



## Brief Original Report

# Standing time and all-cause mortality in a large cohort of Australian adults



Hidde P. van der Ploeg<sup>a,b,\*</sup>, Tien Chey<sup>b</sup>, Ding Ding<sup>b</sup>, Josephine Y. Chau<sup>b</sup>,  
Emmanuel Stamatakis<sup>c,d,e</sup>, Adrian E. Bauman<sup>b</sup>

<sup>a</sup> Department of Public and Occupational Health, EMGO Institute for Health and Care Research, VU University Medical Center, Amsterdam, The Netherlands

<sup>b</sup> Sydney School of Public Health, University of Sydney, Sydney, Australia

<sup>c</sup> Exercise and Sport Sciences, Faculty of Health Sciences, University of Sydney, Sydney, Australia

<sup>d</sup> Charles Perkins Centre, University of Sydney, Sydney, Australia

<sup>e</sup> Physical Activity Research Group (UCL-PARG), Department of Epidemiology and Public Health, University College London, London, UK

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## ABSTRACT

**Objective.** To determine the association between standing time and all-cause mortality.

**Methods.** Prospective questionnaire data from 221,240 individuals from the 45 and Up Study were linked to mortality data from the New South Wales Registry of Deaths (Australia) from February 1, 2006 to June 17, 2012. Hazard ratios for all-cause mortality according to standing time at baseline were estimated in 2013 using Cox regression modelling, adjusted for sex, age, education, urban/rural residence, physical activity, sitting time, body mass index, smoking status, self-rated health and disability.

**Results.** During 937,411 person years (mean follow-up = 4.2 yr) 8009 deaths occurred. All-cause mortality hazard ratios were 0.90 (95% CI 0.85–0.95), 0.85 (95% CI 0.80–0.95), and 0.76 (95% CI 0.69–0.95) for standing 2–≤5 h/d, 5–≤8 h/d, or >8 h/d respectively, compared to standing two or less hours per day. Further analyses revealed no significant interactions between standing and sex ( $p = 0.93$ ), the presence/absence of cardiovascular disease or diabetes ( $p = 0.22$ ), BMI ( $p = 0.78$ ), physical activity ( $p = 0.16$ ) and sitting time ( $p = 0.22$ ).

**Conclusion.** This study showed a dose–response association between standing time and all-cause mortality in Australian adults aged 45 years and older. Increasing standing may hold promise for alleviating the health risks of prolonged sitting.

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## Introduction

Evidence is accumulating on the detrimental health effects of prolonged sitting (Chau et al., 2013; Grontved and Hu, 2011; Proper et al., 2011; Thorpe et al., 2011; van Uffelen et al., 2010; Wilmore et al., 2012). Increasing standing has been proposed as a feasible and promising strategy to reduce sitting time (Alkhajah et al., 2012; Dunstan et al., 2012; Grunseit et al., 2013; Healy et al., 2013; Owen et al., 2011; Pronk et al., 2012). However, little is known about the long-term health implications of standing time. Recently, it was suggested that standing was associated with lower mortality risks among inactive individuals (Katzmarzyk, 2013). The objective of the current study was to determine the association between standing time and all-cause mortality in a large prospective cohort study.

## Methods

## Study population

The analyses used data from the Sax Institute's 45 and Up Study, a large-scale prospective cohort study of men and women aged 45 years and older from the state of New South Wales (NSW), Australia. The 45 and Up Study was approved by the University of NSW Human Research Ethics Committee. The study was approved by the NSW Population and Health Services Research Ethics Committee (reference No. 2010/05/234). A detailed description of the 45 and Up Study can be found elsewhere (45 and Up Study Collaborators, 2008).

## Study variables

Participants completed a baseline questionnaire (available at [www.saxinstitute.org.au/our-work/45-up-study](http://www.saxinstitute.org.au/our-work/45-up-study)) between February 2006 and December 2009. Self-reported time spent standing was assessed with the question 'About how many hours in each 24 h day do you usually spend standing?' Sitting time was assessed with the question 'About how many hours in each 24 h day do you usually spend sitting?' Total moderate to vigorous intensity physical activity was assessed with the Active Australia Survey, which measures walking and other moderate- and vigorous-intensity physical activity

\* Corresponding author at: Department of Public and Occupational Health, VU University Medical Center, van der Boechorststraat 7, 1081BT Amsterdam, the Netherlands.  
E-mail address: [hp.vanderploeg@vumc.nl](mailto:hp.vanderploeg@vumc.nl) (H.P. van der Ploeg).

(Australian Institute of Health and Welfare (AIHW), 2003). All-cause mortality was ascertained from the NSW Registry of Births, Deaths and Marriages for the period 1/2/2006–17/6/2012. More details on the assessments can be found elsewhere (45 and Up Study Collaborators, 2008; van der Ploeg et al., 2012).

### Statistical analyses

Hazard ratios for all-cause mortality according to standing time categories ( $\leq 2$  h/d,  $2-\leq 5$  h/d,  $5-\leq 8$  h/d,  $>8$  h/d) at baseline were estimated using Cox regression modelling (Cox, 1972), in which the underlying time variable was age. Standing time categories were defined a priori and loosely based on quartiles, while still including sufficient contrast within the low-end-skewed standing distribution. Hazard ratios for standing time categories relative to the first standing time category were calculated, as well as tests for trends over the four standing time categories. Cox regression analyses were adjusted for self-reported sex, age (default), education, marital status, urban/rural residence, BMI, physical activity (walking and other moderate to vigorous physical activity), daily sitting time and smoking status. To account for possible reverse causation due to existing disease, self-rated health and receiving help with daily tasks for a long term illness or disability were also adjusted for. People with missing data on standing, sitting time or physical activity or where sitting and standing time added up to more than 24 h/d were excluded from the analyses. Missing data for all other adjustment variables were included in the analyses as a separate category.

The Cox regression models were repeated for a priori defined subgroups of people with cardiovascular disease (including heart disease, stroke, thrombosis) or diabetes, and for people who were considered (relatively) healthy with no cardiovascular disease, diabetes or cancer (with the exception of non-melanoma skin cancer). Regression models were also repeated with stratifications for sex, age, BMI, physical activity and sitting time. To determine if the association between standing and all-cause mortality differed between subgroups, interaction effects were determined with a likelihood ratio test comparing the model with and without interaction term.

Finally, a sensitivity analysis with only participants who had more than 1 year of follow-up was performed to check for potential confounding of occult disease at baseline.

### Results

The characteristics of the cohort participants ( $n = 221,240$ ) by time spent standing are presented in Table 1. Standing time was lowest in people with age 75 years or older, a university degree, fair/poor self-rated health, requirements for help with daily tasks, lower physical activity levels and higher sitting levels.

Mean follow-up time was 4.2 (SD = 0.9) years and during 937,411 person years 8009 deaths occurred. Table 2 presents the results from

**Table 1**  
Characteristics of the cohort participants by time spent standing.

Variable	Standing 0– $\leq 2$ h/d	Standing 2– $\leq 5$ h/d	Standing 5– $\leq 8$ h/d	Standing $>8$ h/d	Total sample
	No. (row %)	No. (row %)	No. (row %)	No. (row %)	No. (column %)
All participants	73,081 (33.0)	66,699 (30.1)	51,187 (23.1)	30,273 (13.7)	221,240 (100.0)
Sex					
Male	35,405 (33.8)	30,883 (29.5)	24,606 (23.5)	13,880 (13.2)	104,774 (47.4)
Female	37,676 (32.3)	35,816 (30.8)	26,581 (22.8)	16,393 (14.1)	116,466 (52.6)
Age (yrs)					
45–54	22,589 (32.6)	20,115 (29.0)	15,501 (22.3)	11,190 (16.1)	69,395 (31.4)
55–64	22,711 (30.7)	22,051 (29.8)	18,037 (24.3)	11,276 (15.2)	74,075 (33.5)
65–74	14,517 (31.2)	14,646 (31.5)	11,707 (25.1)	5695 (12.2)	46,565 (21.0)
$\geq 75$	13,264 (42.5)	9887 (31.7)	5942 (19.0)	2112 (6.8)	31,205 (14.1)
Education					
Low ( $\leq$ did not complete high school)	22,000 (31.8)	20,996 (30.4)	16,508 (23.9)	9666 (14.0)	69,170 (31.6)
Middle	28,422 (30.1)	27,652 (29.3)	23,272 (24.7)	14,930 (15.8)	94,276 (43.1)
High ( $\geq$ completed university)	21,778 (39.5)	17,211 (31.2)	10,779 (19.6)	5350 (9.7)	55,118 (25.2)
Marital status					
Married/de facto	53,488 (31.7)	50,995 (30.2)	40,248 (23.8)	24,151 (14.3)	168,882 (76.7)
Other	19,206 (37.5)	15,385 (30.0)	10,667 (20.8)	5965 (11.6)	51,223 (23.3)
Location of residence					
Rural	18,499 (28.5)	18,962 (29.2)	16,738 (25.8)	10,639 (16.4)	64,838 (29.3)
Urban	54,565 (34.9)	47,717 (30.5)	34,440 (22.0)	19,629 (12.6)	156,351 (70.7)
BMI					
$<18.5$	897 (35.1)	735 (28.7)	572 (22.4)	353 (13.8)	2557 (1.2)
$18.5-<25$	24,207 (31.9)	22,130 (29.2)	18,154 (23.9)	11,416 (15.0)	75,907 (36.6)
$25-<30$	26,730 (32.4)	25,215 (30.6)	19,184 (23.3)	11,270 (13.7)	82,399 (39.8)
$\geq 30$	16,755 (36.2)	14,402 (31.1)	9932 (21.4)	5244 (11.3)	46,333 (22.4)
Smoking status					
Current smoker	4825 (30.5)	4665 (29.5)	3799 (24.0)	2541 (16.1)	15,830 (7.2)
Ex-smoker	26,391 (33.3)	23,876 (30.1)	18,525 (23.4)	10,508 (13.3)	79,300 (35.9)
Never smoked	41,669 (33.2)	37,949 (30.2)	28,712 (22.9)	17,133 (13.7)	125,463 (56.9)
Self-rated health status					
Excellent	10,478 (30.8)	9685 (28.5)	8145 (23.9)	5721 (16.8)	34,029 (15.8)
Very good	24,596 (30.1)	24,803 (30.3)	20,103 (24.6)	12,330 (15.1)	81,832 (38.0)
Good	23,653 (33.1)	22,031 (30.9)	16,555 (23.2)	9148 (12.8)	71,387 (33.2)
Fair	10,015 (41.8)	7281 (30.4)	4552 (19.0)	2102 (8.8)	23,950 (11.1)
Poor	2271 (57.6)	1049 (26.6)	423 (10.7)	200 (5.1)	3943 (1.8)
Help with daily tasks because of long term illness or disability					
No	64,451 (31.9)	61,193 (30.3)	47,999 (23.7)	28,577 (14.1)	202,220 (95.2)
Yes	5652 (54.9)	2824 (27.4)	1258 (12.2)	570 (5.5)	10,304 (4.8)
Moderate to vigorous intensity physical activity (min/wk)					
0	5133 (48.8)	2621 (24.9)	1709 (16.2)	1057 (10.0)	10,520 (4.8)
1–149	15,584 (41.9)	11,195 (30.1)	6812 (18.3)	3581 (9.6)	37,172 (16.8)
150–299	15,521 (38.3)	12,664 (31.2)	8235 (20.3)	4109 (10.1)	40,529 (18.3)
$>= 300$	36,843 (27.7)	40,219 (30.2)	34,431 (25.9)	21,526 (16.2)	133,019 (60.1)
Sitting (h/d)					
0– $<4$	16,756 (29.0)	13,719 (23.7)	13,039 (22.6)	14,256 (24.7)	57,770 (26.1)
4– $<8$	30,141 (27.9)	34,508 (31.9)	28,687 (26.5)	14,811 (13.7)	108,147 (48.9)
8– $<11$	18,235 (43.8)	13,448 (32.3)	8773 (21.1)	1206 (2.9)	41,662 (18.8)
$\geq 11$	7949 (58.2)	5024 (36.8)	688 (5.0)	Excluded	13,661 (6.2)

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