal home care, and more

196 frequently had higher education than those categorized into sedentary or occasionally physically

197 active groups (Table 1).

198

199 For men and women, hospital care decreased and long-term care increased in the last year of life

200 with older age at death (Figure 2 A and B). For men, hospital care decreased with higher level of

201 physical activity from midlife onwards (p for trend 0.026), but there were no differences in long-

202 term care use according to physical activity behavior. For women, we detected an increase in long-

203 term care with lower physical activity level (p for trend 0.021), but there were no differences in

204 hospital care use according to physical activity behavior from midlife onwards (Figure 2 C and D).

205

206 For men, with the active group as the reference, the adjusted risk for all-cause hospital care in the

207 last year of life was higher for those who had been sedentary (risk ratio [IRR] 1.98, 95%

208 confidence interval [CI] 1.14-3.42). The long-term care risk did not differ according to physical

209   activity (Table 2). For women, the risk for hospital care did not differ according to physical

210   activity. The risk for long-term care in the last year of life was higher for those women who had

211   been sedentary (IRR 2.03, 95% CI 1.28-3.21) or occasionally physically active (IRR 1.60, 95% CI

212   1.06-2.43) from midlife onwards, with the consistently physically active as the reference (Table 3).

213   The results remained the same when we used data solely on earlier physical activity as a predictor

214   of need for care.

215

216   We stratified the study group according to age at death (66-79, 80-88, and 89-98 years). For men,

217   the results were similar for all age strata for the risk of hospital and long-term care. For women

218   who had died at the age of 66-79 or 80-88 years, the risk for long-term care in the last year of life

219   was lower among the consistently active women compared to others. However, for women who

220   died at the age of 89-98 years, the statistical significance of physical activity behavior on need for

221   long-term care was diminished (data not shown).

222

223   In addition, the proximity of the interview and death was investigated by excluding persons who

224   had died 1-2 years after the interview, but it did not change the results.

225

226

227

228

229

230

231

232

233

234

9

DISCUSSION

Men who reported consistent physical activity from midlife onwards needed fewer days of hospital care in their last year of life than those who reported less physical activity. For women who died before 90 years of age, the same was true for long-term care. All analyses were performed for a decedent population who had taken part in an ante mortem interview about their physical activity participation. These data were linked with register-based data on hospital and long-term care during the year preceding death.

Our results are in agreement with earlier studies about the need for end-of-life in-patient care and age at death. Hospital care with aggressive forms of care decreases (29,30) and need for long-term care increases with older age at death (2,3). However, most of the earlier research has not included care given both in a hospital and nursing home, which underestimates the total care needed at the end of life (31).

To the best of our knowledge, this is the first study to report on the association of physical activity and the need for hospital and long-term care at the end of a long life. For sedentary men, the higher use of hospital care may be due to their higher incidence of conditions requiring specialized care or longer duration of care compared to physically more active men (32). In men, physical activity earlier in life and length of long-term care in the last year of life did not correlate. A potential explanation is that men needing care are often cared for at home by their spouses and they tend to die before their caregivers (32). Our analyses showed that sedentary women needed more days of long-term care in their last year of life than more active women. This could be due to the fact that sedentary women might have suffered from disability more frequently than their active counterparts and thus would have needed more long-term care at the end of life.

10

260

261   A plausible explanation for the preventive effect of physical activity on the need for care is in line

262   with the disablement process described by Nagi (33). Consistent physical activity from midlife

263   onwards can reduce the risk of disease (6,8,34) and development of functional limitations (14,35).

264   This further postpones or prevents the development of disability (36-38) which is often reflected in

265   increased need for assistance and care in activities of daily living (39). We were able to confirm

266   the relation between physical activity from midlife onwards and disability in old age by further

267   analysis (data not shown). The risk for disability in old age was higher for those who had been

268   sedentary or occasionally active from midlife onwards compared to the consistently active. Thus,

269   consistent physical activity from midlife onwards might help decrease the development and

270   progression of disability, which in turn could contribute to an increase in active life expectancy

271   and a reduced need for end-of-life care.

272

273   The strengths of the study are the decedent study population, the ante-mortem interviews used

274   with register-based data for hospital and long-term, long follow-up, wide range of ages at death

275   and the prospective design. Limitation in the study was that physical activity data were collected

276   with retrospective interview and were based on self-report. Potential recall bias and possible

277   subclinical cognitive impairments the participants might have had at the time of the interview may

278   have influenced the results (5,40,41). Persons who were physically active at the time of the

279   interview may recall their earlier physical activity more accurately. To be categorized as

280   physically active, a person had to report engagement in recreational or competitive sports over all

281   three periods in time, which consistently sedentary persons would probably not report by mistake.

282   Furthermore, we cannot rule out the possibility, that some participants were sedentary in their

283   midlife due chronic diseases. However, we performed subgroup analyses for those who had a

284   disease of the heart and circulatory system. The association of physical activity with need for

285 hospital and long-term care did not differ from the results for the whole study population (data not

286 shown). It has been reported earlier that a higher level of physical activity in midlife correlates

287 with higher function in old age, regardless of adjustment for chronic diseases at baseline (39). Data

288 were not available for us to take into account in our analyses care that took place outside

289 institutions. However, we did adjust the models for marital status, as the spouse is the most likely

290 provider of care outside the institutions. More detailed information on onset of chronic conditions

291 and physical activity behavior throughout the life-span should be included in future studies. It

292 should also be emphasized that our study is based on observational data and therefore definite

293 conclusions about cause and effect can not be drawn.

294

295 Our findings among people who died after 66 years of age, suggest that consistent long-term

296 physical activity may decrease the need for end-of-life hospital care for men and long-term care

297 for women regardless of the common chronic diseases people may have. However, physical

298 activity may not reduce the need for long-term care at the end of life for women with extremely

299 long lives, which is the group of people that will continue to grow within the next few decades in

300 Western countries. Our results provide novel information, which need to be confirmed in further

301 studies.

302

303

304

305

306

307

308

309

310

311

312

313

314 **CONFLICT OF INTEREST**

315

316 None disclosed.

317

318

319 **ACKNOWLEDGEMENTS**

320

325

326

327

328

329

330

331

332

333

334

335

336

337

338

339

340   **REFERENCES**

341

342   1. Scitovsky AA. 'The high cost of dying' revisited. *Millbank Q* 1994;72:561-591.

343

344   2. Yang Z, Norton EC, Stearns SC. Longevity and health care expenditures: the real reasons
345   older people spend more. *J Gerontol Soc Sci* 2003;58B:S1-10.

346

347   3. McGrail K, Green B, Barer ML, Evans RG, Hertzman C, Normand C. Age, costs of acute
348   and long-term care and proximity to death: evidence for 1987-88 and 1994-95 in British
349   Columbia. *Age Ageing* 2000;29:249-253.

350

351   4. Spillman BC, Lubitz J. The effect of longevity on spending for acute and long-term care. *N*
352   *Engl J Med 2000*;342:1409-1415.

353

354   5. Stearns SC, Kovar MG, Hayes K, Koch GG. Risk indicators for hospitalization during the
355   last year of life. *Health Serv Res* 1996;31:49-69.

356

357   6. Fries JF. Aging, natural death, and the compression of morbidity. *N Engl J Med*
358   1980;303:130-135

359

360   7. Hakim AA, Petrovitch H, Burchfield CM, Ross GW, Rodriguez BL, White LR et al.
361   Effects of walking on mortality among non-smoking retired men. *N Engl J Med*
362   1998;338:94-99.

363

364   8. Wannamethee SG, Shaper AG, Walker M. Changes in physical activity, mortality, and
365   incidence of coronary heart disease in older men. *Lancet* 1998;351:1603-1608.

366

367   9. Gregg EW, Cauley JA, Stone K, Thompson TJ, Bauer DC, Cummings SR et al.
368   Relationship of changes in physical activity and mortality among older women. *JAMA*
369   2003;289:2379-2386.

370

371   10. Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P et al.
372   Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired
373   glucose tolerance. *N Engl J Med* 2001;344:1343-1350.

374

375 11. Fries JF. Physical activity, the compression of morbidity, and the health of the elderly. *J R*
376   *Soc Med* 1996;89:64-68.

377

378 12. Vita AJ, Terry RB, Hubert HB, Fries JF. Aging, health risks, and cumulative disability. *N*
379   *Engl J Med* 1998;338:1035-1041.

380

381 13. Leveille SG, Guralnik JM, Ferrucci L, Langlois JA. Aging successfully until death in old
382   age: opportunities for increasing active life expectancy. *Am J Epidemiol* 1999;149:654-
383   664.

384

385 14. Miller ME, Rejeski WJ, Reboussin BA, Ten Have TR, Ettinger WH. Physical activity,
386   functional limitations, and disability in older adults. *J Am Geriatr Soc* 2000;48:1264-1272.

387

388 15. Penninx BWJH, Messier SP, Rejeski J, Williamson JD, DiBari M, Cavazzini C et al.
389   Physical exercise and the prevention of disability in activities of daily living in older
390   persons with osteoarthritis. *Arch Intern Med* 2001;161:2309-2316.

391

392 16. Rovio S, Kåreholt I, Helkala E-L, Viitanen M, Winblad B, Tuomilehto J et al. Leisure-time
393   physical activity at midlife and the risk of dementia and Alzheimer's disease. *Lancet*
394   *Neurol* 2005; 4:705-711.

395

396 17. Patel KV, Coppin AK, Manini TM, Laurentani F, Bandinelli S, Ferrucci L et al. Midlife
397   physical activity and mobility in older age. The InCHIANTI Study. *Am J Prev Med*
398   2006;31:217-224.

399

400 18. Kujala UM, Sarna S, Kaprio J, Koskenvuo M. Hospital care in later life among former
401   world-class Finnish athletes. *JAMA* 1996;276:216-220.

402

403 19. Heikkinen E. Background, design, and methods of the project. *Scand J Soc Med* 1997;53
404   (suppl):1-18.

405

406 20. Ruuskanen JM, Ruoppila I. Physical activity and psychological well-being among people
407   aged 65 to 84 years. *Age Ageing* 1995;24:292-296.

408

409   21. Hirvensalo M, Lampinen P, Rantanen T. Physical exercise in old age: an eight year study

410   on involvement, motives, and obstacles among persons age 65-84. *J Aging Phys Act*

411   1998;6:157-168.

412

413   22. Hirvensalo M, Lintunen T, Rantanen T. The continuity of physical activity a − retropective

414   and prospective study among older people. *Scand J Med Sci Sports* 2000;10:37-41.

415

416   23. Erkinjuntti T, Laaksonen R, Sulkava R, Syrjäläinen R, Palo J. Neuropsychological

417   differentiation between normal aging. Alzheimer's disease and vascular dementia. *Acta*

418   *Neurol Scand* 1986;74:393-403.

419

420   24. Luria AR. The working brain. An introduction to neuropsychology. Harmondsworth:

421   penguin Books, 1973.

422

423   25. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental

424   activities of daily living. *Gerontologist* 1969;9:179-186.

425

426   26. Laukkanen P, Kauppinen M, Era P, Heikkinen E. Factors related to coping with physical

427   and instrumental activities of daily living among people born in 1904-1923. *Int J Geriatr*

428   *Psych* 1993;8:287-296.

429

430   27. World Health Organization. International Classification of Diseases, Ninth Revision (ICD-

431   9). Geneva, Switzerland: World Health Organization, 1977.

432

433   28. Stata Corp. 2003; Stata Statistical Software: Release 8.0. College Station, TX: Stata

434   Corporation. http://www.stata.com

435

436   29. Levinsky NG, Yu W, Ash A, Moskowitz M, Gazelle G, Saynina O et al. Influence of age

437   on Medicare expenditures and medical care in the last year of life. *JAMA* 2001;286:1349-

438   1355.

439

440   30. Menec VH, Lix L, Nowicki S, Ekuma O. Health care use at the end of life among older

441   adults: does it vary by age*? J Gerontol Med Sci* 2007;62A:400-407.

442

443 31. Lubitz J, Beebe J, Baker C. Longevity and Medicare expenditures. *N Engl J Med*
444   1995;332:999-1003.

445

446 32. Guralnik JM, Leveille SG, Hirsh R, Ferrucci L, Fried LP. The impact of disability in older
447   women. *J Am Med Womens Assoc* 1997;52:113-120.

448

449 33. Nagi SZ. An epidemiology of disability among adults in the United States. *Milbank Mem*
450   *Fund Q Health Soc* 1976;54:439-467.

451

452 34. Friedreich CM, Bryant HE, Courneya KS. Case-control study of lifetime physical activity
453   and breast cancer risk. *Am J Epidemiol* 2001;154:336-347.

454

455 35. Hirvensalo M, Rantanen T, Heikkinen E. Mobility difficulties and physical activity as
456   predictors of mortality and loss of independence in the community-living older population.
457   *J Am Geriatr Soc* 2000;48:493-498.

458

459 36. Keysor JJ. Does late-life physical activity or exercise prevent or minimize disablement? A
460   critical review of the scientific evidence. *Am J Prev Med* 2003;25(suppl 2):129-136.

461

462 37. Spirduso WW, Cronin DL. Exercise dose-response effects on quality of life and
463   independent living in older adults. *Med Sci Sports Exerc* 2001;33(suppl):S598-608

464

465 38. Wolinsky FD, Miller DK, Andresen EM, Malmstrom TK, Miller JP, Miller TR. Effect of
466   subclinical status in functional limitation and disability on adverse health outcomes 3 years
467   later. *J Gerontol Med Sci* 2007;62A:101-106.

468

469 39. Katz S, Branch LG, Branson MH, Papsidero JA, Beck JC, Greer DS. Active life
470   expectancy. *N Engl J Med* 1983;309:1218-1224.

471

472 40. Hillsdon MM, Brunner EJ, Guralnik JM, Marmot MG. Prospective study of physical
473   activity and physical function in early old age. *Am J Prev Med* 2005;28:245-250.

474

41. Martin MY, Powell MP, Peel C, Zhu S, Allman R. Leisure-time physical activity and health-care utilization in older adults. *J Aging Phys Act* 2006;14:392-410.

501 **Legends for figures:**

502

503 Figure 1. Formation of the study population, deaths and data collection wave used

504

505 Figure 2. All-cause hospital, long-term and total care in the last year of life according to age at

506 death (A and B) and physical activity behavior (C and D) for men and women