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*Published in:*  
Maturitas

*DOI:*  
[10.1016/j.maturitas.2018.08.006](https://doi.org/10.1016/j.maturitas.2018.08.006)

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*Recommended citation(APA):*  
Mielke, G. I., Burton, N. W., Turrell, G., & Brown, W. J. (2018). Temporal trends in sitting time by domain in a cohort of mid-age Australian men and women. *Maturitas*, 116, 108-115.  
<https://doi.org/10.1016/j.maturitas.2018.08.006>

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## Accepted Manuscript

Title: Temporal trends in sitting time by domain in a cohort of mid-age Australian men and women

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PII: S0378-5122(18)30457-2  
DOI: <https://doi.org/10.1016/j.maturitas.2018.08.006>  
Reference: MAT 7052

To appear in: *Maturitas*

Received date: 9-7-2018  
Revised date: 1-8-2018  
Accepted date: 6-8-2018

Please cite this article as: Mielke GI, Burton NW, Turrell G, Brown WJ, Temporal trends in sitting time by domain in a cohort of mid-age Australian men and women, *Maturitas* (2018), <https://doi.org/10.1016/j.maturitas.2018.08.006>

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# Temporal trends in sitting time by domain in a cohort of mid-age Australian men and women

**Short title: Temporal trends in sitting time in a cohort of adults**

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## Highlights

- There are few prospective data on temporal trends in overall sitting time for different domains of sitting.

- Sitting to watch TV and sitting at work accounted for more than half of total sitting time in a cohort of Australian mid-age adults.
- Total sitting time was stable over a six-year period, but sitting times for home computer use and TV viewing increased over this period.

## ABSTRACT

There are few prospective data on temporal trends in overall sitting time for different domains of sitting. This study examined time trends over 6 years in total and domain-specific sitting time in mid-age Australian men and women. Self-report data from 5,246 participants in four survey waves (2007, 2009, 2011, 2013) of the HABITAT study in Brisbane, Australia, were analysed. Overall trends in 'high' total sitting time (>8h/day sitting) and five domains were examined: a) >5h/day for TV; b) >2h/day for travel; c) >2h/day for home computer use; d) >2h/day for leisure; and e) >6h/day for work.. Sitting to watch TV and sitting at work accounted for more than half of total sitting time. The proportions who reported high sitting for computer use at home increased from 25% in 2007 to 37% in 2013 in men and from 19% to 29% over the same period in women. High TV sitting time was reported by 11.8% of men and 10.2% of women. These estimates increased to 16.5% and 13.2% respectively over the six years. In conclusion, although overall total sitting time remained fairly stable, there were significant increases in sitting time in some domains (home computer use and TV viewing) and in some sub-groups (such as women, and the employed). These increases were countered by declines in work-related sitting due to retirement.

**Keywords:** sedentary time; temporal trends; surveillance; adults; epidemiology

## 1. Introduction

Evidence suggests that high sitting time (>8 hours/day) is associated with increased risk of all-cause mortality [1]. Although one hour per day of moderate-vigorous physical activity can attenuate or even eliminate the increased risk of all-cause mortality associated with high sitting time, nearly half

the population does not achieve that level of physical activity [2]. Furthermore, sitting for long periods (>5 h/day) to watch TV is associated with increased risk of all cause-mortality, even among those who are highly active [1].

Surveillance of population levels of sitting time has become more widespread in recent years. Data from 54 countries show that nearly 15% of adults spend more than seven hours per day sitting. [3]. Another study, with representative samples from 20 countries, found that adults aged 18-65 with high total sitting time were more likely to be younger and more educated than their counterparts [4]. However, the major limitation of most surveillance efforts to date is the scarcity of data collected at more than one time-point in the same population, which precludes the evaluation of temporal trends in sitting time.

Temporal trends data from 27 European countries show decreases in the proportion of participants reporting >4h/day sitting from both 2002 to 2013 and from 2005 to 2013 [5]. It is unclear whether these decreases apply to all domains of sitting, such as TV viewing, or sitting for travel, work, and leisure. More detailed information about the contexts of high sitting time could inform targeted strategies for behaviour change. The aim of this study therefore, was to examine six-year time trends in total and domain-specific sitting time in mid-age Australian men and women.

## **2. Methods**

### **2.1. Design and sample**

Data were from the HABITAT (**H**ow **A**reas in **B**risbane **I**nfluence **h**eal**T**h and **A**c**T**ivity) study, a longitudinal multi-level cohort study based in Brisbane, Australia. At baseline in 2007 a multi-stage sampling and recruitment protocol was used to identify a stratified random sample of 16,128 eligible people aged 40-65 years, from across 200 local areas with contrasting levels of neighbourhood socioeconomic status. A mail-survey was administered at baseline and at subsequent

follow-ups in 2009, 2011 and 2013. The study protocols received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3967H & 1300000161). More details of the methods have been reported previously [6, 7].

## **2.2. Sitting time**

At all surveys, participants were asked to report time (hours/mins) spent sitting on a usual week day and a usual weekend day in each of five domains: (a) watching television (including DVDs, videos, video games); (b) sitting while in transportation; (c) using a computer at home; (d) in overall leisure time (excluding television time and using a computer at home); and (e) sitting at work (for those who were in paid employment at the time of each survey). These measures have acceptable reliability and validity among mid-age Australian adults [8]. For this study, data relating to sitting time on a usual week day was analysed. Total sitting time was calculated by summing the time reported in each specific-domain (TV, transportation, computer at home, overall leisure time and work). For total sitting time, those participants who were not in paid employment were assigned a score of zero for sitting at work. High total sitting time was defined as >8h/day for total; >5h/day for TV; >2h/day for travel; >2h/day for home computer use; >2h/day for leisure (not considering TV viewing and computer use); and >6h/day for work. The thresholds for classification of high total sitting and high TV time were based on a recent meta-analysis, which showed higher risk of all-cause mortality among adults who reported more than eight hours per day in sitting and more than five hours per day watching TV [1]. For travel, home computer, leisure and work-based domains, 'high' sitting time was based on sample distributions; these cut-offs approximately represented the top quartile of sitting time in these domains.

## **2.3. Covariates**

Additional questions were used to assess participants' sociodemographic characteristics including gender, highest level of education completed, gross annual household income, and employment

status. Age was derived from date of birth data obtained at the time of sampling. Table 1 shows how each of these variables were operationalised for analysis.

#### **2.4. Statistical analyses**

Descriptive statistics were used to describe total sitting time [mean and standard deviation (SD)], sitting time in each domain as a proportion of total sitting time, and the prevalence and 95% confidence intervals (95%CI) of 'high' sitting time (overall and in each domain). To estimate the 95% CIs, robust standard errors were calculated by taking into account the clustering that resulted from the two-staged sampling design. The statistical significance of changes between years was calculated by Poisson regression, with the sitting time variable as the outcome of interest and the year of survey as the exposure. Analyses were conducted separately for men and women as previous research with this sample has shown gender differences in sitting time [9], and for participants who were employed/not employed, to evaluate the time trends of total sitting time and of sitting in each domain. Both unadjusted and adjusted (for age and socioeconomic position, SEP) estimates are presented. All analyses were performed using Stata version 12.1 (StataCorp, College Station, Texas, USA).

### **3. Results**

Of the 16,128 potential respondents, 11,035 (2007), 7,867 (2009), 6,901 (2011) and 6,520 (2013) returned the survey at each wave. The 2007 baseline sample (n=11,035) was representative of the Brisbane population, but with slightly more women, tertiary educated and higher income participants [6]. For the present study, the analytical sample comprised the same 5,246 participants who returned the survey at all four waves (2007, 2009, 2011, 2013); this represented 47.5% of the baseline sample. Of the 5,246 participants, the number with complete data for all domains of sitting time ranged from 4,606 in 2007 to 4,302 in 2013. Overall, those with complete case-data were more likely to be women, younger, and with high-income and high education.

Sociodemographic characteristics and descriptive sitting time data are presented in Table 1. At baseline, the participants spent on average nearly 10 hours per day sitting. Total sitting time slightly increased from 2007 to 2013 in both genders. Overall, men consistently spent more time than women sitting in all domains except leisure, with consistent patterns over the 6-year period (Table 1).

The proportional contributions of sitting in each domain to total sitting time are shown for men and women in Figure 1. The upper panel shows data for the complete sample and the middle and lower panel shows data for those who were employed and not employed, respectively. Sitting to watch TV and sitting at work accounted for more than half of total sitting time. Among those who were employed, around 40% of time spent sitting was at work. For the whole sample, there was an increase in TV sitting time and a decrease in sitting at work over six years (see middle panel of Figure 1). When the proportion of total sitting time by domains was analysed only among those participants who were not employed at the time of the survey, TV sitting time was the most important domain, but no changes over the years were observed (see bottom panel of Figure 1).

### **INSERT FIGURE 1**

The prevalence of high total sitting time ( $\geq 8\text{h/d}$ ) in men and women is presented in Figure 2. For the whole sample, from 2007 to 2013 this remained stable, with nearly 66% of men and 54% of women spending more than 8h/day sitting (see top panel of Figure 2). However, among those who were employed or not employed at the time of each survey (see middle and bottom panel of Figure 2) there was a slight increase in the proportions who reported high sitting time over 6-years (in men and women).



**INSERT FIGURE 2**

The proportion who reported sitting for >5h/day to watch TV increased from 11.8% (95%CI: 10.3-13.5) to 16.5% (95%CI: 14.9-18.2) in men and from 10.2% (95%CI: 9.2-11.3) to 13.2% (95%CI: 12.1-14.4) among women (Figure 3). Over this 6-year period, the most pronounced increase was observed in the prevalence of high computer use at home, for both men and women. This changed from 25.1% (95%CI: 23.4-27.1) to 37% (95%CI: 35.0-37.0) in men and from 19.3% (95%CI: 18.0-20.7) to 29% (95%CI: 27.2-30.6) among women. After adjustment for age and SEP, this change represented an average increase over every survey of 11% in men and 15% in women. When data from participants who were employed or not employed were analysed separately (Figure 4 and 5), no changes were observed for TV-viewing among those who were unemployed, and increases in high levels of transportation and work sitting were observed only in employed women.

**INSERT FIGURE 3****INSERT FIGURE 4****INSERT FIGURE 5****4. Discussion**

This study investigated time trends of total and domain specific sitting time among mid-age Australian adults. Our findings showed that total sitting time was stable across the six years, but slight differences by sitting time domain were observed. Our findings highlight the value of assessing sitting time by domains rather than through overall estimates, especially for the planning of interventions targeting specific settings and population subgroups.

Overall sitting time was relatively stable over time, with participants spending on average nearly 10 hours/day sitting. If we assume that individuals spend 7-8hours per day sleeping, this finding suggests that mid-age Australian adults spend almost two thirds of their waking day sitting. In

accordance with previous studies [9], sitting time watching TV and at work were the largest contributors to overall sitting time (accounting for more than half). Other research has noted that TV viewing is a common leisure activity choice, especially for those with low SEP [10, 11].

Because of different measures used across studies, a lack of temporal trends data and because sitting time may vary according to social, cultural and environmental characteristics, it is difficult to compare our findings with other studies. A previous study that investigated trends in sitting time across 27 European countries showed that time spent in total sitting time was stable between 2002 and 2013, but that prolonged sitting time (defined as  $>7$  hours/day) decreased [5]. Another study investigating time trends in high TV viewing ( $>3$  hours/day) in Brazil, found an annual decrease in the proportion of participants who spent  $\geq 3$  hours/day watching TV [12], which contrasts with the findings of our study.

The most noticeable increase in domain specific sitting among both men and women was for high computer use at home. The average increase at each survey, after adjustment for age and socioeconomic position, was 11% in men and 15% in women; with 37% of men and 29% of women reporting high computer use at home at the final survey (2013). This may reflect the increasingly ubiquitous use of computers for a range of activities in daily life e.g., entertainment, emails, social media, locating resources, sourcing information, holiday planning etc. Home computer use may also reflect people engaging in flexible work practices, with approximately one quarter of employees working from home on a regular basis [13]. Data from The Australian Bureau of Statistics indicate that between 2007 and 2013 the proportion of households with access to the internet increased from 67% to 83%, with a computer being the main device used to access the internet from home [13].

The slight decrease in sitting at work and increase in time spent watching TV for the whole sample over time may also reflect people leaving the workforce, as there were no changes in sitting at work

for those participants who remained employed. During the six-year study, the proportion of participants who spent more than two hours per day using the computer doubled from 16 to 32%. Other research has also reported increases in computer use/screen time and TV after retirement [14-19]. In our study, prolonged sitting for TV-viewing increased from 11.8% to 16.5% in men and from 10.2% to 13.2% among women. Given the potentially adverse health implications of prolonged sedentary behaviour, and the age-related decline in functional abilities, this increase is concerning if there are not concomitant changes in physical activity.

There were some gender differences in sitting time prevalence and trends, with men reporting higher sitting times than women in most domains. This is consistent with other research which indicates longer overall sitting times for men, including self-report data from Canada [20] and The Netherlands [21], and objective measures from the USA [22] and Sweden [23]. We and others have previously shown gender differences in domain specific sitting time, with men spending more time than women watching television [9, 24] and in computer use [20, 24]. It should be noted however, that our measure of computer use focused on use at home, and other studies may have been confounded by a gender difference favouring males for occupational computer use, given the typically higher rates of employment among men than women.

We found that women reported longer times for sitting in leisure than men, which is consistent with research from Ireland which used a similar self-report measure of sitting time [24]. This may reflect a gender difference in passive leisure pursuits. Herman and Saunders (2016), for example, found that 46% of women and 33% of men reported > 5 hours/week reading. Although not specified in our assessment, women may have been sedentary in leisure time for e.g., relational or social media activities.

Increases in sitting time for transportation and work over the 6-year period were only observed in women. Other self-report research with Australian mid-aged women has found that an increase in overall sitting time was associated with “changes at work”, which were discussed as potentially reflecting increasing (sedentary) seniority and managerial responsibilities and subsequently more desk based work [25]. Increased occupational sitting time may also reflect more mid-aged women returning to the workforce: Australian workforce data indicate a marked increase in women aged 55-59 in employment during the past decade, from 50% in 2005 to 64% in 2016 [13]. This increase in women in the workforce may also mean more time in travel to and from work. Alternatively, women may be travelling more for recreational and daily activities e.g., socialising, errands.

Some limitations of this study must be acknowledged. Participants with higher education were over represented in the original sample of the HABITAT study. Moreover, there may have been some bias due to differential follow-up losses; the analytical sample included only participants who answered the questionnaire in all three waves. The self-reported measures of sitting time might also introduce bias through social desirability and recall. Moreover, the cut-offs for high sitting time considered in these analyses were based on the sample distribution rather than specific recommendations. However, the focus of this paper was on the population level of change rather than within-person variation. Given the longitudinal nature of our sample, an age effect may also influence the results. The strengths of this study include the population based sampling and standardized data collection methods that remained consistent over time, so that time trends could be evaluated.

In conclusion, this population-based cohort study suggests that the apparent stability of overall total sitting time in men and women in recent years masks significant increases in sitting time in some domains (home computer use and TV viewing) and in some sub-groups (such as women, and the

employed). These data could inform the development of context specific strategies for reducing sedentary behaviour.

### **Contributors**

Gregore I Mielke conceived and designed the study, conducted the analyses and wrote the first draft of the manuscript, contributed to data interpretation, and reviewed, edited and approved the final manuscript.

Nicola W Burton conceived and designed the study, contributed to data interpretation, and reviewed, edited and approved the final manuscript.

Gavin Turrell conceived and designed the study, contributed to data interpretation, and reviewed, edited and approved the final manuscript.

Wendy J Brown conceived and designed the study, contributed to data interpretation, and reviewed, edited and approved the final manuscript.

### **Funding**

The HABITAT study was supported by project grants from the (Australian) National Health and Medical Research Council (NHMRC; ID497236), Brisbane City Council provided additional funding support and specific geographical data. At the time of writing, GIM was supported by a Development Fellowship from the University of Queensland. The funding bodies did not contribute to the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

**Ethical approval**

The study protocols received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3967H & 1300000161).

**Provenance and peer review**

This article has undergone peer review.

**Research data (data sharing and collaboration)**

There are no linked research data sets for this submission. The data used are confidential.

**Conflict of interest**

The authors declare that they have no conflict of interest.

**Acknowledgments**

We acknowledge HABITAT project staff for assistance with data coding and cleaning, and project management.

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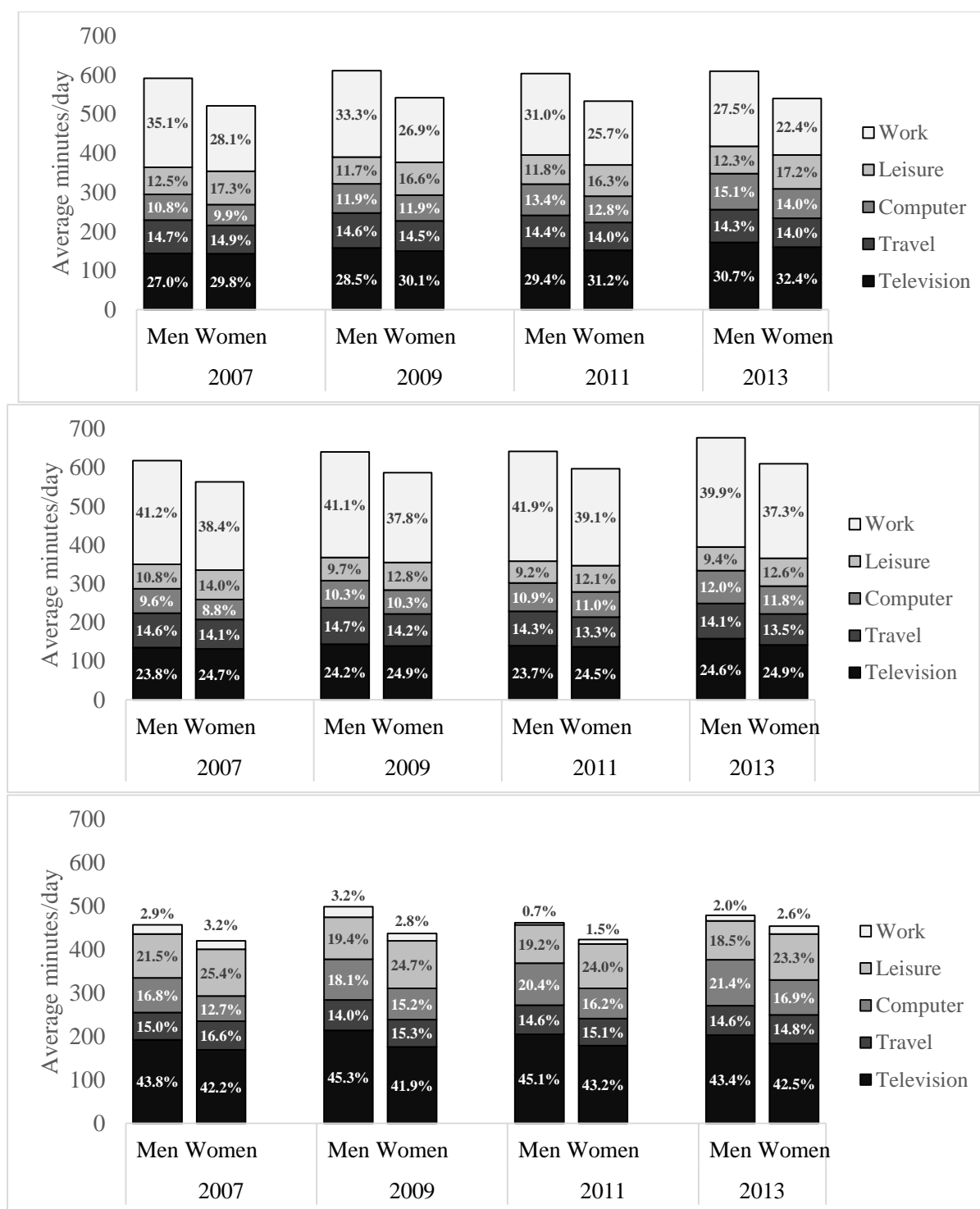
**Figure 1: Total sitting time (min/day) in men and women from 2007 to 2013, showing proportions of time spent in each sitting domain. Top row: total sample (N<sub>2007</sub>=5,245; N<sub>2009</sub>=4,893; N<sub>2011</sub>=5,205; N<sub>2013</sub>=5,108); Middle row: participants who were employed at the time of each survey (N<sub>2007</sub>=3,973; N<sub>2009</sub>=3,540; N<sub>2011</sub>=3,583; N<sub>2013</sub>=3,189); Bottom row: Participants who were not employed at the time of each survey (N<sub>2007</sub>=1,272; N<sub>2009</sub>=1,299; N<sub>2011</sub>=1,622; N<sub>2013</sub>=1,919). Brisbane, Australia (2007-2013). The bar height represents the total sitting time in minutes per day, while the proportional contributions of sitting in each domain to total sitting time are shown.**

**Figure 2: Prevalence of high total sitting time ( $\geq 8$ h/d) in men and women in the total sample (top row: N<sub>2007</sub>=5,245; N<sub>2009</sub>=4,893; N<sub>2011</sub>=5,205; N<sub>2013</sub>=5,108); in participants who were employed at the time of each survey (middle row: N<sub>2007</sub>=3,973; N<sub>2009</sub>=3,540; N<sub>2011</sub>=3,583; N<sub>2013</sub>=3,189); and in participants who were not employed at the time of each survey (bottom row: N<sub>2007</sub>=1,272; N<sub>2009</sub>=1,299; N<sub>2011</sub>=1,622; N<sub>2013</sub>=1,919). Brisbane, Australia (2007-2013).**

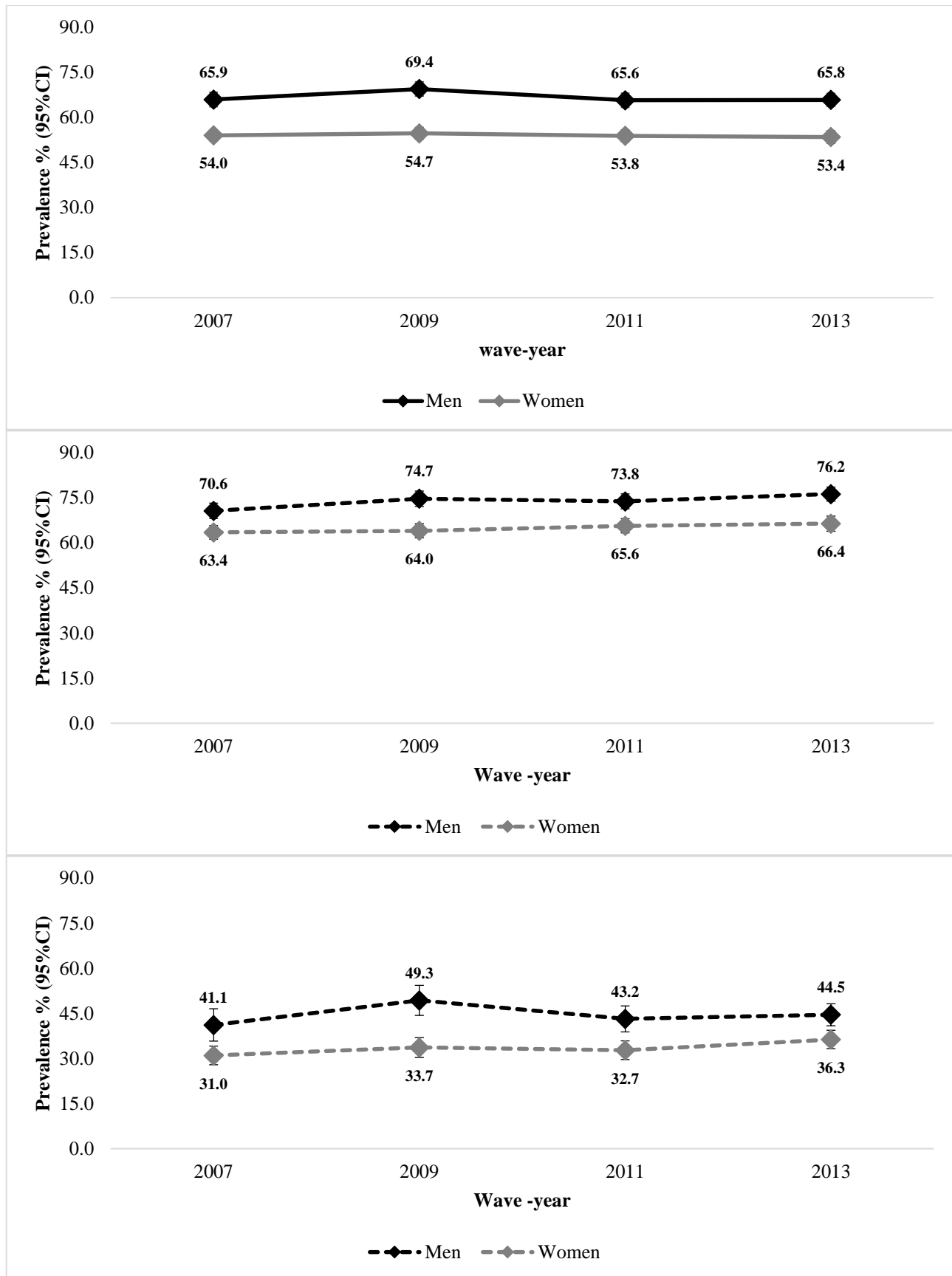
**Figure 3: Time trends in high sitting time by domain among mid-age Australian men and women. Total sample (N<sub>2007</sub>=5,245; N<sub>2009</sub>=4,893; N<sub>2011</sub>=5,205; N<sub>2013</sub>=5,108). Brisbane, Australia (2007-2013).**

**Figure 4: Time trends in high sitting time by domain among mid-age Australian men and women in participants who were employed at the time of each survey (N<sub>2007</sub>=3,973; N<sub>2009</sub>=3,540; N<sub>2011</sub>=3,583; N<sub>2013</sub>=3,189). Brisbane, Australia (2007-2013).**

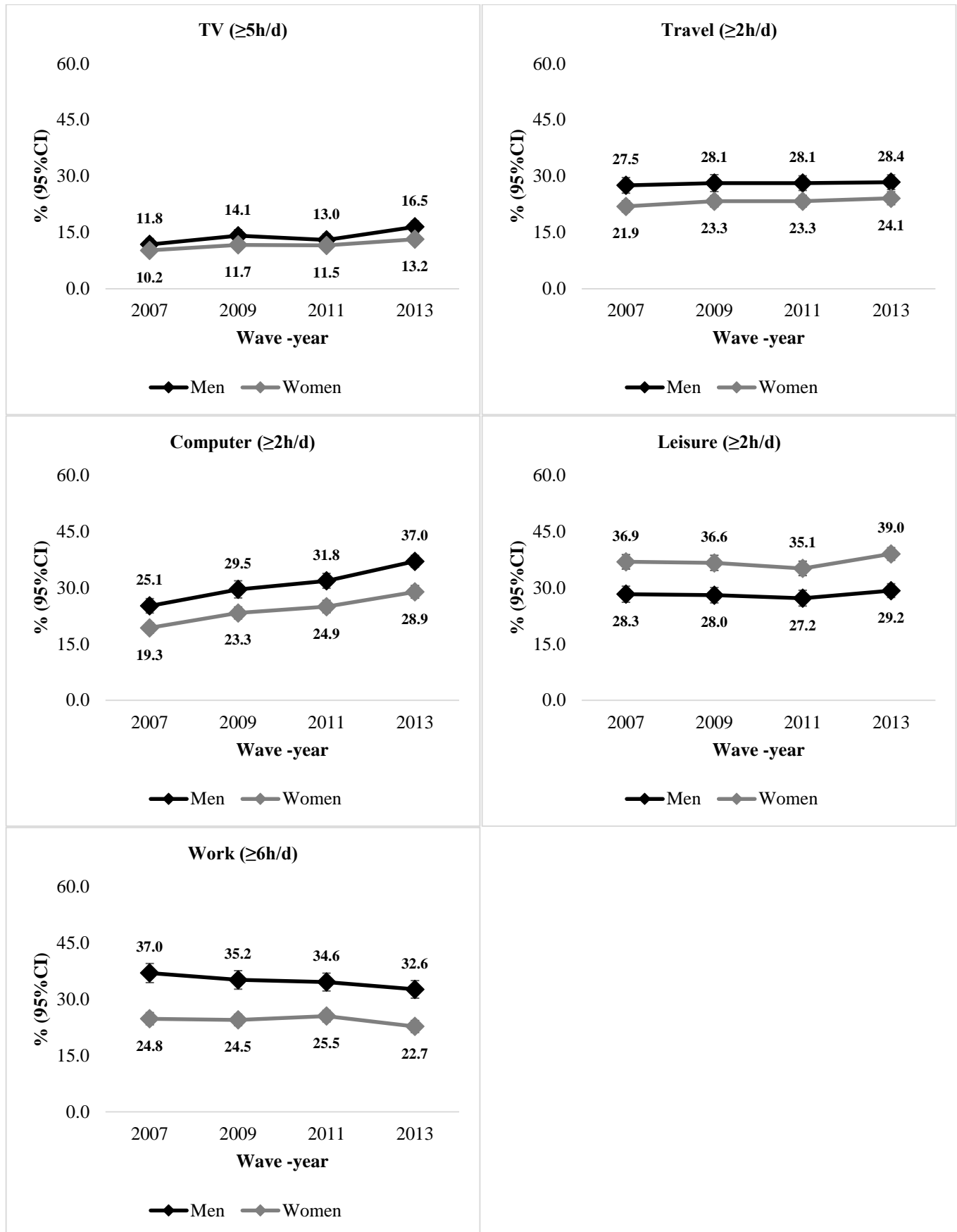
**Figure 5: Time trends in high sitting time by domain among mid-age Australian men and women in participants who were not employed at the time of each survey (N<sub>2007</sub>=1,272; N<sub>2009</sub>=1,299; N<sub>2011</sub>=1,622; N<sub>2013</sub>=1,919). Brisbane, Australia (2007-2013).**



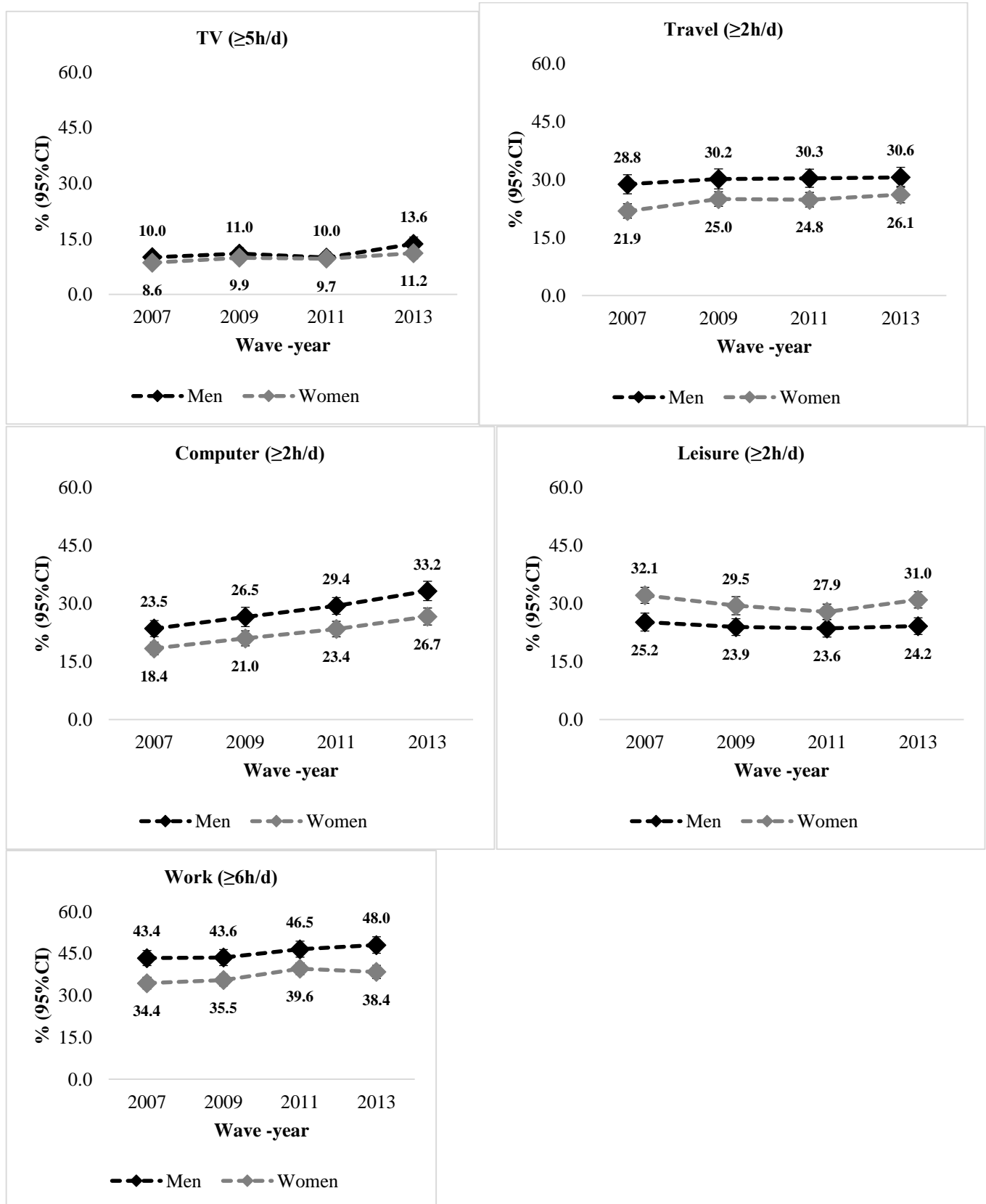
**Figure 1: Total sitting time (min/day) in men and women from 2007 to 2013, showing proportions of time spent in each sitting domain. Top row: total sample ( $N_{2007}=5,245$ ;  $N_{2009}=4,893$ ;  $N_{2011}=5,205$ ;  $N_{2013}=5,108$ ); Middle row: participants who were employed at the time of each survey ( $N_{2007}=3,973$ ;  $N_{2009}=3,540$ ;  $N_{2011}=3,583$ ;  $N_{2013}=3,189$ ); Bottom row: Participants who were not employed at the time of each survey ( $N_{2007}=1,272$ ;  $N_{2009}=1,299$ ;  $N_{2011}=1,622$ ;  $N_{2013}=1,919$ ). Brisbane, Australia (2007-2013). The bar height represents the total sitting time in minutes per day, while the proportional contributions of sitting in each domain to total sitting time are shown.**



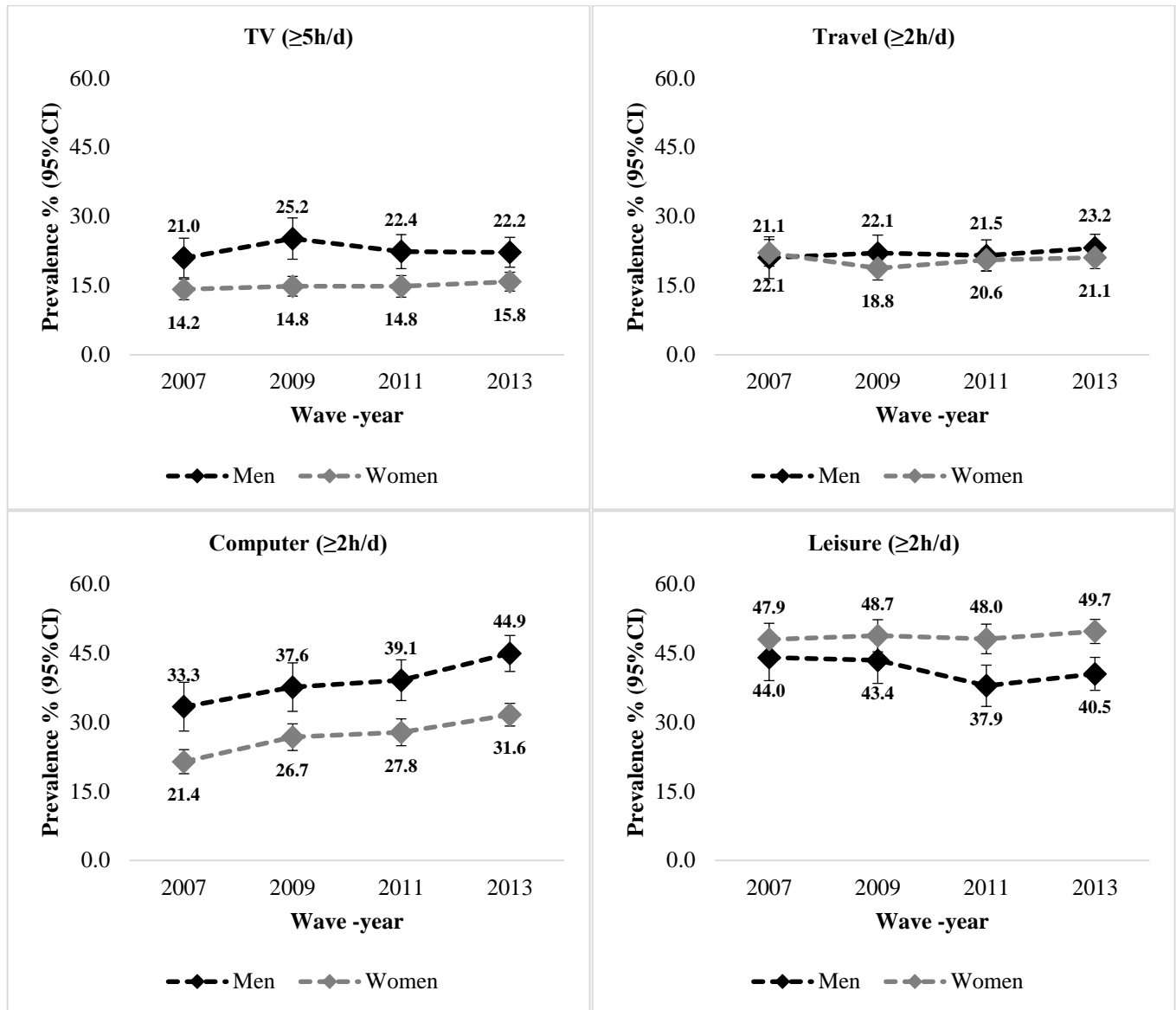
**Figure 2: Prevalence of high total sitting time ( $\geq 8$ h/d) in men and women in the total sample (top row:  $N_{2007}=5,245$ ;  $N_{2009}=4,893$ ;  $N_{2011}=5,205$ ;  $N_{2013}=5,108$ ); in participants who were employed at the time of each survey (middle row:  $N_{2007}=3,973$ ;  $N_{2009}=3,540$ ;  $N_{2011}=3,583$ ;  $N_{2013}=3,189$ ); and in participants who were not employed at the time of each survey (bottom row:  $N_{2007}=1,272$ ;  $N_{2009}=1,299$ ;  $N_{2011}=1,622$ ;  $N_{2013}=1,919$ ). Brisbane, Australia (2007-2013).**



**Figure 3: Prevalence of high sitting time by domain among mid-age Australian men and women. Total sample ( $N_{2007}=5,245$ ;  $N_{2009}=4,893$ ;  $N_{2011}=5,205$ ;  $N_{2013}=5,108$ ). Brisbane, Australia (2007-2013).**



**Figure 4: Prevalence of high sitting time by domain among mid-age Australian men and women in participants who were employed at the time of each survey ( $N_{2007}=3,973$ ;  $N_{2009}=3,540$ ;  $N_{2011}=3,583$ ;  $N_{2013}=3,189$ ). Brisbane, Australia (2007-2013).**



**Figure 5: Prevalence of high sitting time by domain among mid-age Australian men and women in participants who were not employed at the time of each survey (N<sub>2007</sub>=1,272; N<sub>2009</sub>=1,299; N<sub>2011</sub>=1,622; N<sub>2013</sub>=1,919). Brisbane, Australia (2007-2013).**

**Table 1: Descriptive characteristics of the total sample (n=5,246)<sup>a</sup>. Brisbane, Australia (2007-2013).**

Variables	Men (n=2,196)				Women (n=3,050)			
	2007	2009	2011	2013	2007	2009	2011	2013
Age (years) – mean (SD)	51.7 (7.2)	53.7 (7.2)	55.7 (7.1)	57.7 (7.2)	52.1 (7.1)	54.1 (7.1)	56.1 (7.1)	58.2 (7.1)
Age (years) – range	40-65	42-67	44-69	46-71	38-66	40-68	42-70	44-72
Highest completed education (%)								
Bachelor degree or higher	35.7	-	-	-	34.4	-	-	-
Diploma/Associate degree	12.2	-	-	-	11.4	-	-	-
Certificate (trade/business)	21.8	-	-	-	13.9	-	-	-
Year 12 or less	30.2				40.4	-	-	-
Annual gross household income (%) <sup>b</sup>								
AU\$93,600 or more	41.0	43.5	45.7	43.3	32.5	33.3	35.8	34.6
AU\$52,000-93,599/year	33.8	29.6	27.8	27.1	33.4	30.9	28.0	27.8
AU\$20,800-51,999/year	19.8	20.8	20.8	22.4	26.5	25.4	26.9	28.6
< AU\$20,799/year	5.5	6.0	5.7	7.2	7.7	10.4	9.3	9.0
Employment status (%)								
Full-time	72.7	69.5	63.4	56.1	36.8	36.3	34.4	29.6
Part-time	7.0	6.0	6.3	6.8	24.6	22.7	20.7	20.2
Casual	3.9	4.0	4.9	5.2	8.8	9.4	9.6	8.5
Not-working	16.4	20.4	25.4	31.9	29.9	31.6	35.3	41.7
<i>Sitting time variables (min/day)</i>								
Total - mean (SD)	592 (265)	610 (271)	595 (265)	612 (288)	522 (255)	542 (268)	535 (258)	543 (268)
TV - mean (SD)	144 (111)	158 (129)	158 (121)	172 (138)	143 (115)	150 (119)	152 (114)	160 (117)
Travel - mean (SD)	85 (97)	89 (100)	83 (92)	84 (93)	73 (77)	77 (91)	71 (76)	74 (84)
Home Computer - mean (SD)	66 (92)	75 (98)	80 (97)	92 (108)	53 (83)	66 (94)	67 (85)	75 (91)
Leisure - mean (SD)	69 (77)	68 (78)	65 (74)	70 (80)	85 (87)	84 (87)	80 (83)	86 (87)
Work - mean (SD)	228 (185)	221 (186)	209 (198)	194 (200)	167 (171)	165 (171)	164 (186)	147 (187)

<sup>a</sup> including only participants who completed every survey

<sup>b</sup> AU\$ 1.00 = US\$ 0.91 at 30th Jun 2013

SD=standard deviation

- Data for highest completed education were not collected in 2009, 2011, 2013