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Rotating shift work and menstrual cycle characteristics

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Abstract

Background—Shift workers who experience sleep disturbances and exposure to light at night could be at increased risk for alterations in physiologic functions that are circadian in nature.

Methods—We investigated rotating shift work and menstrual cycle patterns in the Nurses' Health Study II using cross-sectional data collected in 1993 from 71,077 nurses aged 28–45 years who were having menstrual periods and were not using oral contraceptives. Log binomial regression was used to estimate relative risks (RRs) and 95% confidence intervals (CIs).

Results—Eight percent of participants reported working rotating night shifts for 1–9 months, 4% for 10–19 months, and 7% for 20+ months during the previous two years. Irregular cycles (>7 days variability) were reported by 10% of participants. Seventy percent of women reported menstrual cycles of 26–31 days, 1% less than 21 days, 16% 21–25 days, 11% 32–39 days, and 1% 40+ days. Women with 20+ months of rotating shift work were more likely to have irregular cycles (adjusted RR = 1.23 [CI = 1.14–1.33]); They were also more likely to have cycle length <21 days (1.27 [0.99–1.62]) or 40+ days (1.49 [1.19–1.87]) (both compared with 26–31 days). For irregular patterns and for 40+ day cycles, there was evidence of a dose response with increasing months of rotating shift work. Moderately short (21–25 days) or long (32–39 days) cycle lengths were not associated with rotating shift work.

Conclusion—Shift work was modestly associated with menstrual function, with possible implications for fertility and other cycle-related aspects of women's health.

Almost 15 million Americans work evening shift, night shift, or rotating shifts. [1] Shift workers who experience exposure to light at night could be at increased risk for disturbed

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physiologic functions that are circadian in nature,[2] such as menstrual function. The length and pattern of the menstrual cycle have been considered a marker for female reproductive health.[3–5] Irregular cycle patterns, as well as short and long cycle length, have been associated with subfertility.[6–10]

Several studies have examined the relation between shift work and menstrual cycle pattern or length, with most having small sample size or few women exposed to shift work.[11–16] We examined the cross-sectional association between rotating shift work and menstrual cycle length and regularity in a large longitudinal cohort study of female nurses. Lifestyle and demographic factors associated with menstrual cycle characteristics are also presented.

METHODS

Study population

The Nurses' Health Study II (NHS-II) is a national cohort study of 116,608 U.S. female registered nurses aged 25 to 42 years at enrollment, established in 1989.[17] Follow-up questionnaires for this prospective study are mailed every two years. Questions about menstrual cycle characteristics, as well as questions on rotating shift work, were included in the 1993 questionnaire.

Overall, 107,669 women responded to the 1993 questionnaire (92% of original cohort). Of those, 13,214 (12%) were excluded because they did not respond to the original questionnaire sent in 1993, but instead responded to a shorter version of the questionnaire that did not include menstrual cycle questions. To remove increased cycle variability caused by perimenopausal changes, we excluded women who were older than 45 in 1993 (n = 4197). We also excluded women who reported that their periods had permanently ceased (n = 4948), that they had used oral contraceptives since 1991 (n = 8737), that they were amenorrheic (n = 3221), or that they had had a hysterectomy or oopherectomy (n = 1243). Women missing information for rotating shift work (n = 383), menstrual cycle length or pattern (n = 641), or parity (n = 8) were also excluded. The distribution of duration of rotating shift work for women missing menstrual cycle pattern or length was similar to those who were included in the study. In total 36,592 (34%) women were excluded, leaving 71,077 participants available for analysis. Finally, a small number of women who were missing information on smoking (n = 77), body mass index (BMI) (n = 129), and age at menarche (n = 223), were further excluded from the analyses of the longest cycles because no one in the missing data categories had long cycles.

Data Collection

Participants were asked "Since June 1991, how many months have you worked ROTATING night shifts (at least three nights/month in addition to other days and evenings in that month)." The following categories were given as choices: none, 1–4 months, 5–9 months, 10–14 months, 15–19 months, and 20+ months. Women who rotated days with evenings, but who did not work three or more nights per month, should have classified themselves as "none." We grouped categories for analysis into none, 1–9 months, 10–19 months, and 20+ months, reasoning that nurses who worked 20+ months in the past two years were likely to be “current” rotating shift workers at the time they responded to the menstrual cycle questions, and that nurses who worked rotating nightshifts for fewer months in the last two years had lower duration and perhaps more distant exposure. No data on “permanent” (i.e. non-rotating) night work were collected.

Participants were also asked to report the current usual pattern of their menstrual cycles when not pregnant or lactating: extremely regular (no more than 1–2 days before or after expected), very regular (within 3–4 days), regular (within 5–7 days), usually irregular, always irregular, and no periods. For analysis, “regular” cycles were defined as being within 7 days variability from cycle to cycle, and irregular cycles as usually or always being irregular.

On the same questionnaire, participants were asked what the current usual length of their menstrual cycle was, defined as the interval from the first day of the period to the first day of the next period. Questionnaire choices included <21, 21–25, 26–31, 32–39, 40–50 days, and “51+ days or too irregular to estimate.” For analysis, we compared moderate and extreme cycle length categories to the women who indicated cycle lengths of 26–31 days. (For example, when we compared women who had cycles <21 days with women whose cycles were 26–31 days, we excluded other cycle lengths.) To distinguish women whose cycles were longer than 51 days from women whose cycles were too irregular to estimate, we excluded women from the long-cycle analyses who reported that their cycles were usually or always irregular (n = 2184).

Data were also collected on age, race/ethnicity, BMI, parity, age at menarche, physical activity, smoking status, and caffeine and alcohol consumption. Because the relationship between age and menstrual cycle outcomes was curvilinear, we modeled age categorically.

Statistical Analysis

Age-adjusted means and prevalence of selected characteristics were calculated. For univariate and multivariate analyses, we computed the log binomial using PROC GENMOD in SAS with the binomial distribution and log link, which allows for direct estimation of relative risks.[18] Covariates that either changed the estimate by 10% or narrowed the confidence interval of the shift work effect estimates were retained in the final multivariate model. We also retained covariates that were significantly associated with the outcome variable to add information to the literature about factors that affect menstrual cycle characteristics. Neither caffeine nor coffee consumption met either criterion, and were therefore eliminated from the models. Only age and BMI changed the effect estimates for shiftwork by at least 10% for at least one menstrual outcome.

We created indicators for missing data on smoking status, alcohol consumption, age at menarche, physical activity, and BMI. By comparing the −2 log likelihood scores of nested models both with and without interaction terms, we tested for multiplicative interactions of rotating shift work (number of months) with age (continuous years), BMI (kg/m^2), and race (white, non-white). Results of interaction models modestly affected only the long-cycle models; therefore we present models without interaction terms.

Our full multivariate models were adjusted for age, age at menarche, parity, race/ethnicity, smoking status, alcohol consumption, physical activity, and BMI as categorical variables. To calculate a dose-response trend for rotating shift work, the midpoint of each reporting category was used to create a continuous variable.

The study was approved by the Institutional Review Board of the Brigham and Women's Hospital. Completion of the self-administered questionnaire implied informed consent.

RESULTS

Nurses in our study (n = 71,077) ranged in age from 28 to 45 years at the time they responded to the 1993 questionnaire (mean = 37.8, standard deviation = 4.3). Table 1 shows selected age-standardized characteristics of participants by rotating shift work categories. Women who worked rotating shifts tended to be younger and have a higher BMI than those working a permanent (non-rotating) shift. Of the nurses who reported working 20+ months of rotating night shift over the past two years, 68% worked as inpatient or emergency room nurses. Race/ethnicity differed by rotating shift work status, with more minority women reporting 20+ months of rotating shift work. Rotating shift workers were more likely to smoke and less likely to be physically active. Caffeinated coffee consumption was higher among rotating shift workers.

Table 2 provides information on the associations between months of rotating shift work and irregular pattern, adjusted for age (in 5-year categories), and then further adjusted for age at menarche, parity, race/ethnicity, smoking status, alcohol consumption, physical activity, and BMI as categorical variables. We observed associations between rotating shift work and irregular pattern, with the relative risks increasing modestly with increasing months of rotating shift work. The trend test shows a 13% increased risk per every 12 months of rotating shift work (95% confidence interval = 13%–13%). Younger and older age groups had increased risks of irregular patterns, and BMI showed a dose-response relationship with irregularity. Asian women, Hispanic women and women of "other" race/ethnicity were more likely than white participants to report irregular cycles. As expected from the frequent association of irregular cycles with subfertility, women with irregular cycles had lower parity.

Tables 3 shows age-adjusted models for the risk of short and long cycle length compared with 26–31 days. Rotating shift work was not associated with moderately short or long cycles, but was associated with extremely short or long cycles. As expected, as women aged, their cycles became shorter.

Table 4 shows the cycle-length analyses adjusted for lifestyle and demographic covariates. The adjusted associations between rotating shift work and cycle length are similar to the age-adjusted models shown in Table 3, although somewhat attenuated, primarily by BMI adjustment. A dose-response relationship of rotating shiftwork with cycles of 40 or more days was observed, with a 25% increased risk for every 12 months of rotating shift work (95% CI = 24%–26%). The positive association between shiftwork duration and extremely short cycles was still evident but less consistent than for extremely long cycles. Older women had shorter cycles, while later onset of menarche was associated with longer cycles. Current smoking was associated with shorter cycle length. There were strong associations of higher BMI with both short and long cycles. In addition, non-white women were more likely to have short cycles. Frequency of physical activity was not associated with cycle length. Alcohol consumption was strongly associated with fewer reports of short or long cycle lengths.

To remove any residual confounding of parity, we conducted a sub-analysis restricted to the 22% of the cohort that was nulliparous in 1993 (n = 15,558). In this subgroup, we observed that 20+ months of rotating shiftwork was not associated with menstrual irregularity (RR=1.06 [95% CI = 0.90–1.24]), but appeared to remain associated with both short (for <21 days, 1.58 [0.95–2.61]) and long (for 40+ days, 1.45 [0.90–2.34]) cycle length.

Because a recent pregnancy might affect both a woman's report of her "current usual length or pattern" and the likelihood of working a rotating schedule, we conducted a sub-analysis that excluded the 13,426 women who reported having given birth during 1991–1993, or who reported being currently pregnant in 1993. The results were similar to our main analyses for all outcomes. The relative risks of working 20+ months of rotating shift work for irregular cycle, short cycle length (<21 days), and long cycle length (40+ days) were 1.21 (1.11–1.32), 1.26 (0.98–1.62), and 1.59 (1.24–2.04), respectively.

Although we did not collect data on permanent night shift work in the two years immediately preceding the menstrual cycle assessment of 1993, we were able to exclude the 7,639 women who reported on a subsequent questionnaire that they had worked at least 6 months of permanent night shifts between 1989–1994. The results were similar to our main analyses; the relative risks of working 20+ months of rotating shift work for irregular cycle, short cycle length (<21 days), and long cycle length (40+ days) were 1.20 (1.09–1.32), 1.28 (0.94–1.74), and 1.32 (0.98–1.79), respectively.

DISCUSSION

Our data a modest association between rotating shift work and menstrual regularity and cycle length. The associations were somewhat stronger with more months of rotating shift work in the previous two years, which could reflect a cumulative effect of shift work. However, because we did not know precisely when the rotating shift work occurred in the two-year time window, it is equally plausible that women who worked more months were more likely to be current shift workers at the time they responded to the questionnaire. Thus, the seeming dose-response associations could also reflect recency of exposure to shift work, suggesting a short-term, reversible effect. Overall, our results indicate a possible effect of shift work on adverse health outcomes related to irregular menstrual cycle pattern or length, such as subfertility.[6–10]

Several studies have examined the relation between shift work and menstrual cycle patterns,[11–16] three of which were studies of nurses.[11–13] While most of these studies reported an association of shift work with menstrual cycle perturbations, four had small sample sizes (ranging from 12 to 151 participants), thereby limiting their ability to adjust for confounding factors.[12,13,15]

One study examined 479 Canadian poultry workers who reported day-to-day variability in work schedule (defined as the day of work beginning at irregular or unpredictable times).[14] The age range in this study was similar to ours, with 24% being 40 years or older. Though not a typical definition of "shift work," schedule variability in that study was associated with long cycles (>33 days) and irregular cycles (>7 days variability), with odds ratios of 2.4 (95% CI = 1.0–5.5) and 2.0 (1.2–3.6), respectively, adjusted for temperature at work, smoking status, use of intrauterine device, parity, and age. The ORs in the study were higher than the RRs in our study, possibly due to differences in the definition of long cycles and shift work, or to possible overestimation of risk when using odds ratios to analyze outcomes are not that rare. A prospective study of Taiwanese 12-hour-shift factory workers who rotated between day and night shift every four months showed an increased risk of having either long (>35 days) or short (<25 days) cycle length in shift workers (n=280) compared with office workers (n = 49) (OR = 1.71 [95% CI = 1.0–2.9]).[16] These results are somewhat difficult to interpret because long and short cycle lengths were combined as a single outcome. None of these studies, including ours, was able to distinguish always working at night from rotating night shifts.

The menstrual cycle is defined by cyclical patterns of circulating reproductive hormones. Shifts in the circadian rhythms, either through sleep disturbances or altered melatonin production, may affect regulation of the reproductive hormones that control the menstrual cycle, although the mechanism is not clear. Produced in the pineal gland during dark hours, melatonin is thought to regulate several physiologic mechanisms including sleep and core body temperature. [19,20]

Effects on animal reproductive behavior of variation in light hours from seasonal and lunar phases, presumably through altered melatonin production, has been well-studied.[2,20] In humans, however, a relation between hours or intensity of light exposure and menstrual cycle parameters, such as cycle length, remains unclear. [20,21] Moreover, while urinary melatonin metabolite levels have been associated with shift work, parity, and amenorrhea,[22–28] an association between melatonin and reproductive hormones has not been established in humans.[19] In one study, plasma melatonin levels remained consistent throughout the menstrual cycle, though melatonin levels were nearly twice as high in amenorrheic women as controls.[26] However, smaller studies have suggested an inverse association between exogenously-administered melatonin and estrogen levels.[29]

Sleep appears to inhibit pituitary luteinizing hormone (LH) secretion[30,31]; therefore, it is possible that altered sleep-wake patterns, as seen in shift workers who work rotating or night shifts, could modify LH secretion and thus change the regularity or length of the menstrual cycle. It is a limitation of our study that we did not collect information on sleep behaviors. Therefore, we cannot distinguish between the effects of lack of sleep and light at night, nor can we comment on whether efforts by participants to recover sleep altered the effects of rotating shift work.

In our study, there was evidence of a dose-response relationship between self-reported BMI and menstrual cycle outcomes. In previous studies, extremes of weight have been associated with the risk of long, irregular,[8,32–34] and anovulatory cycles[6,34] typical of polycystic ovarian syndrome. Moderate overweight has been associated with ovulatory disorder infertility in the NHS-II cohort[17,35] and others.[7] Our study also suggests a dose-response association between alcohol intake and reduced risk of menstrual cycle aberrations. Previous studies have reported reduced cycle length variability with moderate or heavy alcohol intake,[36,37] and a reduced risk of long menstrual cycles among moderate drinkers. [36,38]

The results of our study were fairly robust when we excluded recent pregnancies; however, when we restricted our cohort from 71,077 to the 15,558 nulliparous women, the association of rotating shift work with cycle irregularity was attenuated, though associations with cycle length were not. The attenuated association of shiftwork with menstrual irregularity among the nulliparous could be a chance consequence of smaller numbers. Alternatively, it might indicate the elimination of confounding by factors associated with parity, or it may reflect a higher background risk of cycle irregularity in a group of nulliparous women with infertility.

The assessment of shift work in our study was defined as at least three nights per month in addition to other days and evenings in that month, and was limited to the report of the number of months the nurse worked a rotating shift in the previous two years. A better assessment of the number of nights worked per month would have refined our results by allowing us to investigate a threshold or dose-response effect.

Although permanent night work was not assessed in our study, non-rotating night work can result in a rotation of sleep—wake cycles if the worker reverts to normal hours on their days off. We did not collect sufficiently detailed information on permanent night work to distinguish its effects from the effects of rotating shift work. Unpublished data from a subset of approximately 60 nurses from this cohort suggest that permanent night workers work twice as many nights per month as rotating night workers (12.3 versus 6.4). Since the adverse effects of night work might be more severe among rotating night workers than among permanent night workers, we presume that classifying night workers as having no rotating shift work would have biased our results towards the null. Another possible source of misclassification could result from permanent night workers incorrectly classifying themselves as rotating shift workers. From previous Nurses' Health Study analyses, we have found that about 10% of all reported rotating shift workers were actually permanent night workers (unpublished data). When we excluded nurses who had classified themselves as permanent night workers on subsequent questionnaires, the results were unchanged.

Women reported usual cycle characteristics without the aid of menstrual diaries. A more definitive study of this topic would use prospectively collected work records and menstrual diaries to examine whether change in work schedule induces changes in menstrual cycling. Validation studies of self-reported shift work data, especially among health care workers, are needed. Though it is possible women misclassified their cycle length, the fact that we found the expected differences in cycle length with age, age at menarche, smoking, and BMI suggests that women's self-reported data were adequate. Moreover, because our data are over only a 2-year period, we expect misclassification from self-reported data to have been minimized.

With a sample size of over 70,000 women, our study is by far the largest study of its kind to examine the association between shift work and menstrual patterns. A consequence is that our study had the ability to look at more extreme definitions of short and long cycles than previous studies, and to adjust for BMI and stratify by age.

In conclusion, we found an increased risk for short and long menstrual cycle length and cycle irregularity in nurses who worked rotating shifts, which may have implications for infertility. Future research could clarify the interrelations between sleep-wake patterns, sleep behavior, melatonin production, exposure to light at night, and the reproductive hormones that regulate the menstrual cycle and ovulation. Because night work will continue to be necessary in the nursing profession, intervention studies may be needed to see whether shift work affects fertility.

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Table 1

Age-standardized[a] Characteristics of Participants of the Nurses' Health Study II in 1993 by duration of time worked rotating night shift (n = 71,077)

Characteristic	Total Sample (n=71,077)	Number of Months Worked Rotating Night Shift 1991 to 1993			
		0 (n = 57,728)	1–9 (n = 5623)	10–19 (n = 2647)	20+ (n = 5079)
Days of menstrual cycle, 1993; mean (SD)[b]	68,893	28.6 (4.0)	28.5 (4.0)	28.6 (4.3)	28.7 (4.1)
Age (years); %					
28–30	3777	5	9	8	7
31–35	17,878	24	31	31	28
36–40	27,948	40	38	38	40
41–45	21,474	32	23	23	26
BMI, 1991; %					
<18.5	2006	3	2	2	3
18.5 to <24.9	45,185	65	59	57	55
25 to <29.9	14,252	20	22	21	22
30 to <34.9	5612	7	10	11	11
35+	3805	5	7	8	8
Missing	217	<1	<1	<1	1
Race; %					
African American	954	1	2	2	2
Asian	1186	2	2	2	3
White	65,702	93	92	93	90
Hispanic	952	1	2	1	2
Other	1250	2	2	2	2
Missing	1033	1	1	1	2
Parity, 1993; %					
Nulliparous	15,558	21	27	22	21
1	11,668	17	16	17	15
2–3	39,579	56	51	53	57
4+	4272	6	7	8	7
Age at menarche (years); mean (SD), range	70,848	12.4 (1.4), 9–17	12.4 (1.5), 9–	12.3 (1.4), 9.0–	12.4 (1.5), 9–17

Characteristic	Total Sample (n=71,077)	Number of Months Worked Rotating Night Shift 1991 to 1993			
		0 (n = 57,728)	1–9 (n = 5623)	10–19 (n = 2647)	20+ (n = 5079)
Menstrual cycle duration (days); %					
<21	797	1	1	2	2
21–25	11,034	16	17	17	16
26–31	48,259	70	70	68	69
32–39	7782	11	11	16	12
40–50	785	1	1	1	2
51+	236	<1	<1	<1	<1
irregular	6930	9	11	12	12
regular	64147	91	89	88	88
Consumption of caffeinated coffee (cups/week, 1993), mean (SD) [c], range	65,287	8.5 (10.5), 0–42	9.2 (11.1), 0–42	9.7 (11.5), 0–42	9.7 (11.8), 0–42
Cigarette smoking, 1993; %					
Never smoked					
Past smoker	46,625	66		63 63	64
Current smoker	16,651	24		23 24	22
Missing	7722	10		14 13	14
	79	<1		<1	<1
				<1	
Alcohol consumption, 1991 (gm/day); %[c,d]					
0					
<5	27,486	39		38 39	41
5 to <10	24,876	35		34 36	32
10–<20	6272	9		8 7	8
20+	4120	6		5 5	4
Missing	1402	2		2 2	1
	6921	9		12 11	13
Physical Activity, 1993 (times per week); %					
<= 1					
2–3	41,034	57		58 60	60
4–6	21,068	30		31 30	29

Characteristic	Total Sample (n=71,077)	Number of Months Worked Rotating Night Shift 1991 to 1993			
		0 (n = 57,728)	1–9 (n = 5623)	10–19 (n = 2647)	20+ (n = 5079)
7+	7802	11		10 9	9
Missing	706	1		1 1	1
	467	1		1	1
				<1	

[a]Directly standardized to the cohort by age

[b]Excludes women who reported their cycles were 51+ days and that they usually or always had irregular menstrual patterns (n = 2184)

[c]Assessed on 1991 questionnaire

[d]10 grams of alcohol is comparable to 8 ounces of beer, 3.5 ounces of wine, or one ounce of distilled spirits or liquor.

Table 2

Association of Rotating Shift Work and Other Characteristics with irregular Menstrual Pattern[a] (n = 6930) among 71, 077 Participants of the Nurses' Health Study II (1993)

	Age-adjusted		Full Model	
	RR	**(95% CI)**	**RR**	**(95% CI)**
Rotating Shift work (months)				
0[b]	1.00		1.00	
1–9	1.20	(1.11–1.30)	1.13	(1.05–1.22)
10–19	1.24	(1.12–1.39)	1.18	(1.06–1.31)
20+	1.34	(1.24–1.45)	1.23	(1.14–1.33)
Age (years)				
28–30	1.46	(1.33–1.60)	1.45	(1.32–1.59)
31–35	1.21	(1.14–1.28)	1.21	(1.14–1.28)
36–40[b]	1.00			
41–45	1.20	(1.14–1.27)	1.17	(1.10–1.23)
Age at menarche (years)[c]				
9–11			0.99	(0.94–1.05)
12–13[b]			1.00	
14–17			1.39	(1.31–1.47)
Race/Ethnicity[c]				
African American			0.94	(0.78–1.12)
Asian			1.38	(1.19–1.61)
White[b]			1.00	
Hispanic			1.21	(1.02–1.44)
Other			1.24	(1.07–1.43)
Parity				
Nulliparous[b]			1.00	
1			1.02	(0.95–1.09)
2–3			0.88	(0.83–0.93)
4+			0.71	(0.64–0.80)
Smoking[c]				
Never[b]			1.00	
Past			0.91	(0.86–0.96)
Current			1.02	(0.95–1.09)
Alcohol Consumption (gm/day)[c,d]				
None[b]			1.00	
<5			0.91	(0.87–0.96)
5 to <10			0.92	(0.84–1.00)
10–<20			0.81	(0.72–0.90)
20+			0.76	(0.63–0.92)

	Age-adjusted		Full Model	
	RR	(95% CI)	RR	(95% CI)
Physical Activity (times per week)[c]				
≤ 1[b]			1.00	
2–3			0.91	(0.86–0.95)
4–6			0.92	(0.85–0.99)
7+			0.94	(0.74–1.19)
Adult BMI (kg/m^2), 1991[c]				
<18.5			0.97	(0.83–1.12)
18.5 to <24.9[b]			1.00	
25 to <30			1.27	(1.20–1.34)
30 to <35			1.79	1.67–1.93
35+			2.66	(2.48–2.86)

[a]Irregular pattern defined as >7 days variability among cycles.

[b]Reference category.

[c]Missing values for these variables were assigned a missing indicator, data not shown.

[d]10 grams of alcohol is comparable to 8 ounces of beer, 3.5 ounces of wine, or one ounce of distilled spirits or liquor.

Table 3

Age-adjusted Association between Rotating Shift Work and Menstrual Cycle Length[a] among Participants of the Nurses' Health Study II (1993)

	Menstrual cycle length (days)							
	<21 (n = 794)		21–25 (n = 10,992)		32–39 (n = 7745)		40+ [a] (n = 785)[b]	
	RR	(95% CI)	RR	(95% CI)	RR	(95% CI)	RR	(95% CI)
Rotating Shift work (months)								
0[c]	1.00		1.00		1.00		1.00	
1–9	1.26	(0.98–1.62)	1.04	(0.98–1.11)	0.99	(0.91–1.06)	1.25	(0.99–1.59)
10–19	1.62	(1.18–2.22)	1.07	(0.98–1.17)	1.04	(0.93–1.15)	1.30	(0.93–1.82)
20+	1.44	(1.13–1.83)	1.02	(0.96–1.09)	1.06	(0.98–1.15)	1.61	(1.29–2.02)
Age (years)								
28–30	0.33	(0.20–0.57)	0.58	(0.52–0.64)	1.39	(1.28–1.50)	1.80	(1.39–2.34)
31–35	0.63	(0.51–0.78)	0.70	(0.67–0.74)	1.26	(1.20–1.32)	1.46	(1.24–1.73)
36–40[c]	1.00		1.00		1.00		1.00	
41–45	1.56	(1.34–1.81)	1.25	(1.20–1.30)	0.70	(0.66–0.74)	0.88	(0.73–1.06)

[a]Compared with cycles of 26–31 days (n =48,295, except in the analysis of 40+, in which n = 48,166 due to the exclusion of 129 women who were missing BMI)

[b]Excludes women who reported their cycles were 51+ days long and that they usually or always had irregular menstrual patterns (n = 2184). In addition, to be consistent with multivariate analyses presented in table 4, women who were missing information on smoking (n = 77), BMI (n = 129), and age at menarche (n = 223), were further excluded because no one in the missing data categories had long cycles.

[c]Reference category.

Table 4

Rotating Shift Work and Menstrual Cycle Length[a] among Participants of the Nurses' Health Study II (1993) Adjusted for Lifestyle and Demographic Factors

	Menstrual Cycle Length (days)							
	<21 (n =794)		21–25 (n = 10,992)		32–39 (n = 7745)		40+[b] (n = 785)	
	RR	(95% CI)	RR	(95% CI)	RR	(95% CI)	RR	(95% CI)
Rotating Shift work (months)								
0[c]	1.00		1.00		1.00		1.00	
1–9	1.17	(0.91–1.49)	1.03	(0.97–1.10)	0.98	(0.91–1.06)	1.19	(0.94–1.51)
10–19	1.49	(1.08–2.04)	1.07	(0.97–1.17)	1.03	(0.93–1.15)	1.25	(0.90–1.75)
20+	1.27	(0.99–1.62)	1.01	(0.94–1.08)	1.04	(0.96–1.12)	1.49	(1.19–1.87)
Age (years)[d]								
28–30	0.35	(0.20–0.60)	0.57	(0.51–0.64)	1.41	(1.30–1.53)	1.83	(1.41–2.38)
31–35	0.64	(0.52–0.79)	0.70	(0.67–0.74)	1.26	(1.20–1.32)	1.46	(1.24–1.73)
36–40[c]	1.00		1.00		1.00		1.00	
41–45	1.54	(1.32–1.79)	1.26	(1.21–1.31)	0.68	(0.65–0.72)	0.84	(0.69–1.01)
Age at menarche (years)								
9–11	1.35	(1.16–1.58)	1.06	(1.02–1.11)	0.94	(0.89–0.99)	0.88	(0.73–1.05)
12–13[c]	1.00		1.00		1.00		1.00	
14–17	1.14	(0.94–1.38)	0.94	(0.90–0.99)	1.36	(1.30–1.44)	1.81	(1.54–2.14)
Race/Ethnicity[e]								
African American	2.32	(1.59–3.38)	1.50	(1.34–1.67)	0.73	(0.58–0.92)	0.80	(0.42–1.54)
Asian	1.27	(0.78–2.09)	0.91	(0.79–1.05)	1.28	(1.11–1.48)	1.46	(0.91–2.32)
White[c]	1.00		1.00		1.00		1.00	
Hispanic	2.22	(1.48–3.34)	0.95	(0.81–1.11)	0.94	(0.78–1.13)	1.22	(0.71–2.09)
Other	1.43	(0.92–2.25)	1.18	(1.05–1.33)	0.98	(0.84–1.15)	0.70	(0.38–1.30)
Parity								
Nulliparous[c]	1.00		1.00		1.00		1.00	
1	1.07	(0.85–1.34)	0.94	(0.89–0.99)	1.10	(1.03–1.17)	0.99	(0.80–1.24)

	Menstrual Cycle Length (days)							
	<21 (n =794)		21–25 (n = 10,992)		32–39 (n = 7745)		40+[b] (n = 785)	
	RR	(95% CI)	RR	(95% CI)	RR	(95% CI)	RR	(95% CI)
2–3	1.04	(0.87–1.25)	0.94	(0.90–0.98)	1.10	(1.04–1.16)	0.95	(0.80–1.13)
4+	1.08	(0.80–1.48)	0.88	(0.82–0.96)	1.09	(0.99–1.20)	0.77	(0.54–1.09)
Smoking								
Never[c]	1.00		1.00		1.00		1.00	
Past	1.08	(0.91–1.28)	1.02	(0.98–1.06)	0.93	(0.89–0.98)	0.94	(0.79–1.11)
Current	2.04	(1.70–2.45)	1.35	(1.29–1.42)	0.80	(0.74–0.86)	0.70	(0.54–0.92)
Alcohol Consumption (gm/day)[e,f]								
None[c]	1.00		1.00		1.00		1.00	
<5	0.88	(0.75–1.04)	0.97	(0.93–1.00)	0.98	(0.93–1.03)	0.91	(0.77–1.07)
5 to <10	0.68	(0.50–0.91)	0.94	(0.88–1.00)	0.98	(0.90–1.06)	0.91	(0.69–1.19)
10–<20	0.73	(0.52–1.02)	0.91	(0.85–0.98)	0.88	(0.80–0.98)	0.57	(0.38–0.86)
20+	0.44	(0.23–0.85)	0.85	(0.75–0.96)	0.84	(0.71–1.01)	0.42	(0.19–0.95)
Physical Activity (times per week)[e]								
≤ 1[c]	1.00		1.00		1.00		1.00	
2–3	1.02	(0.87–1.20)	0.98	(0.95–1.02)	0.96	(0.91–1.00)	0.88	(0.75–1.04)
4–6	1.15	(0.92–1.44)	1.07	(1.01–1.13)	0.97	(0.90–1.04)	0.85	(0.66–1.09)
7+	0.97	(0.46–2.04)	1.15	(0.98–1.33)	0.97	(0.78–1.22)	1.14	(0.57–2.27)
Adult BMI (kg/m^2), 1991[d,e]								
<18.5	1.51	(1.03–2.23)	1.01	(0.91–1.12)	0.97	(0.86–1.10)	0.84	(0.53–1.35)
18.5 to <25[c]	1.00		1.00		1.00		1.00	
25 to <30	1.12	(0.94–1.34)	0.93	(0.89–0.97)	1.14	(1.08–1.21)	1.55	(1.30–1.84)
30 to <35	1.39	(1.11–1.76)	0.90	(0.84–0.96)	1.41	(1.31–1.52)	2.03	(1.61–2.56)
35+	1.39	(1.05–1.83)	0.78	(0.71–0.85)	1.72	(1.59–1.87)	3.18	(2.52–4.02)

[a]Compared with cycles of 26–31 days (n = 48,295, except in the analysis of 40+, in which n = 48,166 due to the exclusion of 129 women who were missing BMI)

[b]Excludes women who reported their cycles were 51+ days and that they usually or always had irregular menstrual patterns from the analysis of 40+ day cycles (n = 2184). In addition, women who were missing information on smoking (n = 77), BMI (n = 129), and age at menarche (n = 223), were further excluded because no one in the missing data categories had long cycles.

[c]Reference category.

[d] Age was a confounder in the analysis of short cycles and adult BMI was a confounder in the analysis of long cycles, while the other covariates are presented because they are associated with the outcome variables.

[e] Missing values for these variables were assigned a missing indicator, data not shown

[f] 10 grams of alcohol is comparable to 8 ounces of beer, 3.5 ounces of wine, or one ounce of distilled spirits or liquor.