Impact of Shift Work and Race/Ethnicity on the Diurnal Rhythm of Blood Pressure and Catecholamines

Fumiyasu Yamasaki, Joseph E. Schwartz, Linda M. Gerber, Katherine Warren, Thomas G. Pickering

Abstract—To evaluate the effects of shift work and race/ethnicity on the diurnal rhythm of blood pressure and urinary catecholamine excretion of healthy female nurses, 37 African American women and 62 women of other races underwent ambulatory blood pressure monitor and urine collection for 24 hours that included a full work shift: day shift (n=61), evening shift (n=11), and night shift (n=27). Awake and sleep times were evaluated from subjects’ diaries. Of African Americans, 79% who were working evenings or nights and 32% working day shifts were nondippers (<10% drop in systolic pressure during sleep), whereas only 29% of others working evening+night and 8% working day shifts were nondippers. Regression analyses indicated that evening+night shift workers had a 5.4 mm Hg (P<0.001) smaller drop than day shift workers, and African Americans had a 4.0 mm Hg (P<0.01) smaller drop than others. The odds of an evening+night shift worker being a nondipper were 6.1 times that of a day shift worker (P<0.001), and the odds of an African American were 7.1 times that of others (P<0.001). Total sleep time was significantly greater in the non–African American day shift workers than in the other 3 groups. After controlling for work shift and race/ethnicity, we determined that longer sleep times predicted less dipping (absolute and relative) in blood pressure. Urinary norepinephrine and epinephrine were higher during work than nonwork in both racial groups of day shift workers, but in evening+night shift workers the difference was small and in the opposite direction. These results indicate that being African American and working evening or night shifts are independent predictors of nondipper status. Higher sleep blood pressure may contribute to the known adverse effects of shift work. (Hypertension. 1998;32:417-423.)

Key Words: work schedule tolerance ■ race ■ blood pressure monitoring, ambulatory ■ catecholamines

Arterial blood pressure (BP) normally shows physiological diurnal fluctuations, with higher levels during the day and lower levels during the night. The diurnal fluctuations of some biological parameters are dependent on endogenous circadian rhythms and thus resistant to changes in the cycle of activity and sleep.1 We and others have shown that physical and mental activity play an important role in determining the diurnal BP rhythm.2-10 The effects of shift work on BP have been examined using ambulatory blood pressure (ABP) monitoring in a few studies.11-15 Another factor that has been reported to influence the nocturnal fall of BP is race, with several studies showing that African Americans are more likely to be classified as nondippers (<10% drop in systolic BP during sleep) than whites,16-18 although the literature on this is not consistent.19 However, little is known about the impact of race/ethnicity on the diurnal BP pattern of shift workers.

There has been considerable interest in the possible pathological significance of classification as a dipper or a nondipper.20-21 Hypertensive patients whose pressures remain high at night (nondippers) have been reported in some studies to show more target organ damage than those who exhibit the normal pattern (dippers),22-24 although this has not been our experience,25 and women who are nondippers may be at greater risk of cardiovascular morbidity than those who are dippers.26 The mechanisms, however, have not yet been clarified, and there is no study evaluating an association between shift work and dipper/nondipper status.

Plasma catecholamine levels fall during sleep, which is consistent with a diminished sympathetic activity.27-28 Urinary catecholamines (both epinephrine [EP] and norepinephrine [NE]) also show a diurnal rhythm, with the lowest levels at night.29,30 This rhythm is still apparent in recumbent subjects who remain awake during the night, but it has a smaller amplitude.29 Urinary catecholamine levels are influenced by occupational stress as well as by physical activity.6,29,31 In this study we evaluated the effects of shift work and race/ethnicity on the diurnal rhythm of BP and urinary catecholamine excretion.

Methods

Subjects

The subjects for this study were recruited as part of the larger Work Site Blood Pressure Study from the nursing staff (registered nurses, nurse practitioners, and nurse aides) of a large private hospital. With the permission of the hospital, we conducted BP screening of 727...
posture, location, and mood in a diary. Awake and sleep times were evaluated from the diary entries. Dippers were defined as subjects whose average sleep systolic BP declined by at least 10% from their average awake systolic BP. Six subjects were excluded from the BP analyses because they had fewer than 4 valid sleep readings, the minimum number used to compute an average.

### Urinary Catecholamine Measurement

Urine was collected throughout the same 24-hour period that the BP monitor was worn. Subjects were asked to void just after being fitted with the monitor and were given 2 collection containers each with 0.5 g sodium metabisulfite and a minimum number used to compute an average.

#### Results

The 3 work shift groups (day, evening, and night) did not differ significantly with respect to age, length of employment, height, arm circumference, screening diastolic BP, race/ethnic group, and having a history of secondary hypertension or renal disease (self-reported and confirmed by medical records). The urine samples were prepared according to the procedure described by James et al.32 Throughout the subject's work shift, all urine was collected into the container labeled “Work.” All other urine was collected into the container labeled “Nonwork.” Subjects were specifically instructed to void into the Work container at the conclusion of their work shift and into the Nonwork container just before beginning their commute back to work. Seven nurses declined to collect urine, 3 nurses reported failing to collect 1 void, and 1 sample was inadvertently contaminated. Thus, analyses of catecholamines are based on the remaining sample of 88.

The measurement of urinary catecholamines (NE and EP) in the 2 collections was done by the New York Hospital Clinical Research Center according to the method described by James et al. The total volume of each sample and the duration of time covered by each collection (to the nearest 5 minutes) were recorded after each urine collection. A sample was taken from each container and stored at −20°C until the assays were performed. EP and NE concentrations (ng/mL) were determined using the Cat-a-kit (radioenzymatic) assay by Amersham. In this assay, the enzyme catechol-o-methyltransferase (COMT) is used to catalyze the transfer of a 3H-methyl group from L-3,5-dimethoxy-4-hydroxyphenylalanine (3H-6-O-methyl-L-3,5-dimethoxytyramine) to EP and NE. The urine samples were prepared according to the procedures described by the kit manufacturer, which are expected to reduce bias and increase sensitivity.33 By using the urine volumes and the duration of the collection periods, the NE and EP concentrations were transformed into average rates of excretion (nanograms per minute) over each time period (work and nonwork). Finally, all excretion rates were transformed to natural logarithms to reduce the positive skewness of the distributions.

### Statistical Analysis

Data are expressed as mean±1 SD. ANOVA was used to assess the differences among subgroups defined according to work shift and race/ethnicity. Paired t tests were used to examine within-group differences between awake and sleep BPs, urinary concentrations of catecholamines, and sleep duration. The 3 work shift groups were compared using 1-way ANOVA with post hoc multiple comparisons (Dunn’s test) and the Tukey-Kramer test. The χ2 test was used to examine differences between dippers and nondippers. A stepwise multiple regression analysis was used to predict each measure of dipping from work shift, race/ethnicity, age, BMI, and hours of sleep. A 2-tailed α level of 0.05 was the cutoff used to indicate statistical significance.

#### Results

The 3 work shift groups (day, evening, and night) did not differ significantly in age, BMI, or percentage of African Americans. The average awake and sleep ambulatory BPs and heart rates (HRs) of the 3 shift groups are shown in Table 1. In each group, BP and HR were lower during sleep than wakefulness (all P<0.001). Twenty-eight percent of all subjects were classified as nondippers. Of day shift workers, 16% were classified as nondippers, but 45% of evening shift workers were classified as dippers. Of evening shift workers, 21% were classified as dippers, but 11% of night shift workers were classified as dippers.
workers and 50% of night shift workers were nondippers (Figure 1). Because of the small number of evening workers and the similar distribution of dipper status in the evening and night shift workers, these 2 groups were combined for further analysis. This showed that the difference in dipper status between the groups was primarily due to a significantly higher sleep systolic BP in the evening
1
night shift workers than in day shift workers (105.4 versus 99.4 mm Hg, 
P
0.01). The awake-sleep drop in diastolic BP was also smaller for the evening
1
night shift workers than for the day shift workers (14.1 versus 17.0 mm Hg, 
P
0.05). Awake-sleep differences in HR in day shift workers did not differ significantly from those of evening
1
night shift workers (Table 1). Total sleep time was significantly greater for the day than the evening
1
night shift workers (6.8 versus 5.9 hours, 
P
0.001) (Table 1).

Effects of Race/Ethnicity and Shift Work on 24-Hour ABP and Sleep Duration
In all groups, BP and HR were lower during sleep than wakefulness. Of African Americans, 79% working the evening
+ night shifts and 32% working the day shift were classified as nondippers, whereas only 29% of others working the evening
+ night shifts and 8% working the day shift were nondippers (Figure 2). This difference was primarily due to sleep BP levels (see Table 2). Total sleep time was significantly greater for the non–African Americans working the day shift than for the other 3 groups (Table 2).

In a stepwise multiple regression analysis predicting absolute change between awake and sleep systolic BPs, work shift, race/ethnicity, and hours of sleep were statistically significant (Table 3). Evening
+ night shift workers had a 5.4 mm Hg (P<0.001) smaller drop than day shift workers, and African Americans had a 4.0 mm Hg (P<0.01) smaller drop than nurses of other race/ethnicity. Hours of sleep, which did not have a significant bivariate correlation with dipping status, was associated with a smaller dip in BP during sleep (1.1 mm Hg smaller drop for each additional hour of sleep, P<0.05) after controlling for work shift and race/ethnicity.

Table 1. Mean±SD of ABP and HR by Work Shift

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Day (n=58)</th>
<th>Evening (n=11)</th>
<th>Night (n=24)</th>
<th>Evening+Night (n=35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic ABP, mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake</td>
<td>116.3±8.2</td>
<td>120.8±12.0</td>
<td>116.2±7.0</td>
<td>117.6±8.9</td>
</tr>
<tr>
<td>Sleep</td>
<td>99.4±8.0</td>
<td>109.3±13.7‡</td>
<td>103.5±8.6</td>
<td>105.4±10.6‡</td>
</tr>
<tr>
<td>Awake-sleep*</td>
<td>16.9±6.2</td>
<td>11.5±7.1†</td>
<td>12.6±7.8‡</td>
<td>12.3±7.5‡</td>
</tr>
<tr>
<td>Diastolic ABP, mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake</td>
<td>76.8±6.3</td>
<td>79.4±7.4</td>
<td>75.4±5.2</td>
<td>76.7±6.2</td>
</tr>
<tr>
<td>Sleep</td>
<td>59.7±6.5</td>
<td>66.3±9.0‡</td>
<td>60.8±5.8</td>
<td>62.5±7.3</td>
</tr>
<tr>
<td>Awake-sleep*</td>
<td>17.0±5.6</td>
<td>13.1±4.7†</td>
<td>14.6±5.1</td>
<td>14.1±5.0†</td>
</tr>
<tr>
<td>HR, bpm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake</td>
<td>82.9±8.3</td>
<td>80.3±8.8</td>
<td>79.0±7.3†</td>
<td>79.4±7.7†</td>
</tr>
<tr>
<td>Sleep</td>
<td>68.1±6.9</td>
<td>65.6±7.7</td>
<td>67.9±6.4</td>
<td>67.2±6.8</td>
</tr>
<tr>
<td>Awake-sleep*</td>
<td>14.8±7.0</td>
<td>14.7±4.1</td>
<td>11.1±6.4†</td>
<td>12.2±6.0</td>
</tr>
<tr>
<td>Hours of sleep</td>
<td>6.8±1.1</td>
<td>6.5±2.1</td>
<td>5.6±1.3§</td>
<td>5.9±1.6§</td>
</tr>
</tbody>
</table>

*All means are significantly greater than zero, P<0.001 (paired t test).
Mean is significantly different from mean for day shift employees, †P<0.05; ‡P<0.01; §P<0.001.
| Mean is significantly different from mean for evening shift employees, P<0.05.

Figure 1. Proportion of nondippers by work shift.

Figure 2. Proportion of nondippers by work shift and race/ethnicity.
shift work, race, and diurnal blood pressure

**Table 2. Mean±SD of ABP and HR by Race/Ethnicity and Work Shift**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>African American (n=19)</th>
<th>Evening + Night (n=14)</th>
<th>All Others (n=39)</th>
<th>Evening + Night (n=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic ABP, mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake</td>
<td>119.5±8.0a</td>
<td>121.4±9.5ab</td>
<td>114.7±7.9a</td>
<td>115.1±7.8a</td>
</tr>
<tr>
<td>Sleep</td>
<td>103.6±9.9a</td>
<td>112.8±9.6ab</td>
<td>97.3±6.1a</td>
<td>100.4±8.1b</td>
</tr>
<tr>
<td>Awake-sleep*</td>
<td>15.9±7.2a</td>
<td>8.6±5.0abc</td>
<td>17.4±5.6b</td>
<td>14.8±7.9c</td>
</tr>
<tr>
<td>Diastolic ABP, mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake</td>
<td>80.2±5.4ab</td>
<td>78.2±7.0</td>
<td>75.1±6.1a</td>
<td>75.6±5.5a</td>
</tr>
<tr>
<td>Sleep</td>
<td>64.0±6.8ab</td>
<td>66.1±7.7bc</td>
<td>57.6±5.2ab</td>
<td>60.1±6.0bc</td>
</tr>
<tr>
<td>Awake-sleep*</td>
<td>16.2±5.5a</td>
<td>12.1±3.8ab</td>
<td>17.5±5.6a</td>
<td>15.5±5.3</td>
</tr>
<tr>
<td>HR, bpm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awake</td>
<td>81.4±9.8</td>
<td>77.8±8.8b</td>
<td>83.7±7.4a</td>
<td>80.4±7.0</td>
</tr>
<tr>
<td>Sleep</td>
<td>69.4±9.2</td>
<td>67.4±7.6</td>
<td>67.5±5.5</td>
<td>67.0±6.4</td>
</tr>
<tr>
<td>Awake-sleep*</td>
<td>12.0±5.9b</td>
<td>10.4±6.9</td>
<td>16.1±7.2ab</td>
<td>13.5±5.1</td>
</tr>
<tr>
<td>Hours of sleep</td>
<td>6.2±1.0a</td>
<td>5.9±2.0b</td>
<td>7.1±1.0abc</td>
<td>5.9±1.4b</td>
</tr>
</tbody>
</table>

*All means are significantly greater than zero, P<0.001 (paired t test).

**Table 3. Regression Estimates Predicting Absolute and Relative Change in Awake vs Sleep Systolic BP and Nondipping Status (n=93)**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Awake-Sleep (Absolute), B</th>
<th>1−(Sleep/Awake) (Relative), B</th>
<th>Nondipping (Categorical), Odds Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work shift (evening+night vs day)</td>
<td>−5.43§</td>
<td>−0.046§</td>
<td>6.14§</td>
</tr>
<tr>
<td>Race/ethnicity (African American vs others)</td>
<td>−3.97§</td>
<td>−0.038§</td>
<td>7.11§</td>
</tr>
<tr>
<td>Hours of sleep</td>
<td>−1.13†</td>
<td>−0.009†</td>
<td>NS</td>
</tr>
<tr>
<td>R²</td>
<td>19.8%</td>
<td>23.2%</td>
<td>...</td>
</tr>
</tbody>
</table>

*Odds ratio based on logistic regression analysis.
†P<0.05; ‡P<0.01; §P<0.001.

ethnicity. When predicting relative change, the same predictors were significant; evening+night shift workers had a 4.6% (P<0.001) smaller drop, African Americans had a 3.8% (P<0.001) smaller drop in ABP, and each additional hour of sleep was associated with a 0.9% (P<0.05) smaller drop in BP from awake to sleep. In the logistic regression analysis predicting dipping category, only work shift and race/ethnicity were significant; the odds of an evening+night shift worker being a nondipper were 6.1 times that of a day worker (P<0.001), and the odds of an African American were 7.1 times that of other nurses (P<0.001). Each stepwise regression analysis also tested for possible effects of age and BMI or an interaction effect of race/ethnicity with shift work; none of these tests showed statistical significance. For the absolute and relative measures of dipping, but not the categorical measure, there was a slight trend for the effect of work shift to be greater among African Americans than other nurses (P=0.11 and P=0.09, respectively, after controlling for the factors shown in Table 3).

**Urinary Catecholamines**

The urinary catecholamine excretion rates (transformed to the natural log) of each group during work and nonwork are shown in Table 4. Urinary NE and EP were significantly higher during work than nonwork in day shift workers (P<0.001), but the differences were not significant in the evening+night shift workers (Table 4). This tendency was apparent in both race/ethnicity groups (Table 5): NE was higher during work than nonwork in both African Americans and others who worked the day shift (P<0.05 and P<0.001), and EP was also higher during work than nonwork in others who worked the day shift (P<0.001). However, in evening+night shift workers, the differences between work and nonwork levels were small and in the opposite direction (Table 5). While not statistically significant, the reversal of the usual work versus nonwork difference among evening+night shift workers suggests that the biological circadian rhythm of NE and EP may be as strong or stronger than the effect of activity (work versus nonwork+sleep). In regression analyses predicting NE and EP (natural logs) from race/ethnicity and work shift, only the effect of work shift was statistically significant. The results (not shown) exactly mirrored the comparison in Table 4 of the evening+night shift workers with the day shift workers.

Correlations between urinary catecholamines and BP levels were mostly nonsignificant, but there were some signifi-
Shift Work and BP

The diurnal BP rhythm is mainly determined by the cycle of activities, especially sleep-awake activity, and in humans is largely independent of the circadian clock. Thus, it shows almost immediate adaptation to a shifted phase of activity and sleep, as shown in 3 studies of normotensive workers who rotated shifts.\textsuperscript{11-13} In 2 of these studies, the amplitude of the awake-sleep difference in BP was unaffected by shift work\textsuperscript{11,13}; in the third, the periods of high ABP were longer when subjects worked during the morning or night than when they worked during the afternoon, although the average 24-hour pressures were not very different. These differences may have been due to differences in sleep patterns, which were not reported in this study.

In a study of bakery workers that resembles ours in that each subject was only monitored once, Sternberg et al\textsuperscript{15} found that the awake-sleep difference in mean systolic/diastolic ABP was greater in day workers (15.5/13 mm Hg) than in night workers (7.9/7 mm Hg). In our study evaluating 58 day shift workers and 35 evening+night shift workers, the evening+night workers had a significantly smaller drop in

### Table 4. Mean±SD of Urinary Catecholamine Excretion Rates by Work Shift

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Day (n=54)</th>
<th>Evening (n=9)</th>
<th>Night (n=25)</th>
<th>Evening+Night (n=34)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norepinephrine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>3.17±0.62</td>
<td>2.85±0.45</td>
<td>2.66±0.93†</td>
<td>2.71±0.83†</td>
</tr>
<tr>
<td>Nonwork</td>
<td>2.77±0.58</td>
<td>2.91±0.52</td>
<td>2.81±0.72</td>
<td>2.84±0.66</td>
</tr>
<tr>
<td>Work-nonwork</td>
<td>0.40±0.69*</td>
<td>−0.07±0.71</td>
<td>−0.15±0.97†</td>
<td>−0.13±0.90‡</td>
</tr>
<tr>
<td>Epinephrine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>1.70±0.82</td>
<td>1.47±0.44</td>
<td>1.07±1.23‡</td>
<td>1.18±1.09†</td>
</tr>
<tr>
<td>Nonwork</td>
<td>1.03±0.89</td>
<td>1.34±0.88</td>
<td>1.48±0.94†</td>
<td>1.44±0.91†</td>
</tr>
<tr>
<td>Work-nonwork</td>
<td>0.67±1.10*</td>
<td>0.14±1.01</td>
<td>−0.41±1.17§</td>
<td>−0.26±1.14§</td>
</tr>
</tbody>
</table>

### Table 5. Mean±SD of Urinary Catecholamine Excretion Rates by Race/Ethnicity and Work Shift

<table>
<thead>
<tr>
<th>Outcome</th>
<th>African American</th>
<th>All Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day (n=16)</td>
<td>Evening+Night (n=14)</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>3.03±0.67</td>
<td>2.46±0.91</td>
</tr>
<tr>
<td>Nonwork</td>
<td>2.69±0.57</td>
<td>2.72±0.69</td>
</tr>
<tr>
<td>Work-nonwork</td>
<td>0.33±0.61*</td>
<td>−0.27±0.99</td>
</tr>
<tr>
<td>Epinephrine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>1.54±0.93</td>
<td>0.90±1.39</td>
</tr>
<tr>
<td>Nonwork</td>
<td>1.16±0.79</td>
<td>1.30±0.90</td>
</tr>
<tr>
<td>Work-nonwork</td>
<td>0.37±1.01</td>
<td>−0.40±1.41</td>
</tr>
</tbody>
</table>

Rates are transformed to natural logarithms to reduce positive skewness of distribution. Work/nonwork difference is significantly greater than zero (paired t test), $P<0.05$; $\dagger P<0.001$.

Means for day vs evening+night shift employees of same race/ethnic group differ significantly, $\dagger P<0.05$; $§ P<0.01$.

$\dagger$ Mean for African American evening+night shift employees differs significantly from mean for other day shift employees, $P<0.01$. 

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cant correlations with measures of change. When nondippers were defined categorically, nondippers had a lower work-period NE value ($r=-0.26$, $P<0.02$) and a smaller change in NE from work to nonwork ($r=-0.21$, $P=0.06$). Similarly, when dipper status was defined as the absolute or percent difference in BP, subjects who had a smaller wake-sleep difference in BP had lower EP levels at work ($r=-0.25$, $P<0.03$) and a smaller change in EP from work to nonwork ($r=-0.22$, $P<0.04$). In addition, those who slept longer had a larger drop in EP from work to nonwork ($r=0.22$, $P<0.04$).

### Discussion

The main finding of the present study is that working the evening or night shift alters the normal diurnal rhythm of BP, and perhaps that of urinary catecholamine excretion, that is typically seen in day shift workers. BP follows the cycle of rest and activity rather than the time of day, although the amplitude of the awake-sleep difference is somewhat smaller for evening and night shift workers than for day shift workers. In addition, African Americans are more likely to be nondippers (show a flatter diurnal rhythm of BP) than others.
systolic BP during sleep than day shift workers, largely attributable to higher sleep systolic BP in the evening + night shift group. Our finding that shift work alters the amplitude of the awake-sleep difference in BP is consistent with that of Sternberg et al.\textsuperscript{13} but different from the 3 other previous studies. This may be due to the fact that most of our participants, as well as those of Sternberg et al., had been working their current shift for a prolonged period, whereas in the other 3 studies the subjects were monitored as they rotated to the new shifts. The present study probably also has greater statistical power to detect differences because of its much larger sample size.

The use of a between-subject research design, as opposed to the within-person design used in the first 3 studies,\textsuperscript{12–14} leaves open the possibility that group differences in factors other than work shift might account for the observed differences in dipping. Two possible factors, age and BMI, were examined but were found to be unrelated to both work shift group and dipping.

The earlier studies did not classify subjects as dippers or nondippers. Our results and those of Chau et al.\textsuperscript{12} suggest that the present finding that more evening + night shift workers than day workers were classified as nondippers may be due to the quality of sleep being impaired by shift work, as reflected by the higher sleep BPs in the shift workers. Unfortunately, none of the studies, including ours, obtained subject reports of sleep quality. We did find that the reported duration of sleep was longer in non–African American day shift workers, but longer sleep duration was associated with less dipping rather than more.

The pathophysiology of dipping is poorly understood. Several studies have reported an association between nondipping state and cardiovascular abnormalities and in women, an adverse prognosis.\textsuperscript{26} An underlying assumption of these studies is that an individual’s dipping status is relatively stable, although reproducibility studies have shown that this is not necessarily the case,\textsuperscript{34} and one of the implications of our study is that dipping is influenced by extrinsic factors such as shift work. Clearly, it can also be affected by what happens during working hours, as well as by what happens during sleep.

Race/Ethnicity and Diurnal BP Change
Our study confirms the finding of others that being African American has an independent effect on the diurnal rhythm of BP.\textsuperscript{18–19} James\textsuperscript{4} showed that African Americans had higher BPs during sleep, independent of their perception of work stress. In our data, African Americans also had a smaller drop in sleeping systolic BP than other race/ethnicity groups. Moreover, the odds of an African American being classified as a nondipper were 7.1 times that of someone of another race/ethnicity group, after controlling for work shift. The absence of an interaction effect of race/ethnicity with work shift in the regression analyses (Table 3) indicates that the 2 effects operate independently of each other. This implies that African American women working the evening and night shifts are the group with the smallest drops in BP during sleep, both relative and absolute, and the highest rate of nondipping. Interestingly, this group also has the highest mean levels of both awake and sleep systolic ABP. Future research should examine prospectively the relationship between mean 24-hour ABP and dipping status.

Shift Work and Urinary Catecholamines
The rationale for studying urinary catecholamines in conjunction with ABP in this study was that the sympathetic nervous system is an important mediator of the effects of physical and mental activity on BP and that urinary catecholamines are a marker of the integrated activity of the sympathetic nervous system over prolonged periods. Thus, as mentioned above, the diurnal rhythm of catecholamine excretion and BP normally go hand in hand.\textsuperscript{29}

James et al.\textsuperscript{4} showed that even when women work in similar occupations at the same work site, their cardiovascular responses to the work and home environments can differ substantially depending on how women perceive their environments. James et al.\textsuperscript{4} also found that the diurnal changes in BP and catecholamine excretion were correlated in the work-stressed but not in the home-stressed women, suggesting that the increased catecholamines resulting from work stress drive a day-long sympathetic response that alters BP. In our data, shift work had a profound effect on the catecholamine rhythm. Only the day shift workers showed the normal pattern, with higher excretion rates of NE and EP during the work period. Evening and night shift workers both showed an absence of any increase in catecholamines from the nonwork to work periods. This was the result of both higher excretion rates during the nonwork periods (EP) and lower rates during the work period (NE and EP). It is unlikely that this is due to a lower level of physical activity when working at night as opposed to the day, because the BPs and HRs of the evening and night shift workers were no different while these subjects were on the job than those among the day shift workers. We suspect that there may be an endogenous circadian rhythm (lower at night and higher during the day) that is amplified by an additional increase in excretion rate during work in day shift workers. However, in those who work evenings and nights, the 2 effects would operate in opposite directions, largely canceling each other out. This is consistent with other research showing that the amplitude of the diurnal pattern of catecholamines is reduced in those who stay awake at night.\textsuperscript{29} Given the slight reversal of sign in the work/nonwork difference in excretion rates of those working evenings and nights, we might tentatively infer that the circadian effect is slightly stronger than the work effect. Future research could try to estimate these independent effects.

There are, however, 2 provisos concerning the present catecholamine results. First, the concentration of catecholamines in urine is higher than in plasma and may represent renal synthesis in addition to plasma levels.\textsuperscript{35} Second, the collections of urine during work and nonwork periods in our study overlap but do not coincide with the waking and sleeping periods used to define diurnal BP changes. With respect to the former, it would not have been possible to obtain plasma samples during the course of the work day without (1) disrupting the normal work routine and (2) probably altering the ABP assessments. Despite these limitations, our finding of significant correlations between the
diurnal changes of BP and of catecholamines is consistent with the sympathetic nervous system being a mediator of the effects of situational and behavioral factors on BP.

Conclusion

Being African American and working evening or night shifts are independent predictors of non-dipper status. The higher sleep BP may contribute to the reported adverse effects of shift work. The higher catecholamine excretion rates during sleep that are typical of day workers are not observed in shift workers. This may be due to the counteracting effect of an endogenous circadian rhythm. Future research will be necessary to determine whether the findings of this study can be generalized to men and employees in other occupations.

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