Shift work and risk factors for cardiovascular disease: a study at age 45 years in the 1958 British birth cohort

Claudia Thomas, Chris Power

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CARDIOVASCULAR DISEASE

Shift work and risk factors for cardiovascular disease: a study at age 45 years in the 1958 British birth cohort

Claudia Thomas · Chris Power

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Abstract This study examined associations between exposure to shift-work and risk factors for cardiovascular disease (CVD) and whether the associations are explained by socio-economic circumstances, occupational factors or health behaviours. Biological risk factors for CVD were measured in 7,839 participants of the 1958 British birth cohort at age 45 years who were in paid employment. Regular ($\geq$1/week) shift-workers included 46% working evenings (1800–2200), 28% weekends, 13% nights (2200–0400) and 14% early mornings (0400–0700). Adverse levels of several CVD risk factors were found in association with increasing participation in any shift-work. Men regularly working all four shift-work types had increased CVD risk factors of approximately 0.1–0.2 standard deviations (e.g. 0.8 kg/m^2 for body mass index; 1.2 cm for waist circumference) than those not regularly working shifts; for women, there was a positive linear trend for triglyceride levels, but a negative trend for diastolic blood pressure. Separate analyses of shift-work types showed associations primarily for night/morning working rather than evening/weekend working. Men had adverse levels of all CVD risk factors except blood pressure and total-cholesterol in association with night or early morning work and women had adverse triglyceride levels. Adjustment for socioeconomic, occupational factors and health behaviours explained most associations except for adiposity and C-reactive protein. Our results highlight night and early morning working associations with an adverse profile of CVD risk factors, which are partly explained by socioeconomic, other occupational factors and health behaviours.

Keywords Cardiovascular disease · Cohort studies · Employment · Shift work · Work hours

Abbreviations

BMI	Body mass index
CHD	Coronary heart disease
CI	Confidence interval
CRP	C-reactive protein
CVD	Cardiovascular disease
HbA1c	Glycosylated haemoglobin
HDL	High density lipoprotein
SD	Standard deviation
UK	United Kingdom
WC	Waist circumference

Introduction

Understanding the links between exposures in the workplace, such as shift-work, and cardiovascular disease (CVD) is essential to tackling socioeconomic inequalities in health [1]. Not only being in work but experiencing good working conditions are vital for health and well-being [2, 3].

More than 3.5 million people are employed as shift-workers in the UK [4]. Although most research on the health consequences of shift-work focuses on night or

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C. Thomas · C. Power
MRC Centre for Epidemiology of Child Health, UCL Institute of Child Health, 30 Guilford Street, London, UK

C. Thomas (✉)
Division of Population Health Sciences and Education, St Georges University of London, Cranmer Terrace, London SW17 0RE, UK
e-mail: clthomas@sgul.ac.uk

rotating shift-work, by definition shift-work includes employment outside of standard working hours such as evening and weekend work [5]. Approximately 20% of industrialised populations are required to work outside the standard 8 a.m. to 5 p.m. working day and this percentage is forecast to increase as demand grows for the provision of goods and services around the clock [6]. Night-work is estimated to increase the risk of coronary heart disease (CHD) by 40% [7]. Adverse changes have also been reported for a range of CVD risk factors although findings are inconsistent due to methodological differences [8–19].

It is unclear why shift-work is associated with increased CVD risk. Several pathways have been suggested including: disturbed circadian rhythms resulting in sleep deprivation and desynchronisation of metabolic processes; neuroendocrine effects of stress arising from the nature of night-work or through social and domestic problems arising from working anti-social hours; and behavioural changes (e.g. diet and smoking) related to stress and/or a consequence of working conditions [20]. The specific pathways involved may depend on the type of shift-work undertaken. For example, night-work may be more strongly related to circadian disruption whereas evening or weekend work may be more closely related to social disruption [20]. To date supporting evidence is lacking on the proposed pathways, although several studies have found poorer health behaviours among night-workers compared to day-workers [10, 21, 22]. We aim to improve understanding of the relationship between shift-work and biological risk markers for CVD in employed British adults. The objectives are to establish whether (1) different types (night, early mornings, evening, weekend) and total burden of shift-work are associated with risk factors for CVD at age 45 years; (2) associations are explained by socio-economic circumstances, occupational factors and health behaviours.

Methods

Study sample and design

Data are mainly from the 45 years and 42 years surveys of the 1958 British birth cohort. The cohort consists of 18,558 individuals: born in one week in March 1958 in England, Scotland and Wales (17,638) with the addition of immigrants ($n = 920$) with the same birth dates up to age 16 years [23]. At 45 years, 11,971 cohort members who had not died or emigrated, were still in contact with the survey, and who were able to provide informed consent were invited to a clinical examination undertaken in their home by a trained nurse; 9,377 (78%) participated. Ethical approval for the 45 years follow-up was given by the South East Multi-Centre Research Ethics Committee. Information from earlier contacts with the cohort was used as described below for shift-work (at 42 years), potential confounding and mediating factors (42 years) and to allow for sample attrition (birth and 7 years). Analyses presented here are based on 7,839 cohort members participating in the clinical evaluation at 45 years and who were in paid employment at 42 years.

Measurement of CVD risk factors

All outcome measurements were taken by nurses using standardised protocols at 45 years. Blood pressure was measured three times using an Omron 705CP automated sphygmomanometer (Omron, Tokyo, Japan). Mean systolic (SBP) and diastolic blood pressure (DBP) were calculated from the measures obtained that the nurses reported to be reliable. Non-fasted venous blood samples were obtained. Glycosylated haemoglobin (HbA1c) was assayed by ion exchange high performance liquid chromatography on whole blood (Tosoh A1c2.2 Glycohemoglobin Analyser, HLC-723GHb, Tosoh Corp, Tokyo, Japan). Triglycerides, total and high density lipoprotein (HDL) cholesterol were measured by autoanalyser. Fibrinogen was measured by the Clauss assay in an MDA-180 automated coagulometer (Biomerieux, Basingstoke). Fibrinogen values >5.62 g/l ($n = 9$) were excluded due to the potential for distortion from assay imprecision and from acute-phase reactions [24]. C-reactive protein (CRP) was measured on citrated plasma by high-sensitivity nephelometric analysis of latex particles coated with CRP-monoclonal antibodies. CRP values >10 mg/l ($n = 154$) indicating acute inflammation, e.g. due to infection, were excluded [25]. Standing height was measured using a Leicester portable stadiometer and weight was measured to the nearest 0.1 kg. Self reported weight or height was recorded when accurate measurements or consent for measurement were not available. Body mass index (BMI) was calculated as kg/m^2. Waist circumference (WC) was measured midway between the costal margin and iliac crest.

Measurement of shift-work

Participants reported the frequency of working at night (2200–0400), early mornings (0400–0700), evenings (1800–2200) and weekends (Saturday or Sunday) in their main job at 42 years as "never" "less often than once a month", "at least once a month", and "at least once a week" (meaning every weekend in the case of weekend work). "Any shift-work" was defined as any regular employment (≥once/week) outside the hours of 0700–1800 [5].

Covariates

Factors associated with CVD and shift-work were included in the analyses as confounders. These included the number of hours worked per week in the participant's main job, whether the participant was self-employed or an employee and socio-economic position (SEP) using the Registrar General's Social Class, and grouped as I&II, III non-manual, III manual, IV&V.

Information on health behaviours at 42 years was included as mediators of associations between shift-work and risk factors for CVD. Smoking was coded in four categories from never or ex-smoker to current smoker of ≥20 cigarettes/day. Frequency of alcohol consumption was analysed using five categories from never or rarely to most days. For diet, participants reported consumption of chips, fried food, and fruit and vegetables, categorised as never, <1, 1–2 or ≥3 days/week. Frequency of leisure activity ranged from <2–3 times/month to 4–7 days/week. Full details on measurement of diet and physical activity have been reported previously [26].

Data analysis

Associations between risk factors for CVD and shift-work exposure were analysed using multiple linear regression. The distributions for triglycerides and CRP were positively skewed therefore natural log transformations were used; geometric means and standard deviations are presented. Geometric means are also presented for HbA1c, but regression analyses use untransformed data with robust standard errors as the assumption of constant error variance could not be met with transformation [27]. For regression models, all CVD risk factors were converted to standard deviation scores (mean = 0, SD = 1) in order to facilitate comparison across outcomes.

Total burden of shift work participation was analysed by summing the number of shift-work types worked ≥1/week (0–4). For analyses of different shift work types we conducted exploratory analyses for all four shift-work types separately. These exploratory analyses revealed similar associations with CVD risk factors for night and early morning work; likewise relationships were similar for evening and weekend work. Therefore, indices of regular (≥1/week) night/early morning (0–2) and evening/weekend (0–2) work were calculated to isolate potential circadian effects of shift-work [20]. Shift-work variables were modeled as categorical (coefficients represent the difference in mean levels of the outcome for number of regular shift-work types relative to the baseline category) and continuous variables (linear trends across shift work categories for each additional increase in shift-work type).

Men and women were analysed separately as there were gender differences in shift work participation and levels of CVD risk factors (Table 1). Models were adjusted for (1) confounding factors: SEP, hours worked/week, employee or self-employed (plus night/morning or evening/weekend index for evening/weekend and night/morning models, respectively); (2) health behaviours: smoking status, alcohol consumption, diet, physical activity and adiposity (CVD risk factors except BMI and WC); (3) confounding factors plus health behaviours (and adiposity as before).

We investigated the effects of factors that could influence measurement of outcomes on shift-work/CVD risk factor associations. We examined adjustments for diabetes medication for analyses of HbA1c, anti-hypertensive medication for blood pressure, and lipid regulating medication for lipids. We also examined adjustments for time of day, delay in the laboratory receiving the blood sample, month of nurse visit, recent food consumption, type of flooring, air temperature. Final models included adjustments for time of day (blood pressure and triglycerides), type 1 diabetes and treatment for type 2 diabetes (HbA1c).

The sample with complete data on CVD risk factor outcomes, shift-work, confounding and mediating factors ranged from 6,775 (BMI) to 5,486 (CRP). Previous work has demonstrated that attrition has resulted in moderate under-representation of specific groups in the 45 years survey, including those from families with no male head and those with childhood behavioural or cognitive problems [28]. Analyses were repeated using inverse probability weighting to assess bias due to attrition, however, results were similar and unweighted results are presented. Analyses were undertaken using STATA version 10.1 (StataCorp, Texas).

Results

Men had less favourable levels of all risk factors for CVD compared to women except for CRP and were also more likely to undertake shift-work (Table 1). Evening work (1800–2200) was most common for both men and women (54 and 37%, respectively), while men were more likely to participate in all forms of shift-work. Approximately 50% of those working nights also worked early mornings, while 94 and 75% of night and morning workers, respectively, also worked evenings (Supplementary Table 1).

Most shift-work types were associated with risky health behaviours with a few notable exceptions (Table 2). There was no difference in the percentage of evening workers who smoked. Lack of exercise was associated only with weekend work, and frequency of fried food and chip consumption was not always consistently related to shift-work. Alcohol consumption was higher for evening and weekend, but not for night or morning work.

First for total burden of shift-work, Fig. 1 presents differences in CVD risk factors according to the number of types of regular shift-work. For men, there was a significant positive linear trend between number of shift-work types and BMI, WC, total cholesterol, triglycerides, HbA1c

Table 1 Shift work patterns at 42 years and CVD risk factors at 45 years in 4,141 Male and 3,698 Female Members of the 1958 Cohort

	Men		Women		
	Total *N*	*n* (%)	Total *N*	*n* (%)	*P*-value[b]
Shift work, ≥1/week[a]					
Any shift work, 42 years	4,138	2,710 (65.5)	3,696	1,665 (45.0)	<0.001
Night (2200–0400)		662 (16.0)		368 (10.0)	<0.001
Morning (0400–0700)		776 (18.7)		300 (8.1)	<0.001
Evening (1800–2200)		2,226 (53.8)		1,357 (36.7)	<0.001
Weekend		1,358 (32.8)		864 (23.4)	<0.001
Number shift types worked ≥1/week					
0 (no shift work)		1,428 (34.5)		2,031 (55.0)	
1 type		1,261 (30.5)		865 (23.4)	
2 types		782 (18.9)		474 (12.8)	
3 types		471 (11.4)		228 (6.2)	
4 types (all)		196 (4.7)		98 (2.7)	<0.001
Night/mornings ≥1/week					
0 (no night or morning)		3,056 (73.9)		3,203 (86.7)	
1 (night or morning)		726 (17.5)		318 (8.6)	
2 (night and morning)		356 (8.6)		175 (4.3)	<0.001
Evenings/weekends ≥1/week					
0 (no evening or weekend)		1,552 (37.5)		2,071 (56.0)	
1 (evening or weekend)		1,558 (38.4)		1,029 (27.8)	
2 (evening and weekend)		998 (24.1)		596 (16.1)	<0.001
		Mean (SD)		Mean (SD)	
BMI (kg/m^2)	4,131	27.82 (4.22)	3,687	26.92 (5.47)	<0.001
Waist circumference (cm)	4,114	98.38 (10.94)	3,666	85.26 (12.56)	<0.001
Systolic blood pressure (mmHg)	4,116	132.91 (14.95)	3,659	120.32 (15.50)	<0.001
Diastolic blood pressure (mmHg)	4,116	82.08 (10.39)	3,659	75.59 (10.24)	<0.001
Triglycerides (mmol/l)[c]	3,510	2.08 (1.22)	3,074	1.34 (0.71)	<0.001
Total cholesterol (mmol/l)	3,523	6.07 (1.13)	3,081	5.68 (0.99)	<0.001
HDL-cholesterol (mmol/l)	3,510	1.44 (0.33)	3,079	1.70 (0.40)	<0.001
HbA1c (%)[c]	3,565	5.27 (0.57)	3,120	5.15 (0.47)	<0.001
C-reactive protein (mg/l)[b, d]	3,393	0.91 (0.95)	2,931	0.94 (1.13)	0.19
Fibrinogen (g/l)[e]	3,444	2.86 (0.56)	3,016	3.00 (0.61)	<0.001

BMI body mass index; *HbA1c* glycosylated haemoglobin; *HDL* high density lipoprotein

[a] Outside the hours of 0700 and 1800 or on weekends

[b] *P* values from *t* test or χ^2 test of sex difference as appropriate

[c] Geometric mean (SD)

[d] CRP excludes values >10 mg/l, $n = 154$

[e] Fib excludes values >5.62 g/l, $n = 9$

and CRP levels. Trends for fibrinogen and HDL were non-significant. For those with the heaviest shift-work burden, regularly working all four shift-work types, CVD risk factors were approximately 0.1–0.2 standard deviations (SD) higher than non shift-workers. For example, this equates to an increased BMI and WC of 0.8 kg/m^2 and 1.2 cm, respectively. For women, there was a positive linear trend for triglyceride levels only, but an inverse relationship for DBP. The associations for CVD risk factors were of a similar magnitude, ranging from 0.02 to 0.04 SD per unit increase in number of shift-work types (Table 3). After adjustment effect sizes were reduced, with the greatest attenuation following adjustment for SEP and other work-related factors for all outcomes, except for triglycerides. Adjustment for adult health behaviours had little impact on the associations seen for BMI and WC; the attenuation for lipids and CRP was due to adjustment for adiposity rather than health behaviours (data not shown).

Table 2 Relationships between shift-work, confounding and health behaviour mediating variables at 42 years

	Nights, %		Mornings, %		Evenings, %		Weekends, %	
	<1/week	≥1/week	<1/week	≥1/week	<1/week	≥1/week	<1/week	≥1/week
Self-employed	14.0	18.7***	14.7	14.3	9.5	20.8***	10.8	24.3***
Works >48 h/week	20.1	40.2***	19.7	41.2***	10.6	39.1***	16.2	41.8***
Manual social class	33.8	39.2***	32.0	50.6***	39.8	28.3***	33.5	37.3***
Current smoker	22.1	26.4***	21.6	29.4***	22.8	22.6	21.7	25.3***
Exercises ≤1/week	33.7	34.5	33.6	35.1	33.3	33.2	32.5	37.1***
Fruit and vegetables <once/day	42.2	46.1*	42.0	47.0**	40.4	45.4***	41.1	46.6***
Fried food at least 1/week	45.8	49.2*	46.0	47.9	43.2	49.9***	45.2	48.9**
Chips at least 1/week	43.8	45.9	43.2	49.4***	45.2	42.6*	43.0	46.8**
Drinks most days	20.8	21.2	21.2	18.7	18.4	23.8***	20.2	22.5*

*** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$ (from χ^2 test)

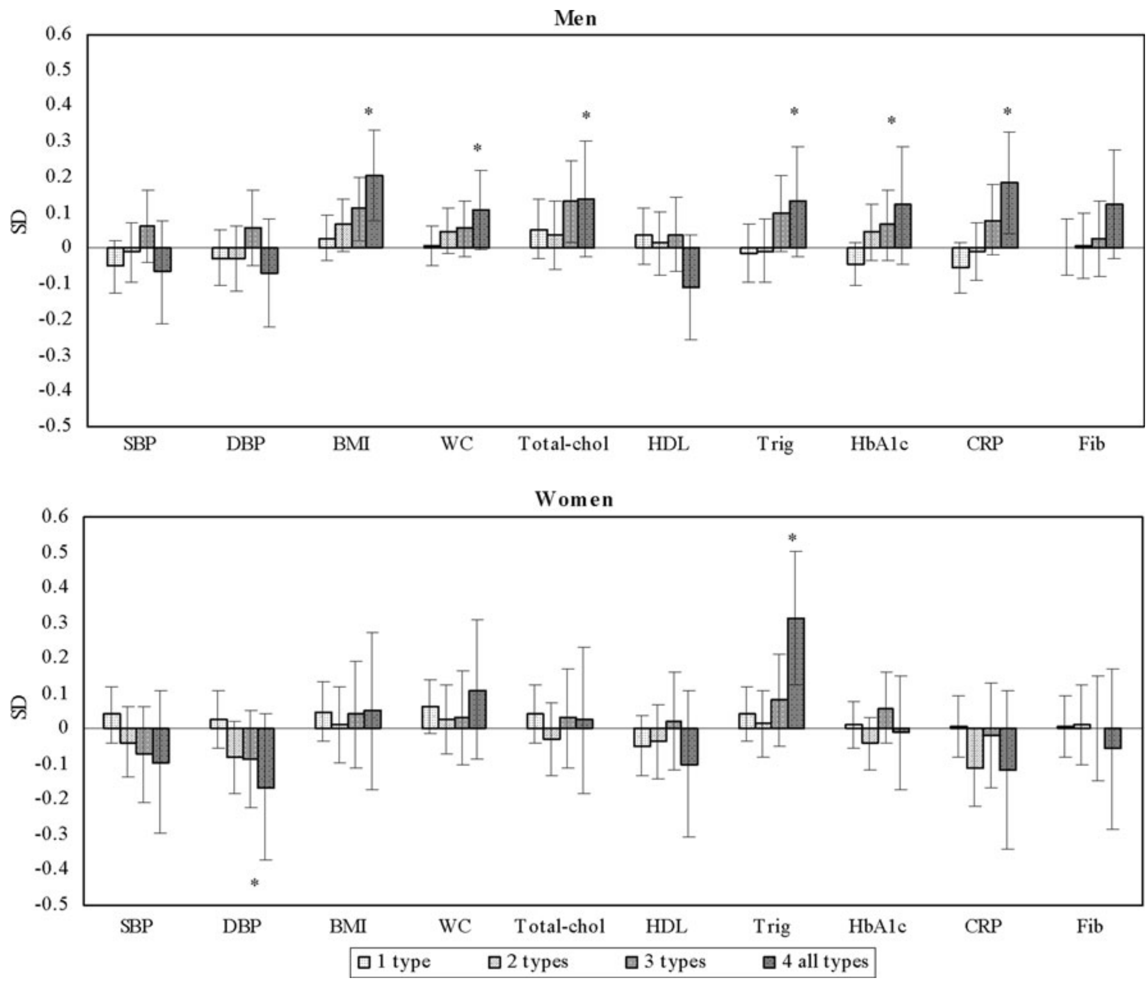

Fig. 1 Differences in CVD risk factor SD scores in association with number of types of regular shift work (nights, early mornings, evenings or weekends ≥1/week). * Trend $P < 0.05$. Vertical bars represent 95% confidence intervals

Next, for separate analyses of night/morning and evening/weekend work, associations were found primarily for the former and few for the latter (Fig. 2). Among men, adverse levels of all CVD risk factors except for blood pressure and total-cholesterol were observed for those working night/early mornings, whereas, BMI and total-cholesterol were significantly elevated in those who worked evenings/weekends. For women, only triglyceride levels

Table 3 Differences in CVD risk factor SD scores (95% CI) per unit increase in number of regular shift types with adjustments for confounders and health behaviours

Outcome	*N*	Unadjusted	Adjustments					
			Confounders[a]	%	Health behaviours[b]	%	All	%
Men								
BMI	4,048	0.042 (0.020, 0.064)	0.025 (0.000, 0.049)	−40	0.045 (0.023, 0.067)	7	0.027 (0.003, 0.051)	−36
WC	4,048	0.024 (0.005, 0.043)	0.011 (−0.011, 0.032)	−54	0.025 (0.006, 0.044)	4	0.013 (−0.008, 0.034)	−46
Total chol	3,453	0.034 (0.006, 0.063)	0.026 (−0.006, 0.057)	−24	0.025 (−0.003, 0.053)	−26	0.023 (−0.008, 0.054)	−32
HbA1c[c]	3,495	0.029 (0.004, 0.054)	0.018 (−0.006, 0.043)	−38	0.018 (−0.006, 0.043)	−38	0.010 (−0.014, 0.034)	−66
Triglyceride[d]	3,441	0.027 (0.000, 0.055)	0.029 (−0.001, 0.059)	7	0.008 (−0.018, 0.033)	−70	0.017 (−0.011, 0.045)	−37
CRP	3,329	0.031 (0.006, 0.056)	0.023 (−0.004, 0.051)	−26	0.011 (−0.011, 0.034)	−65	0.013 (−0.011, 0.038)	−58
Women								
DBP[d]	3,153	−0.033 (−0.064, −0.002)	−0.042 (−0.076, −0.009)	27	−0.041 (−0.071, −0.012)	24	−0.047 (−0.079, −0.015)	42
Triglyceride[d]	3,020	0.038 (0.009, 0.067)	0.049 (0.018, 0.080)	29	0.019 (−0.007, 0.045)	−50	0.027 (−0.001, 0.055)	−29

[a] Social class, total hours worked/week, employee or self employed

[b] Physical activity, diet, smoking and alcohol (plus BMI and WC in non-adiposity models)

[c] Adjusted for diabetes treatment

[d] Adjusted for time of day

were significantly elevated in association with night/early morning work, although effect sizes were similar to those seen in men for BMI, WC, HDL and HbA1c. There was some indication that both night/early morning and evening/weekend work were associated with lower blood pressure in women; furthermore, women regularly working evenings and weekends had reduced CRP levels (associations that were robust to adjustment; data not shown). Table 4 shows that for night/early morning work, adjustments for socio-economic and work-related factors partially explained associations with CVD risk factors except HDL. Adjustment for health behaviours had little impact on measures of adiposity (BMI, WC) but markedly attenuated associations with blood lipids, HbA1c and inflammatory factors. Only BMI, WC and CRP remained significantly elevated in association with night/morning work in men following adjustment. An association between evening/weekend work and BMI in men was no longer evident after allowing for night/morning shift-work (coeff = −0.002, 95%CI = −0.042, 0.037), whereas the association with total cholesterol was reduced by 50% following full adjustment.

Discussion

In this British population sample of 45-year-olds, adverse levels of several risk factors for CVD were observed in association with increasing levels of night and early morning work rather than evening or weekend work. Relationships were explained by socio-economic, other occupational factors and health behaviours for most CVD risk factors examined. More than 50% of study participants reported that they worked non-standard hours at least once per week, mostly in the evenings or at weekends. Similar proportions regularly worked nights or early mornings (approximately 13%). Directly comparable data on the prevalence of shift-work is scarce, in general, however, our population resembles the working population in Britain in respect of the extent to which they worked non-standard hours [29–31].

The main strength of this study is that it uses a large population-based cohort with key advantages over occupational cohorts, namely, that the results are generalisable to the whole working population rather than narrowly defined occupations, and follow-up is not determined by employment status [32]. Few population-based studies have published findings for exposures such as shift-work despite collecting data, while others have less occupational diversity and are therefore limited in generalisability [1]. We also studied different types of shift-work, including evening and weekend work that to date have received little attention, and the availability of frequency data permitted the examination of dose–response relationships. The cohort

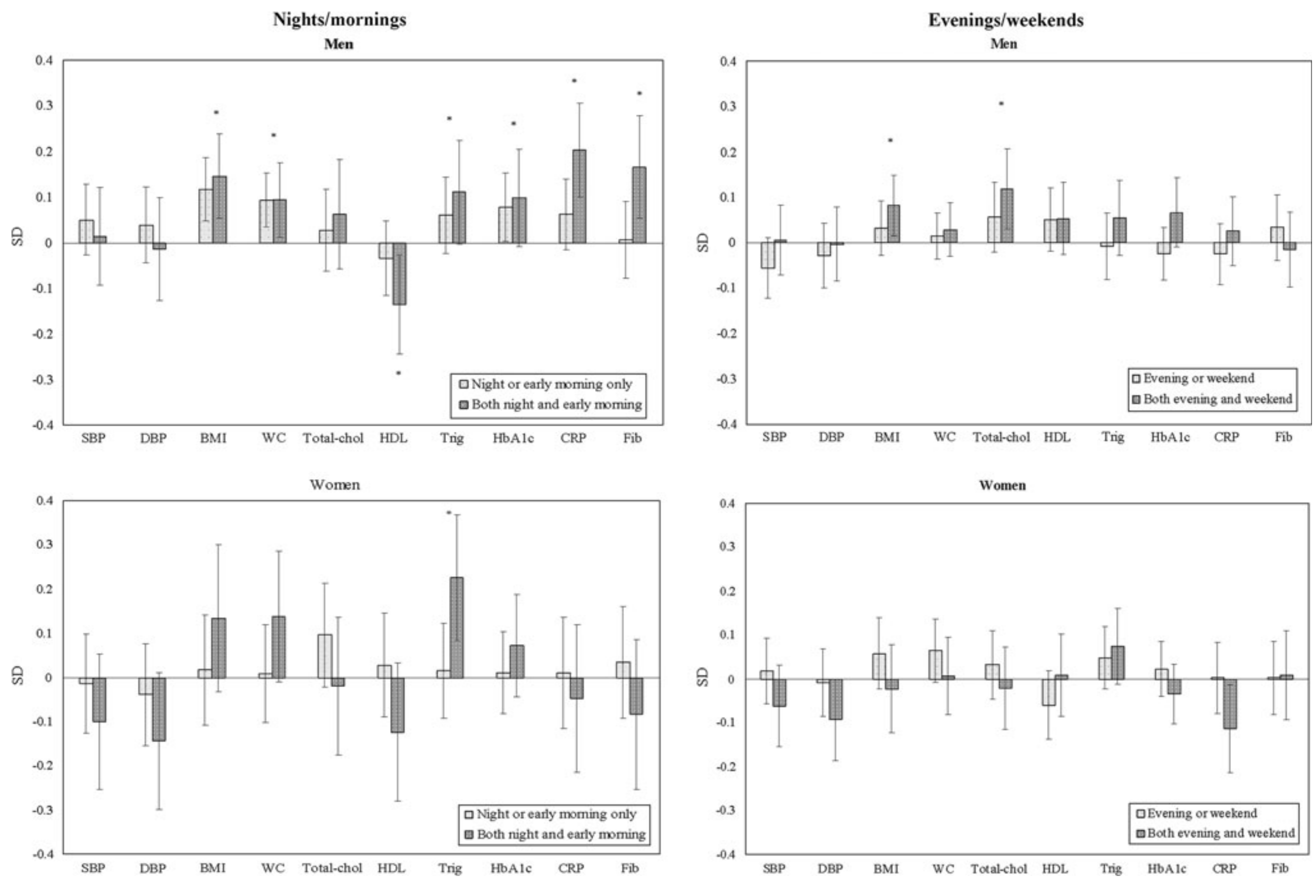

Fig. 2 Differences in CVD risk factor SD scores in association with regular (≥1/week) night/early morning work and evening/weekend work. * Trend $P < 0.05$. Vertical bars represent 95% confidence intervals

also benefits from a range of biological risk factors for CVD measured in mid-adulthood.

The main limitation was that, due to attrition, the sample with complete data was less than half of the original birth cohort, leading to an under-representation of participants from disadvantaged backgrounds [28]. Because associations between work and health may be underestimated in a more advantaged population, analyses were repeated using inverse probability weighting, however, we found that bias was negligible. For practical reasons non-fasted blood samples were obtained, although recent evidence suggests that non-fasted triglyceride levels are independently associated with incident cardiovascular events and may therefore be a better predictor of cardiovascular risk than fasted triglyceride levels [33, 34]. Interpretation of results should take into consideration that individuals only needed to partially participate in the time intervals defining the shift-work types, and therefore may not have worked the whole interval, e.g. an evening worker need not have worked all 4 h between 6 p.m. and 10 p.m.

We studied men and women separately because of their differing cardiovascular risk profiles, as well as patterns of exposure to shift-work. Formal tests of interaction did not detect gender differences in associations between shift-work and CVD risk factors, which could be due to the smaller number of women participating in shift-work. Although the only significant finding for women who regularly undertook night-work was increased triglycerides, associations with adiposity and HDL were of a similar magnitude to those seen for men, suggesting that women may be similarly affected by night-work. Our findings are consistent with those from other population-based studies that have also reported increased adiposity and triglyceride levels in female night-workers [9, 10]. We also found that women regularly working shift-work had lower DBP, thus raising the possibility of selection effects, such that women with hypertension do not undertake shift-work [35]. Selection effects may also explain the lack of association seen for blood pressure in men. Evidence for an association between night-work and blood pressure is generally weak [20]. Effect sizes may be underestimated if selection out of shift-work is related to high blood pressure, which is plausible given the free health assessments offered to night-workers under the European working hours directive [36].

In accordance with previous studies, we found regular night-work to be associated with adverse levels of several

Table 4 Differences in CVD risk factor SD scores (95% CI) per unit increase in night/morning work and evening/weekend work with adjustments for confounders and health behaviours

Outcome	*N*	Unadjusted	Adjustments					
			Confounders[a]	%	Health behaviours[b]	%	All	%
Night/morning work								
Men								
BMI	4,048	0.086 (0.045, 0.126)	0.058 (0.012, 0.103)	−33	0.089 (0.048, 0.129)	3	0.060 (0.015, 0.105)	−30
WC	4,048	0.060 (0.025, 0.096)	0.046 (0.006, 0.085)	−23	0.063 (0.027, 0.098)	5	0.051 (0.011, 0.090)	−15
HDL	3,441	−0.059 (−0.107, −0.011)	−0.076 (−0.130, −0.023)	29	0.006 (−0.038, 0.050)	−110	−0.024 (−0.072, 0.025)	−59
Triglyceride[d]	3,441	0.057 (0.007, 0.107)	0.051 (−0.005, 0.107)	−11	0.014 (−0.033, 0.061)	−75	0.025 (−0.027, 0.077)	−56
HbA1c[c]	3,495	0.057 (0.011, 0.103)	0.025 (−0.023, 0.074)	−56	0.026 (−0.019, 0.070)	−54	0.005 (−0.042, 0.053)	−91
CRP	3,329	0.091 (0.045, 0.136)	0.076 (0.025, 0.126)	−16	0.044 (0.003, 0.085)	−52	0.052 (0.007, 0.098)	−43
Fibrinogen	3,377	0.062 (0.013, 0.111)	0.037 (−0.018, 0.092)	−40	0.014 (−0.033, 0.061)	−77	0.010 (−0.042, 0.062)	−84
Women								
Triglyceride[d]	3,020	0.084 (0.023, 0.146)	0.062 (−0.006, 0.130)	−26	0.043 (−0.012, 0.098)	−49	0.039 (−0.022, 0.100)	−54
Evening/weekend work								
Men								
BMI	4,048	0.040 (0.007, 0.073)	−0.002 (−0.042, 0.037)	−105	0.044 (0.011, 0.078)	10	0.000 (−0.039, 0.040)	100
Total chol	3,453	0.059 (0.015, 0.102)	0.037 (−0.016, 0.089)	−37	0.045 (0.002, 0.088)	−24	0.031 (−0.020, 0.083)	−47

[a] Social class, total hours worked/week, employee or self employed, evening/weekend work index

[b] Physical activity, diet, smoking and alcohol (plus BMI and WC in non-adiposity models)

[c] Adjusted for diabetes treatment

[d] Adjusted for time of day

CVD risk factors in men including adiposity, blood lipids and blood glucose [8–11, 13–15, 18, 19]. An important new finding in our study was the elevated levels of inflammatory factors, CRP and fibrinogen, in association with night-work. We are aware of one small, cross-sectional study of factory workers where no difference in CRP levels between night and day workers was found [37]. Whilst most associations were for night-work and less so for evening/weekend work, the graded association between number of types of shift-work and several CVD risk factors suggests that evening/weekend work may contribute to the overall burden of shift-work. In the case of BMI, the evening/weekend work association was due to the overlap between evening work and night work, and was attenuated once night-work had been taken into account. It has been previously suggested that if night workers are more at risk of CVD than workers of other atypical hours this would implicate the disturbance of metabolic rhythms in the development of CVD in night-workers [20]. However, we found that most associations were explained by socio-economic factors, workplace characteristics, and health behaviours. Associations for non-adiposity CVD risk factors were generally explained by concurrent adiposity and health behaviours, but the association between night-work and adiposity remained significant after adjustment. In this study and elsewhere [10, 21, 22], night-workers were more likely to smoke and have a poorer diet compared to day workers, and yet health behaviours explained little of the associations with adiposity. However, health behaviours at one point in time only were taken into account and may not reflect longer term patterns. Since health behaviours and SEP are closely related, it is possible that some of the longer term influence of health behaviours was accounted for by adjustment for SEP, and in the case of CVD risk factors other than BMI and WC, by adjustment for adiposity. Hence, there is some potential for residual confounding. In addition, the number of years employed in shift-work may influence the extent to which current health behaviours affect disease risk. Alternatively, individuals who work at nights and early mornings may differ with respect to risk factors for CVD before they become shift-workers.

In conclusion, the results from this study indicate that observed associations between night work and adverse profiles of CVD risk factors are related to socioeconomic, other occupational factors and health behaviours.

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References

1. MacDonald LA, Cohen A, Baron S, Burchfiel CM. Occupation as socioeconomic status or environmental exposure? A survey of practice among population-based cardiovascular studies in the United States. Am J Epidemiol. 2009;169(12):1411–21.
2. Black C. Working for a healthier tomorrow. London: The Stationary Office; 2008.
3. Coats D, Max C. Healthy work: productive workplaces: why the UK needs more good jobs. London: The Work Foundation and The London Health Commission; 2005.
4. Health and Safety Executive. Shift work and fatigue. 30/11/2007 [cited 1/2/2008]. Available from: URL: http://www.hse.gov.uk/humanfactors/shiftwork/index.htm.
5. Monk T, Folkard S. Making shift work tolerable. London: Taylor and Francis; 1992.
6. Rajaratnam SM, Arendt J. Health in a 24-h society. Lancet. 2001;358(9286):999–1005.
7. Bøggild H, Knutsson A. Shiftwork, risk factors and cardiovascular disease. Scand J Work Environ Health. 1999;25:85–99.
8. Di Lorenzo L, De Pergola G, Zocchetti C, L'Abbate N, Basso A, Pannacciulli N, et al. Effect of shift work on body mass index: results of a study performed in 319 glucose-tolerant men working in a Southern Italian industry. Int J Obes Relat Metab Disord. 2003;27(11):1353–8.
9. Karlsson B, Knutsson A, Lindahl B. Is there an association between shift work and having a metabolic syndrome? Results from a population based study of 27, 485 people. Occup Environ Med. 2001;58(11):747–52.
10. Lasfargues G, Vol S, Caces E, Le CH, Lecomte P, Tichet J. Relations among night work, dietary habits, biological measure, and health status. Int J Behav Med. 1996;3(2):123–34.
11. Morikawa Y, Nakagawa H, Miura K, Soyama Y, Ishizaki M, Kido T, et al. Effect of shift work on body mass index and metabolic parameters. Scand J Work Environ Health. 2007; 33(1):45–50.
12. Niedhammer I, Lert F, Marne MJ. Prevalence of overweight and weight gain in relation to night work in a nurses' cohort. Int J Obes Relat Metab Disord. 1996;20(7):625–33.
13. Parkes KR. Shift work and age as interactive predictors of body mass index among offshore workers. Scand J Work Environ Health. 2002;28(1):64–71.
14. van Amelsvoort LG, Schouten EG, Kok FJ. Duration of shiftwork related to body mass index and waist to hip ratio. Int J Obes Relat Metab Disord. 1999;23(9):973–8.
15. Nagaya T, Yoshida H, Takahashi H, Kawai M. Markers of insulin resistance in day and shift workers aged 30–59 years. Int Arch Occup Environ Health. 2002;75(8):562–8.
16. Morikawa Y, Nakagawa H, Miura K, Ishizaki M, Tabata M, Nishijo M, et al. Relationship between shift work and onset of hypertension in a cohort of manual workers. Scand J Work Environ Health. 1999;25(2):100–4.
17. Fialho G, Cavichio L, Povoa R, Pimenta J. Effects of 24-h shift work in the emergency room on ambulatory blood pressure monitoring values of medical residents. Am J Hypertens. 2006; 19(10):1005–9.
18. Romon M, Nuttens MC, Fievet C, Pot P, Bard JM, Furon D, et al. Increased triglyceride levels in shift workers. Am J Med. 1992;93(3):259–62.

19. Mikuni E, Ohoshi T, Hayashi K, Miyamura K. Glucose intolerance in an employed population. Tohoku J Exp Med. 1983;141(Suppl):S251–6.
20. Knutsson A, Bøggild H. Shiftwork and cardiovascular disease: a review of disease mechanisms. Rev Environ Health. 2000;15:359–72.
21. van Amelsvoort LG, Jansen NW, Kant I. Smoking among shift workers: more than a confounding factor. Chronobiol Int. 2006;23(6):1105–13.
22. Kivimaki M, Kuisma P, Virtanen M, Elovainio M. Does shift work lead to poorer health habits? A comparison between women who had always done shift work with those who had never done shift work. Work Stress. 2001;15:3–13.
23. Power C, Elliott J. Cohort profile: 1958 British birth cohort (National Child Development Study). Int J Epidemiol. 2006;35:34–41.
24. Wood AM, White I, Thompson SG, Lewington S, Danesh J. Regression dilution methods for meta-analysis: assessing long-term variability in plasma fibrinogen among 27, 247 adults in 15 prospective studies. Int J Epidemiol. 2006;35(6):1570–8.
25. Pearson TA, Mensah GA, Alexander RW, Anderson JL, Cannon RO III, Criqui M, et al. Markers of inflammation and cardiovascular disease: application to clinical and public health practice: a statement for healthcare professionals from the Centers for Disease Control and Prevention and the American Heart Association. Circulation. 2003;107(3):499–511.
26. Parsons TJ, Manor O, Power C. Changes in diet and physical activity in the 1990s in a large British sample (1958 birth cohort). Eur J Clin Nutr. 2005;59:49–56.
27. White H. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica. 1980;48(4):817–38.
28. Atherton K, Fuller E, Shepherd P, Strachan DP, Power C. Loss and representativeness in a biomedical survey at age 45 years: 1958 British birth cohort. J Epidemiol Community Health. 2008;62:215–22.
29. Riedmann A, Bielenski H, Szcurowska T, Wagner A. Working time and work-life balance in European companies. 14/1/2008 [cited 1/2/2008]. Available from: URL: http://www.eurofound.europa.eu/publications/htmlfiles/ef0627.htm.
30. Beese B. Comparative survey on operating hours and working time. 11/7/2006 [cited 1/2/2008]. Available from: URL: http://www.eurofound.europa.eu/ewco/2006/05/DE0605059I.htm.
31. McOrmond T. Changes in working trends over the past decade. 8/1/2004 [cited 1/2/2008]. Available from: URL: http://www.statistics.gov.uk/CCI/article.asp?ID=684&Pos=2&ColRank=2&Rank=224.
32. MacDonald LA, Cohen A, Baron S, Burchfiel CM, MacDonald, et al. Respond to "search for preventable causes of cardiovascular disease". Am J Epidemiol. 2009;169(12):1426–7.
33. Bansal S, Buring JE, Rifai N, Mora S, Sacks FM, Ridker PM. Fasting compared with nonfasting triglycerides and risk of cardiovascular events in women. JAMA. 2007;298(3):309–16.
34. Nordestgaard BG, Benn M, Schnohr P, Tybjaerg-Hansen A. Nonfasting triglycerides and risk of myocardial infarction, ischemic heart disease, and death in men and women. JAMA. 2007;298(3):299–308.
35. Knutsson A. Methodological aspects of shift-work research. Chronobiol Int. 2004;21(6):1037–47.
36. Harrington JM. Health effects of shift work and extended hours of work. Occup Environ Med. 2001;58:68–72.
37. Lavie L, Lavie P. Elevated plasma homocysteine in older shift-workers: a potential risk factor for cardiovascular morbidity. Chronobiol Int. 2007;24(1):115–28.