Curr Obes Rep (2016) 5:344–360
DOI 10.1007/s13679-016-0227-6

The Impact of Obesity in the Workplace: a Review of Contributing Factors, Consequences and Potential Solutions

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Published online: 22 July 2016

Abstract This narrative review summarized findings from previous reviews and the most recently published studies, regarding the following: (1) the association between two occupational risk factors—shift work and sedentary work—and obesity, (2) the effects of obesity on workplace productivity and (3) the effectiveness of workplace interventions aimed at preventing or reducing obesity. Despite some inconsistencies in findings, there is convincing evidence that shift work increases the risk of obesity, while most studies did not show a significant association between sedentary work and obesity. Overweight and obesity were found to be associated with absenteeism, disability pension and overall work impairment, whilst evidence of their relationship with presenteeism, unemployment and early retirement was not consistent. Due to the vast heterogeneity in the types of workplace-based interventions to prevent or treat obesity, no sound conclusions can as yet be drawn about their overall effectiveness and best practice recommendations for their implementation.

This article is part of the Topical Collection on *The Obesity Epidemic: Causes and Consequences*

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Keywords Obesity · Work productivity · Sedentary work · Shift work · Indirect costs · Absenteeism · Presenteeism

Introduction

Obesity is a condition in which the amount of accumulated excess body adipose tissue is so great that it may adversely affect health [1, 2]. It is most commonly defined using body mass index (BMI). BMI is calculated as an individual's body weight in kilograms divided by height in meters squared and is a simple measure of excess weight for use both in the clinical setting and in population health research. An individual with a BMI equal to or greater than 30 kg/m^2 is classified as 'obese' and between 25 and 30 kg/m^2 as 'overweight'. Based on a secondary data analysis including more than 19 million adult participants, the global age-standardized prevalence of obesity in 2014 was 11 % in men and 15 % in women [3]. The prevalence was greater than 30 % for both men and women in high-income English-speaking countries and for women only in the Middle East and in southern and northern Africa. By 2025, the global prevalence of obesity was estimated to be 18 % in men and over 21 % in women, with over 6 % of men and 9 % of women in the 'severely obese' category ($\geq$35 kg/m^2) [3].

The high prevalence of obesity is particularly concerning because of its strong association with a range of adverse health outcomes. The most important obesity-related comorbidities include cardiovascular disease, type 2 diabetes, several types of cancers, osteoarthritis, sleep apnoea and psychological problems [2]. The severity of these health risks highlights the importance of primary prevention and early management of obesity and overweight.

A number of factors may contribute to one's risk of obesity, including behavioural, psychological, environmental, genetic, societal, cultural and economic factors [4]. Recent evidence suggests that working conditions may also impact one's likelihood of weight gain [5]. The risk of obesity seems to increase among workers in high-demand and low-control job settings and among those working long hours and in various shift schedules [5]. Recently, another important work-related risk factor for obesity has been proposed, namely excessive sedentary behaviour (sitting) at work. Technological innovations have decreased physical strain and energy expenditure, resulting in jobs that are more sedentary [6]. As many individuals spend a great deal of their waking hours in the workplace, reducing sitting at work may need to be given special attention.

Obesity may pose an economic burden to the workplace through direct costs (healthcare costs) and indirect costs, such as increased absenteeism from work due to health problems and reduced productivity [7, 8]. Because of these impacts, workplaces may be particularly motivated to conduct interventions to reduce the risk of obesity and/or to encourage weight loss among overweight or obese workers.

The purpose of this narrative review was to summarize findings from previous reviews and the most recently published studies, regarding the following: (1) the association between occupational factors—specifically, shift work and sedentary work—and obesity; (2) the effects of obesity on workplace productivity, namely indirect costs, including absenteeism, presenteeism, disability, early retirement and premature mortality-related costs; and (3) the effectiveness of workplace interventions aimed at preventing or reducing obesity.

Shift Work and Obesity

The number of people working in shifts has grown with the increase in demand of services around the clock and competitiveness of the market [9]. It is estimated that approximately 20 % of European and North American workforce are exposed to shift work schedules including night shifts [10, 11]. Shift work typically refers to an arrangement of working hours so that services can be provided over 24 h. Shift work includes evening or night schedules, rotating shifts, split shifts, on-call or casual shifts, 24-h shifts and other irregular schedules or non-day schedules [12]. Shift work and night work are most common in the healthcare, transportation, industrial manufacturing, communication, mining, leisure or recreation and hospitality sectors [13].

A 2011 review by Van Drongelen et al. [14] concluded that there was strong evidence for an association between exposure to shift work and subsequent increase in body weight. However, when adjusted for potential confounders (e.g., gender, body weight at baseline and physical activity at work or during leisure), the findings were inconsistent. In a 2013 review of cross-sectional and prospective studies, Amani et al. [15•] found that BMI was greater among shift workers compared to non-shift workers. Shift workers have also been found to consume meals more frequently and have poorer eating habits compared to non-shift workers [15•]. In a 2016 review of exclusively longitudinal studies, Proper et al. [16•] found strong evidence for an association between shift work and increased BMI and limited evidence for an association between shift work and increased waist circumference.

Since the publication of the reviews above, several other studies have been published examining the association between shift work and obesity (Table 1). These studies are predominantly cross-sectional [17, 19, 21–28, 30–33], whilst some used prospective cohort [18, 29] and retrospective cohort [20] study designs.

Most cross-sectional studies reported that shift work was significantly and positively associated with higher BMI [17, 19, 21, 24–28, 30–33]. For example, Ko et al. [24] found that sleep quality was poor in night shift workers, and this poor sleep quality was associated with increased risk of obesity, suggesting that sleep quality may be the causal factor that links night shift work to obesity. However, other studies found no association between shift work and BMI [22, 23]. Kim et al. found a significant association between shift work and obesity in unadjusted analysis but no association in a multivariate model adjusted for age, current smoking status, regular drinking habit, breakfast skipping, regular exercise, marital status, family income, education, sleep problem and self-perceived health status [23]. Overall, the risk of obesity seems to increase with the number of years of working in shifts [28].

A 2012 retrospective cohort study by Gholami et al. [20] found no significant difference in BMI between shift workers and day workers. Another prospective cohort study found that although there was increase in weight in normal-weight workers who changed from regular days to shift work, there was no difference in weight gain between night/shift workers compared to day workers throughout the study period [18]. Some cohort studies also found that there was an increased prevalence of metabolic risk factors (especially impaired glucose tolerance) in shift workers compared to day workers [16•, 34]. The evidence presented here (Table 1) and in the previous reviews [14, 15•] supports the widely hypothesized association between shift work and obesity, although longitudinal findings were not completely consistent.

While the precise mechanism linking shift work and obesity is not entirely understood, differences in dietary intake between shift workers and non-shift workers, as well as hormonal and physiological changes that result from circadian disruption, are suggested to be important contributors [35]. Shift workers seem to eat more incomplete meals and snacks than complete meals. Such 'incomplete' meals are less likely to include fruit and vegetables and are more likely to be sandwich-type meals [15•]. There is a clear change in the

Table 1 Studies on the association between shift work and obesity (studies published from January 2011 to May 2016)

Study	Sample	Study design	Type of shift schedule	Weight-related measures	Main findings
Barbadoro et al. [17]	Participants in an occupational surveillance program in 2008 ($n = 339$)	Cross-sectional	Rotating shift work	BMI calculated based on self-reported height and weight	Compared to daytime workers ($n = 229$), rotating shift workers ($n = 110$) displayed higher BMI (mean BMI was 27.6 ± 3.9 and 26.7 ± 3.6 kg/m^2 for shift workers and daytime workers, respectively; $p < 0.05$)
Bekkers et al. [18]	Participants in the Netherlands Working Conditions Cohort Study ($n = 5951$)	Prospective cohort study	Evening shifts, night shifts, rotating shifts	BMI calculated based on self-reported height and weight	A larger weight increase was seen in normal-weight workers changing from day to shift work ($\beta = 0.93$ %; 95 % CI 0.01–1.85) compared with stable non-shift workers. No further associations were, however, found to support the hypothesis that people working during nights or in shifts over a period are at increased risk of gaining extra weight compared with people only working daytimes.
Buchvold et al. [19]	Randomly selected sample ($n = 6000$) of registered members of the Norwegian Nurses Organization	Cross-sectional	Evening only, day and evening, three-shift rotation, night only or another schedule including night work.	BMI calculated based on self-reported height and weight	Number of night shifts worked previous year was significantly and positively associated with BMI, both against BMI as a continuous variable ($\beta = 0.055$, $p < 0.05$) and against obesity (OR = 1.01, 95 % CI 1.00–1.01).
Gholami et al. [20]	Annual observation from workers who worked at Isfahan's Mobarakeh Steel Factory ($n = 6713$)	Retrospective cohort	Routine shift: 2-day morning at work, 2-day afternoon at work, 2-day night at work and 2-day off Weekly shift: 3-day morning at work, 3-day afternoon at work and alternatively 1-day off within a 2-week-long work.	BMI calculated from measured height and weight	No statistically significant difference was observed between BMIs of routine shift workers and day workers. Weekly shift workers had lower BMI (on average by 0.781) in comparison with day workers.
Griep et al. [21]	2372 registered nurses (2100 women) from 18 largest public hospitals in Rio de Janeiro, Brazil.	Cross-sectional	Working at night at least once a week or four times a month in 12-h shifts.	BMI calculated based on self-reported height and weight	Association between years of exposure to night work and BMI was statistically significant for both women and men after adjusting for all covariates ($\beta = 0.036$; (95 % CI 0.009–0.063) and $\beta = 0.071$ (95 % CI 0.012–0.129), respectively]
Huth et al. [22]	A convenience sample of licensed nurses employed by a magnet-recognized paediatric hospital in north-eastern Ohio ($n = 378$).	Cross-sectional	Night/shift work	BMI calculated based on self-reported height and weight	No statistically significant difference of proportions of BMI >30 kg/m^2 between night shift and day shift respondents ($p > 0.05$).
Kim et al. [23]	9989 nurses among 10,000 who registered on the survey web site	Cross-sectional	n/a	BMI calculated based on self-reported height and weight	A significant positive association between obesity and shift work duration was found in the unadjusted analysis;

Table 1 (continued)

Study	Sample	Study design	Type of shift schedule	Weight-related measures	Main findings
					however, it was attenuated and no longer significant in the multi-variate model.
Ko et al. [24]	Data from the National Survey of Midlife Development in the United States II (MIDUS II study) and the MIDUS II Biomarker Project ($n = 883$)	Cross-sectional	Night shift work	BMI calculated from measured height and weight	Sleep quality was found to be low among night shift workers. Sleep quality was significantly associated with obesity (OR 1.10, 95 % CI 1.03–1.18)
Macagnan et al. [25]	1206 employees 18 to 50 years of age who were working on a production line in a poultry processing plant	Cross-sectional	Night shift work	BMI calculated from measured height and weight and measured waist circumference	Nightshift workers compared to dayshift workers showed a higher prevalence of overweight (42.2 vs. 34.3 %; $p = 0.020$) and abdominal obesity (24.9 vs. 19.5 %; $p = 0.037$).
Marqueze et al. [26]	941 nursing professionals from a public Hospital	Cross-sectional	Night shift work	BMI calculated based on self-reported height and weight	Working at night was associated with a gain in BMI greater than ($\beta = 0.24$ kg/m^2) working during the day ($\beta = 0.15$ kg/m^2).
Neil-Sztramko et al. [27]	Data from the Canadian Health Measures Survey	Cross-sectional	Rotating and permanent night shift work	BMI, waist circumference and waist-hip ratio measured in a mobile clinic	Shift workers were more likely to be obese (OR 1.39, 95 % CI 1.09, 1.53) and be in high-risk categories of waist-hip ratio (OR 1.37, 95 % CI 1.18, 1.60) and waist circumference (OR 1.31, 95 % CI 1.14, 1.51).
Peplonska et al. [28]	724 female nurses and midwives, aged 40–60 years in Łódź, Poland	Cross-sectional	Rotating night shift work	BMI calculated from measured height and weight	Both current and cumulative night work was associated with obesity, with OR = 3.9 (95 % CI 1.5–9.9), in women reporting eight or more night shifts per month.
Ross et al. [29]	Data from Helsinki Health Study (HHS) questionnaire surveys	Prospective cohort	Night/shift work	BMI calculated based on self-reported height and weight	Shift work that included night shifts was associated with increased risk of weight gain among women after adjustment for age (OR = 1.43, 95 % CI 1.13–1.82). The pattern among men was similar, but not statistically significant (OR = 1.29, 95 % CI 0.90–1.86).
Smith et al. [30]	Secondary analysis of a sample from National Survey on the Work and Health of Nurses ($n = 9291$).	Cross-sectional	Regular evening schedule, regular night schedule and mixed schedules.	BMI calculated based on self-reported height and weight	After adjustment for all confounders, female respondents working night shifts had BMI scores 0.67 points higher than those working regular daytime schedules, with respondents working mixed shift schedules having BMI scores 0.44 point higher
Son et al. [31]	Wage workers from the Korea National Health and Nutrition Examination Survey,	Cross-sectional	Night shifts (between 21:00 and 8:00 the next morning), day and night shifts, 24-h	Percentage of total body fat (total fat mass / total mass × 100) was measured using	The risk of obesity in shift work showed a statistically significant increase (OR = 1.779, 95 % CI 1.050–

Table 1 (continued)

Study	Sample	Study design	Type of shift schedule	Weight-related measures	Main findings
	2008–2011 (*n* = 2952)		work shifts and irregular shift work.	dual-energy X-ray absorptiometry	3.015) in the male manual worker group. No significant results in the male non-manual and female worker groups were found.
Tada et al. [32]	Japanese female nurses (1179-day workers and 1579 rotating shift workers) aged 20–59	Cross-sectional	Rotating shift work	BMI calculated based on self-reported height and weight	The BMI of shift workers was significantly greater than among day workers. The multi-variable linear regression coefficients for BMI showed a significant relationship with rotating shift work (*B* = 0.051), after controlling for lifestyle habits.
Yoon et al. [33]	Female workers from 2008 community health survey in south Korea (*n* = 42,234)	Cross-sectional	Night/shift work	BMI calculated from measured height and weight	Night/shift was significantly associated with obesity only in non- manual workers (aOR = 1.20, 95 % CI 1.01–1.42).

aOR adjusted odds ratio, *B* unstandardized regression coefficient, β standardized regression coefficient, *BMI* body mass index, *OR* odds ratio, *p* p value, *CI* confidence interval

routine of sleep and food intake in night shifts. Those who work in night shifts often have no choice but to have small convenience meals (high-fat and high-sugar foods) due to poor access to 'healthy food' at night [32, 36, 37]. There is also some evidence to suggest that shift workers are less likely to participate in regular physical activity than day workers due to their irregular shift schedules [38, 39].

Sedentary Work and Obesity

Since the 1960s, the percentage of jobs in the US private industry that required moderate-intensity physical activity (energy consumption of 3–6 metabolic equivalents [METs]) has dropped from almost 50 % to less than 20 %. This is on account of a significant increase in the prevalence of light-intensity (2–3 METs) and sedentary occupations (<1.5 METs) [40]. International time use surveys also show a marked decline in physical activity and an increase in sedentary behaviour at work in other countries [41]. It is hypothesized that the resulting reduction in occupational energy expenditure may account for a significant portion of the increase in mean body weight in both males and females that occurred during the same time period [42].

A 2010 review by van Uffelen et al. [43•] reported some evidence from cross-sectional studies and inconclusive evidence from longitudinal studies on the association between sedentary work and obesity. Out of ten cross-sectional studies included, five reported a significant positive relationship between occupational sitting time and BMI (in one or both genders), whilst other studies reported non-significant or even inverse relationships [43•]. Out of three prospective studies, two found no significant associations between occupational sitting and subsequent obesity, whilst one study found a significant association only in females [43•].

Following the publication of the review by van Uffelen et al. [43•], 21 studies on the association between sedentary work and obesity have been published (Table 2). Most studies (*n* = 16) were cross-sectional [44–50, 53–57, 59, 62–64], whilst others used prospective cohort [52, 58, 60, 61] or qualitative study design [51]. Nearly half of the cross-sectional studies found no significant associations between sedentary work and BMI [44–46, 52, 54, 55, 60, 61, 63], waist circumference [46, 55, 63], waist to hip ratio [44] and/or proportion of adipose tissue [46, 63]. Most of the remaining studies reported mixed or unclear results [47–49, 56, 59, 64]. For example, Choi et al. [49] found that amongst male firefighters, only those in the highest category of sedentary work had a significantly higher prevalence of obesity (based on BMI) than those in the lowest sedentary work category. However, in the same study, no significant associations were found between sedentary work and obesity based on waist circumference or body fat percentage. Choi et al. [48] found a significant association between sedentary work and obesity in males, but not in females. By contrast, Yang et al. [64] found a significant association only in females. Only four cross-sectional studies obtained uniform results [50, 53, 57, 62]. However, one of them was conducted only among male workers and did not adjust for potential confounders [57] and another adjusted only for age and gender [62].

Table 2 Studies on the association between sedentary work and obesity (studies published from May 2009 to May 2016)

Study	Sample	Study design	Measures of occupational sedentarism	Weight-related measures	Main findings
Al-Habsi and Kilani [44]	Omani females aged 18–48 years ($n = 277$)	Cross-sectional	Self-reported using the Domain-Specific Sitting Time Questionnaire (D-SSTQ) and expressed in minutes/day	BMI calculated from measured height and weight; waist to hip ratio calculated from measured waist and hip circumferences	In the unadjusted analysis, no significant differences in occupational sitting time were found between BMI categories or between waist to hip ratio categories.
Bennie et al. [45]	Desk-based employees in Melbourne, Australia ($n = 801$)	Cross-sectional	Self-reported occupational sitting time in minutes/day ('During the last 7 days, how much time did you usually spend sitting at work?')	BMI calculated from self-reported height and weight	In the unadjusted analysis, no significant differences in median occupational sitting time between underweight/ normal weight, overweight and obese participants were found. In the adjusted analysis, BMI was not significantly related to the time spent sitting at work ($B = 0.20$; $p = 0.854$)
Carr et al. [46]	US employees in full-time sedentary jobs who reported having a sit-stand desk ($n = 31$) or a standard desk ($n = 38$)	Cross-sectional	Occupational sitting time estimated by activPAL3 VT inclinometers (PAL Technologies, Glasgow, UK)	BMI calculated from measured height and weight; measured waist circumference; fat mass and body composition estimated by bioelectrical impedance using InBody 720 (BioSpace Inc., Cerritos, CA, USA)	Employees with sit-stand desk sat on average around 1 h less than those with standard desks ($p = 0.02$). No significant differences between the groups were found in average BMI ($p = 0.55$), fat mass ($p = 0.60$), percentage of body fat ($p = 0.26$) and waist circumference ($p = 0.49$)
Chau et al. [47]	Australian workers aged 15–69 years in full-time or part-time jobs ($n = 7400$)	Cross-sectional	Self-reported usual activity at work (response options: 'mostly heavy labour or physically demanding work', 'mostly walking', 'mostly standing', 'mostly sitting')	BMI calculated from measured height and weight	No clear association was found between sedentary work and overweight or obesity. In the adjusted analysis, those 'mostly standing' at work were the only group with significantly lower risk of overweight/ obesity and obesity when compared to those 'mostly sitting' at work (RR = 0.88, 95 % CI 0.82–0.95 and RR = 0.87, 95 % CI 0.76–1.00, respectively).
Choi et al. [48]	US workers aged 32–69 years ($n = 2019$)	Cross-sectional	Self-reported occupational sitting ('How often does your job require you to sit for long periods of time during your work-shift?' with 'all/ most', 'some', 'little of time/never' response options)	BMI calculated from self-reported height and weight; self-reported waist circumference	In the unadjusted analysis, no significant associations were found between sedentary work and total and central obesity in male workers. Female workers in 'middle levels' of sedentary work had the lowest prevalence of total and central obesity. In the adjusted analysis, only middle levels of sedentary work increased the risk of total obesity in male workers (OR = 1.54, 95 % CI 1.02–2.33, respectively). Among males, both high and middle levels of sedentary work increased the risk of central obesity (OR = 1.78, 95 % CI 1.24–2.53 and 1.52, 95 % CI 1.02–

Table 2 (continued)

Study	Sample	Study design	Measures of occupational sedentarism	Weight-related measures	Main findings
					2.26, respectively). The adjusted analyses showed no significant associations between sedentary work and total or central obesity in female workers.
Choi et al. [49]	US firefighters aged 25–64 years ($n = 308$)	Cross-sectional	Self-reported occupational sitting using a Likert-type item 'My job often requires sitting for long periods of time?' with response options 'strongly disagree', 'disagree' and 'agree' and 'strongly agree'	BMI calculated from measured height and weight; measured waist circumference; skinfold thickness-based body fat percent	In the adjusted analysis, only those in the highest category of sedentary work had significantly higher prevalence of BMI-based obesity than those in the lowest sedentary work category (PR = 4.18, 95 % CI 1.03–16.99). No significant associations were found between sedentary work and obesity category based on waist circumference or body fat percentage.
De Cocker et al. [50]	Australian employees ($n = 993$; mean ± SD age = 51 ± 11.2 years)	Cross-sectional	Self-reported occupational sitting in hours/day (the Workforce Sitting Questionnaire (WSQ))	BMI calculated from self-reported height and weight	The unadjusted analysis showed no significant differences in mean occupational sitting time between 'normal-weight' and 'overweight/obese' participants. In the adjusted analysis, BMI (a continuous variable) showed a significant positive relationship with occupational sitting ($B = 0.094$, 95 % CI 0.018–0.170).
Dobson et al. [51]	Four focus groups of US firefighters: group 1 (FF/engineers, $n = 8$); group 2 (captains, $n = 4$); group 3 (FF/ engineers, $n = 3$); and group 4 (battalion chiefs, $n = 5$)	Focus groups	n/a (qualitative study)	n/a	Sedentary work was identified as one of five themes in discussions within focus groups about the work-related causes of obesity. It was mentioned that (1) the job has become less physically demanding, (2) promotion into higher ranks leads to more sedentary work, (3) sedentary work is increasing even in lower ranks due to greater use of technology, (4) training for lower ranks has also become computerized and (5) physically demanding job tasks are infrequent.
Eriksen et al. [52]	Danish workers aged 18–59 years ($n = 3482$)	Prospective cohort (5-year follow-up)	Self-reported using the question 'Does your work imply sitting?' with six response categories ('almost all the time', 'approximately three fourths of the time', 'approximately one half of the time', 'approximately one fourth of the time',	BMI calculated from self-reported height and weight; Change in BMI calculated as the difference between BMI scores at the follow-up and at the baseline	For both sexes, no cross-sectional associations were found between categories of occupational sitting time and BMI. In the adjusted analysis, the change in occupational sitting categories and the change in BMI between baseline and follow-up were

Table 2 (continued)

Study	Sample	Study design	Measures of occupational sedentarism	Weight-related measures	Main findings
			'rarely/very little' and 'never')		positively related among female workers ($B = 0.13$, 95 % CI 0.06–0.20), but no significant relationship was found among male workers.
Garcia et al. [53]	Brazilian employees of industrial companies ($n = 47{,}477$)	Cross-sectional	Self-reported using the question 'How would you describe your activities at work?' with the response options 'I spend most of the time seated and, at most, walk short distances', 'I perform moderate activities, such as walking fast or performing manual tasks, for most of the day', and 'I frequently perform vigorous physical activities.'	BMI calculated from self-reported height and weight	In the adjusted analyses, sedentary work was associated with obesity in both males and females (OR = 1.27; 95 % CI 1.15–1.41 and OR = 1.24, 95 % CI 1.04–1.48, respectively).
Hadgraft et al. [54]	Australian full-time workers ($n = 1235$; mean ± SD age 53 ± 7 years)	Cross-sectional	Self-reported using the question: 'Estimate the total time during the last week that you spent sitting down as part of your job while at work or working from home, including meal and snack breaks, sitting to do work such as at desk or in meetings, sitting to use the computer at work and sitting for travel as part of work such as being a taxi driver?' and expressed in hours/day	BMI calculated from measured height and weight	In the unadjusted analysis, no significant associations were found between BMI (entered to the model as a continuous variable) and categories of occupational sitting (high sitting = above median; low sitting = below median).
Honda et al. [55]	Japanese full-time office workers aged 20–64 years ($n = 823$)	Cross-sectional	Self-reported using the Japan Arteriosclerosis Longitudinal Study Physical Activity Questionnaire (JALSPAQ) and categorized as 'almost all the time', 'more than half of working hours', 'approximately half of working hours', 'less than half of working hours' and 'almost none of the time'	BMI calculated from measured height and weight; measured waist circumference	In the unadjusted analysis, no significant relationship was found between BMI or waist circumference (entered to the model as continuous variables) and categories of occupational sitting time.
Kazi et al. [56]	UK employees in education, local government, retail, telecoms and service industry ($n = 1141$; mean age 38 years)	Cross-sectional	Self-reported using the Domain-Specific Sitting Time Questionnaire (D-SSTQ) and expressed in minutes/day	BMI calculated from self-reported height and weight	A significant positive Spearman's rank correlation was found between BMI (analyzed as a continuous variable) and occupational sitting time ($p < 0.05$). No significant differences were found between 'normal-weight', overweight and obese employees in occupational sitting time.
Kim et al. [57]	Korean male office workers ($n = 84$)	Cross-sectional	Physical activity diary over two weekdays and one weekend day	BMI calculated from measured height and weight	In the unadjusted analysis, overweight/obese workers had significantly higher sedentary work time than 'normal-weight' workers ($p < 0.001$). A significant positive correlation was found between sedentary work time and BMI.

Table 2 (continued)

Study	Sample	Study design	Measures of occupational sedentarism	Weight-related measures	Main findings
Lin et al. [58]	US workers aged 38–45 years ($n = 5285$)	Prospective cohort (8-year follow-up)	Self-reported using the question 'How much time in your current job do you spend sitting?' with response options: 'never', 'less than half of the time', 'about half of the time', 'more than half of the time' and 'continuously or almost continuously'	BMI calculated from self-reported height and weight	In the adjusted analysis, workplace sitting time was positively related to BMI in male workers ($\beta = 0.086$, $p < 0.01$), but not in female workers.
Nicholas et al. [59]	Canadian full-time workers aged 35–69 years ($n = 12{,}409$)	Cross-sectional	Self-reported time (h/day) sedentary behaviour defined as time in activities with MET values of ≤1.5	BMI calculated from self-measured height and weight; self-measured waist circumference; waist to hip ratio calculated from self-measured waist and hip circumferences	In the adjusted analyses, >5 h/day of occupational sitting was associated with higher waist circumference and waist to hip ratio among male workers (OR = 1.46, 95 % CI 1.17–1.83 and OR = 1.34, 95 % CI 1.00–1.79, respectively). Among females, no significant association between occupational sitting and waist circumference was found. Female workers who sat >5 h/day were less likely to have high waist to hip ratio than those reporting 0 h of sitting per day. Mixed associations were found between occupational sitting and BMI categories.
Picavet et al. [60]	Workers from Doetinchem, Netherlands ($n = 1509$)	Prospective cohort (five examinations over 15 years of follow-up)	Self-reported usual activity at work (response options: 'mainly sedentary', 'mainly standing', 'manual' and 'involving high physical loads'); in the fifth round of follow-up, also self-reported number of hours/day of occupational sitting	BMI calculated from measured height and weight	In the adjusted analysis, no significant association was found between BMI (entered to the model as a continuous variable) and 'stable' occupational sitting (over the follow-up period). A separate analysis of round 5 data showed no significant cross-sectional association between BMI and hours/day of occupational sitting.
Pulsford et al. [61]	Civil servants from London, UK ($n = 7830$)	Prospective cohort (15–19 years of follow-up)	Self-reported using the question 'On average, how many hours per week do you spend sitting at work?'	BMI calculated from measured height and weight	In the adjusted analyses, no cross-sectional or prospective associations were found between occupational sitting time and obesity. Prior obesity was not prospectively associated with subsequent occupational sitting time.
Ryde et al. [62]	Full-time office workers from Brisbane, Australia ($n = 151$)	Cross-sectional	Sitting time measured using a pressure-sensitive sitting pad, categorized into 'high-desk-based sitting time' (above median) and 'low-desk-based sitting time' (below median)	BMI calculated from measured height and weight; measured waist circumference	The unadjusted analysis showed significantly higher BMI ($p = 0.02$) and waist circumference ($p = 0.01$) among 'high sitters' when compared to 'low sitters'. In the age- and gender-adjusted models, being a 'high sitter' was significantly associated with obesity (OR = 8.95,

Table 2 (continued)

Study	Sample	Study design	Measures of occupational sedentarism	Weight-related measures	Main findings
					1.87–42.85) and high waist circumference (OR = 2.69, 95 % CI 1.17–6.19).
Saidj et al. [63]	Workers from the greater Copenhagen area, Denmark, aged 18–69 years (*n* = 2544)	Cross-sectional	Self-reported using the question 'During work, how many hours and minutes per day do you engage in sedentary work' from the Physical Activity Scale 2 (PAS2) and expressed in hours/day	BMI calculated from measured height and weight; measured waist circumference; percentage of body fat estimated by bioelectrical impedance using scale TBF-300 (Tanita Corp., Japan)	In the adjusted analyses, occupational sitting time showed no significant associations with BMI ($p = 0.08$), waist circumference ($p = 0.08$) and body fat percentage ($p = 0.26$).
Yang et al. [64]	Inhabitants of the Missouri metropolitan area, USA, aged 21–65 years (*n* = 1891)	Cross-sectional	Self-reported occupational sitting time using the item 'Please estimate how many hours you spent sitting each day while at work' and categorized into fourths	BMI calculated from self-reported height and weight	In the adjusted analysis, odds ratios for being classified as obese were significantly higher for female workers reporting 31–180 min/day (OR = 1.53, 95 % CI 1.02–2.31), 181–360 min/day (OR = 1.90, 95 % CI 1.23–2.94) and >360 min/day (OR = 1.70, 95 % CI 1.08–2.67) of occupational sitting when compared to the reference group (≤30 min of occupational sitting/day). No significant associations between occupational sitting time and obesity were found in male workers.

B unstandardized regression coefficient, β standardized regression coefficient, *BMI* body mass index, *OR* odds ratio, *p* p value, *PR* prevalence ratio, *RR* relative risk *CI* confidence interval, *FF* firefighters, *n/a* not available

In two out of four prospective cohort studies, there was no significant association between sedentary work and subsequent obesity [61] or BMI [60]. The other two studies reported contrasting results; Lin et al. [58] found a significant positive relationship between workplace sitting time and BMI only in men, whilst Eriksen et al. [52] found a significant relationship between these variables only among women. Interestingly, a recent prospective study presented evidence supporting reverse causation, i.e., that higher BMI at baseline elevates the risk of later increase in total sitting time (including sitting at work and outside work) [65]. Pulsford et al. [61], however, did not find a significant association between prior obesity and subsequent occupational sitting time. Hence, it may be that the reverse causality only exists between obesity and total or non-occupational sitting time.

The evidence presented here and in the previous review [43•] does not seem to strongly support the hypothesized association between sedentary work and obesity. The conceptual models that include sedentary work as one of the main occupational risk factors for obesity [66] may need to be revised to account for mostly null findings presented in the current review. A rather modest difference between energy costs of sitting and standing [67, 68] implies that simply replacing sitting at work by standing is unlikely to help prevent or manage obesity. This somewhat explains the lack of association between occupational sitting and overweight/obesity. To provide stronger evidence about the association between sedentary work and obesity, future studies should use longitudinal study design and objective measures of occupational sitting time (e.g., inclinometers, pressure-sensitive sitting pads). To allow for adequate adjustments for physical activity (both during occupational time and outside of work hours), future studies may also need to consider using compositional data analyses according to the recently proposed activity balance (AB) model [69].

Obesity and Workplace Productivity

Excess weight may lead to functional limitations and impaired quality of life [2]. Thus, obesity and overweight may increase utilization of healthcare services and negatively influence work ability and productivity. The economic burden, i.e., the costs of illness, includes both direct costs (healthcare costs) and indirect costs (lost or decreased work productivity) [70]. Indirect costs are non-medical costs to society and include morbidity-related (absenteeism, presenteeism, disability, early retirement) and mortality-related costs (premature death). Indirect costs may occur due to decreases in worker's job performance, as a result of excess weight and work-related characteristics (e.g., high physical loads). In this section, we will focus on morbidity-related costs related to workplace productivity (Table 3).

Workplace productivity can be quantified in several ways. Absenteeism is absence from work because of illness or other factors. Obese and overweight employees tend to have more days of sick leave compared to normal-weight employees, and obese persons tend to have longer duration of individual sick leaves [70, 73, 77]. Somewhat less studied is presenteeism (lost on-the-job productivity), that is, attending work while being ill. This often results in working at reduced capacity and with reduced productivity due to the illness. It is unclear whether or not excess weight increases the risk of presenteeism [70].

The most recent data on both direct and indirect costs of both overweight and obesity have been reviewed by Dee and coworkers [71•], based on a systematic literature search published from 2000 to 2011. They included five studies, which were similar in methodological approaches from Canada, Germany, Sweden, Switzerland and the USA. Indirect costs accounted for 51–59 % of total costs, whilst being the highest in the USA and the lowest in Germany. In another study in the USA, presenteeism accounted for the largest share (56–68 %) of total costs of overweight and obesity [78]. In five European Union countries, indirect costs of overweight and obesity were assessed using a questionnaire on work and activity impairment [79]. The study suggested that overall work impairment (i.e., absenteeism, presenteeism and productivity loss) increased with increased BMI.

A review by Neovius et al. [72] suggested a strong J-shaped association between BMI and disability pension, with the risk starting to rise exponentially with BMI of more than 25 kg/m^2. The risk is clearly increased for obese employees with musculoskeletal, cardiovascular and mental disorders [72]. In a prospective cohort study of Finnish twins, BMI was found to be an early predictor of disability pensions due to musculoskeletal diseases [80].

In addition to disability pension, premature exit from paid employment (displacement from the labour market) can take place through early retirement or termination of employment initiated by the employer. However, there is limited evidence that obesity is associated with unemployment or early retirement [74].

Workplace-Based Interventions to Reduce Obesity and Overweight and to Improve Productivity

In recent years, the workplace has been identified as a potential avenue through which high-risk individuals may be identified and interventions may be implemented to reduce obesity and overweight. This has the potential to be beneficial not only to individual employees, but also to employers in improving productivity and reducing indirect costs due to excess weight. To date, a number of studies have been conducted to test a variety of workplace interventions with the aim to reduce obesity and overweight, but few have concentrated on productivity. These interventions generally focused on increasing physical activity and decreasing sedentary time both at work and during leisure, and/or improving nutrition, and have been implemented in various combinations, sometimes with financial incentive (Table 4). Interventions, to date, have been conducted at multiple levels, either targeted at the individual or at a higher level by intervening on the work unit or organization as a whole [91].

Several systematic reviews have focused on workplace-based interventions with primary outcomes that are closely related to obesity. In 2014, Malik et al. conducted a systematic review of workplace interventions aimed specifically at increasing physical activity either at work or during leisure time [81]. The included studies assessed targeted exercise interventions, counselling or behavioural support, or health promotion messages or information. Results were mixed, with 32 of 58 studies reporting a statistically significant increase in physical activity from baseline to follow-up. Several methodological limitations were common across studies, including the use of only self-report measures of physical activity and inclusion of multiple heterogeneous components of interventions with varying levels of participants' adherence, making it difficult to conclude which aspects were effective at promoting behaviour change. Shrestha et al. [82] reviewed the interventions aimed specifically at reducing sitting at work in desk-based workers. The 20 studies included assessed the effectiveness of modified desks (e.g. sit-stand desks), walking during breaks, educational information and counselling and multi-pronged interventions in reducing sitting behaviour at work. In six studies, it was found that sit-stand desks reduced the time spent sitting at work on average by half an hour to 2 h at short-term (less than 3 months) follow-up, with no adverse effects. However, the quality of evidence from the reviewed studies was low. Replacing 2 h of sitting with standing using sit-stand desks might not be enough to lose excess weight for overweight or obese employees or to prevent weight gain. The effects of other types of interventions on reducing sitting time at work were inconsistent or non-significant. In a more recent cluster randomized controlled trial (RCT), Danquah et al. [83] reported a reduction in body fat percentage by 0.6 % ($p = 0.011$) in a multi-component intervention group that used sit-stand desks, compared to the control group. While this reduction is statistically

Table 3 Studies on obesity and work productivity

Review ID	Characteristics of review	Measures of economic burden	Main findings
Dee at al. [71•]	7 studies included in qualitative synthesis, and 5 studies included in quantitative synthesis	Direct costs and indirect costs: sick leave, early retirement, disability, absenteeism and presenteeism, premature mortality	Healthcare costs increase as BMI increases and so do costs associated with lost productivity. The costs associated with lost production are higher than direct healthcare costs.
Neovius et al. [72]	16 studies included, three cross-sectional, eight longitudinal, five interventional	Disability pension, long-term sick leave, working status, insurance status	BMI was significantly associated with disability pension, but the direction of causality may vary with underlying cause. Interventions had positive productivity effects in the morbidly obese, but whether this holds for the overweight remains to be proven
Neovius et al. [73]	36 non-intervention studies and intervention studies	Frequency of sick leave, work time lost due to sick leave	A clear trend towards greater sick leave among obese compared with normal-weight workers. Substantial weight loss in obese subjects resulted in reduced sick leave, at least temporarily.
Robroek et al. [74]	28 studies Appraisal of study quality	Disability pension, unemployment and early retirement	Obese [relative risk (RR) = 1.53] and overweight (RR = 1.16) individuals had an increased likelihood of exit from paid employment through disability pension but were not at statistically significant increased risk for unemployment or early retirement.
Schmier et al. [75]	8 studies	Absenteeism, sick leave, disability	Overweight or obese employees had higher sick leave or disability use. Healthcare costs were also consistently higher for employees with higher body mass indices.
Trogdon et al. [76]	31 studies; cohort (7 studies), cross-sectional (12 studies), aetiologic fraction (10 studies) and non-traditional designs (2 studies).	Absenteeism, disability, premature mortality, presenteeism, workers' compensation and total indirect costs	Compared with non-obese workers, obese workers miss more workdays due to illness, injury or disability. Costs of premature mortality vary substantially across countries. The results for presenteeism and workers' compensation were mixed.
van Duijvenbode et al. [77]	13 studies Appraisal of study quality	Sick leave	Inconclusive evidence for a relationship between overweight and sick leave but strong evidence for positive relation between obesity and sick leave

significant, the small absolute reduction in body fat percentage has limited clinical relevance. Some evidence indicates that frequent breaks in sitting time may be beneficially associated with BMI and waist circumference [92] independent of total sedentary time, but more research is needed to examine this hypothesis specifically in the occupational setting.

Three recent reviews have been conducted to summarize the effects of workplace weight management interventions. In the most recent review, Weerasekara et al. [93•] identified 23 randomized interventions consisting primarily of nutrition and/or physical activity. All but two interventions reported a decrease in body weight and BMI at 6 or 12 months, but the effect was statistically significant only in three studies [93•]. Of ten studies reviewed by Ausburn et al. [84], five studies used a combination of physical activity, diet and health education materials, three studies tested interventions targeting both physical activity and diet, one focused on increasing physical activity, and one focused on increasing physical activity and health education materials (for physical activity promotion and other health-related information) [84]. The authors concluded that the inclusion of education materials was essential for weight management programs and that modification of the work environment (such as providing healthier food choices in vending machines, introducing 'healthy' cafeteria menus) and weight loss competitions may be the most effective strategies for reducing obesity in the workplace. In another review published in 2009, Anderson et al. conducted a meta-analysis to assess the effectiveness of worksite nutrition and physical activity programs to promote healthy weight among employees [85]. Based on nine RCTs, a modest but statistically significant reduction in body weight was found after 6–12 months of the interventions (on average −1.3 kg, 95 % CI −1.3, −0.5).

Despite the growing evidence on the association between obesity and workplace productivity, only few

Table 4 Summary of reviewed studies addressing worksite health promotion programs and their effect on productivity

Study/review	Type of study	Interventions	Outcome	Results
Malik et al. [81]	Systematic review 58 studies Appraisal of study quality	Targeted exercise interventions, counselling or behavioural support interventions, or health promotion messages/information interventions	Physical activity at work	Mixed results, with 32 of 58 studies reporting a significant increase in physical activity from baseline to follow-up
Shrestha et al. [82]	Systematic review and meta-analysis 20 studies Appraisal of study quality	Changes in desks, walking during breaks, information and counselling and multiple category interventions	Time spent sitting at work	Sit-stand desks reduced sitting at work between half an hour and 2 h (6 studies). Low-quality evidence
Danquah et al. [83]	Cluster RCT for 3 months $n = 317$	Appointment of local ambassadors, management support, environmental changes (high meeting tables in meeting rooms, offices and corridors and routes for walking meetings), a lecture and a workshop.	Time spent sitting (at work and leisure), body weight, fat mass, fat-free mass and body fat percentage using a scale-type BC-418 MA (Tanita Corp., Tokyo, Japan)	Total sitting time was reduced by 48 min at 3 months follow-up. The body fat percentage was lower by 0.61 percentage points.
Ausburn et al. [84]	Systematic review 10 studies Appraisal of study quality	Workplace-based interventions on physical activity, diet and health education materials	Body weight	Inclusion of education materials is essential for any weight management program. Modification of the work environment and weight loss competitions may be the most effective approach to reduce obesity.
Anderson et al. [85]	Systematic review and meta-analysis 47 studies Appraisal of study quality	Workplace-based physical activity or nutrition interventions	Body weight, body mass index (BMI) and percent body fat	A modest reduction in weight in 9 RCTs (−1.3 kg, 95 % CI −1.3, −0.5)
Bilger et al. [86]	Secondary analysis on pooled data from two RCTs $n = 1868$	Weight loss intervention for overweight and obese employees	Absenteeism and presenteeism	A non-statistically (but marginally) significant reduction in absenteeism by 0.26 days per month and low presenteeism in those who achieved a clinically meaningful weight reduction of 5 % compared to those who did not
Harden et al. [87]	Secondary analysis of RCT $n = 1030$	Internet-based weight loss program for overweight and obese employees	Absenteeism and presenteeism	No differences in absenteeism or presenteeism in those lost >5 % of weight compared to those who did not
Morgan et al. [88]	Cluster RCT for 14 weeks $n = 110$	Weight loss intervention including an education session, interactive study website, pedometer and financial incentives for overweight and obese male employees	Body weight, absenteeism and presenteeism	4.4-kg difference in weight loss between the intervention and control group A significant improvement in presenteeism and reduction in absenteeism
Meenan et al. [89]	Cluster RCT for 2 years $n = 11,559$	Multi-component weight loss intervention	BMI, waist to hip ratio and absenteeism	A significant decrease in BMI Increase in absenteeism
Gussenhoven et al. [90]	RCT $n = 1386$	Educational modules on physical activity, nutrition and behaviour change	Bodyweight, sick leave costs and productivity	No effect on weight or productivity

studies have examined the effects of a weight loss intervention on productivity-related outcomes. Most often, weight loss intervention studies have included productivity measures as secondary outcomes. Bilger et al. pooled the results from two RCTs of 12-month weight loss interventions to compare their effects on absenteeism and presenteeism in those who lost weight and those who did not [86]. Among those who lost a clinically significant >5 % of body weight, a significant reduction in absenteeism of 0.26 days per month was observed. There was a non-significant effect on presenteeism. Harden et al. [87] also conducted a secondary analysis in an RCT of an internet-based weight loss program in overweight employees. In the primary intention-to-treat analysis, there was no difference in absenteeism or presenteeism in the intervention compared to the control group. In the secondary analysis, favourable differences in both outcomes were observed in those who lost >5 % of their body weight compared to those who did not [87]. It is important to note that both these studies were not initially designed to examine the association between weight loss and productivity; thus, they may not have been adequately powered. Conducting a secondary analysis by pooling the study groups and comparing them by weight loss status also ignores the benefits of the randomized design; thus, these findings should be interpreted with caution.

Other weight loss intervention studies that have included measures of work productivity have produced variable findings. In a single-group retrospective cohort study examining the effects of a multi-tiered health benefit plan including changes to the work schedule and environment, along with access to a wellness coach and educational materials and financial incentives and reimbursement for physical activity, Guo et al. found a significant decrease in the prevalence of obesity over time (−4.8 % on average each year), with a simultaneous increase in self-reported job performance and decreased absenteeism in the past 28 days [94]. In a cluster RCT of male employees taking part in a multi-pronged 14-week weight loss intervention (including an education session, interactive study website, pedometer and financial incentives), a significant mean difference in weight of 4.4 kg between the intervention and control group was observed, along with a significant improvement in presenteeism and reduction in absenteeism over the past 3 months [88]. In another cluster RCT of a 2-year multi-component weight loss intervention, Meenan et al. observed a significant decrease in BMI and waist to hip ratio in the intensive intervention vs. the comparison group. However, they found an unexpected increase in employee absenteeism [89]. Finally, Gussenhoven et al. conducted a three-arm RCT consisting of ten educational modules based on cognitive behavioural theory, focused on physical activity, nutrition and behaviour change either delivered over the internet or by a personal coach [90]. No change in sick leave costs or productivity was observed at 12-month follow-up. Importantly, the study did not find a significant difference in the change in weight amongst the three groups, suggesting no effect of the intervention itself, rather than no effect of weight loss on productivity.

Conclusion

Despite some inconsistencies in findings, there is convincing evidence that shift work increases the risk of obesity, while most studies did not show a significant association between sedentary work and obesity. More longitudinal research using objective measures of occupational sitting and adequate adjustments for physical activity (both at work and during leisure) is needed to draw sound conclusions about whether or not sedentary work is associated with the risk of obesity. The indirect costs of obesity may have great implications for the workplace, and strategies to minimize obesity may be of particular interest to employers. Overweight and obesity were found to be associated with absenteeism, disability pension and overall work impairment, whilst evidence of their relationship with presenteeism, unemployment and early retirement was not consistent. Workplace interventions have been designed to address obesity and productivity. However, due to the vast heterogeneity in the types of interventions employed across a variety of study populations with different working and overweight status, currently, there is no consensus on best practice recommendations for workplace-based interventions that aim to prevent or reduce obesity or overweight. However, these interventions might address some of the outcomes other than obesity like sick leave or work productivity. The literature, to date, suggests that a change in both diet and in physical activity at work or during leisure is needed to influence obesity and, thus, workplace productivity. In order to achieve this goal, a multi-component approach is most likely needed.

Compliance with Ethical Standards

Conflict of Interest Nipun Shrestha has received financial support through a VU Research Scholarship 2016 from Victoria University.

Zeljko Pedisic declares that he has no conflict of interest.

Sarah Neil-Sztramko has received financial support through a Doctoral Student Award and Postdoctoral Fellowship from the Canadian Institutes of Health Research.

Katriina T. Kukkonen-Harjula declares that she has no conflict of interest.

Veerle Hermans declares that she has no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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