Associations Between Nocturnal Blood Pressure Dipping and the Metabolic Syndrome in High- Vs. Low-Acculturated Mexican American Women

Smriti Shivpuri, Matthew A. Allison, Caroline A. Macera, Suzanne Lindsay, and Linda C. Gallo

BACKGROUND
Less nocturnal blood pressure (BP) dipping has been associated with greater odds for the metabolic syndrome (MetS), a constellation of risk factors associated with cardiovascular disease (CVD). Little work has examined this association in Hispanics, who have elevated rates of MetS, or investigated differences in this relationship by level of acculturation. The purpose of this study was to examine the association between BP dipping and MetS in Hispanic women and to determine if this association is moderated by acculturation status.

METHODS
Two hundred eighty-six Mexican American women underwent assessment of MetS components (BP, waist circumference, fasting glucose, high-density lipoprotein cholesterol, and triglycerides) and completed a 36-hour ambulatory BP monitoring protocol, during which systolic BP (SBP) and diastolic BP readings were obtained. Nocturnal BP dipping was calculated as the percentage difference between average daytime and nighttime BP. Acculturation was defined by the language (Spanish, English) in which participants preferred to complete study instruments.

RESULTS
Although no significant main effects for BP dipping or acculturation emerged for MetS, the SBP dipping by acculturation interaction was significantly related to MetS ($P < 0.01$). Simple slope analyses revealed that less SBP dipping related to greater odds of MetS in high-acculturated women, but SBP dipping and MetS were unrelated in low-acculturated women.

CONCLUSIONS
The strength of the association between BP dipping and CVD risk (as measured by MetS) appears to vary by acculturation in Hispanic women. Future studies should explore mechanisms behind the BP dipping and CVD risk association and relevant modifying factors.

Keywords: acculturation; blood pressure; blood pressure dipping; Hispanic; hypertension; metabolic syndrome.

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Blood pressure (BP) exhibits a circadian variation, with a marked decrease in levels of BP evidenced when sleep is initiated. On average, individuals exhibit a BP decrease (“dip”) of 10%–20% from diurnal to nocturnal hours. However, in some individuals, a nocturnal BP decrease of $<10\%$, or a “non-dipping” pattern has been observed. This blunted decrease in nocturnal BP dipping or nondipping pattern has been associated with increased risk for a variety of morbidities including cardiovascular disease (CVD). Blunted nocturnal BP dipping has also been associated with increased risk for heart failure, myocardial infarction, stroke, and sudden death.

However, how BP dipping relates to more intermediate conditions implicated in the development of the clinical endpoint of CVD is poorly understood. The metabolic syndrome (MetS), which is characterized by the clustering of metabolic abnormalities, including central adiposity, dyslipidemia, elevated BP, and hyperglycemia, provides an early indication of future CVD risk. Some studies have found that MetS is more prevalent in BP nondippers than dippers. However, null relationships have been reported in other studies, and reviews of the literature indicate that overall the findings are inconclusive.

Moreover, the majority of work in this area has been conducted with hypertensive subjects; less is known about the relationship between BP dipping and MetS in normotensive subjects. Additionally, we are aware of no studies that have examined the BP dipping–MetS relationship in Hispanics, who represent the largest and fastest growing ethnic minority population in the United States and also have the highest rates

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of MetS of any US ethnic minority group. Hispanic women in particular, especially those of Mexican descent, are at high risk for MetS relative to their male counterparts and relative to non-Hispanic white women. Thus, identifying factors relevant to understanding MetS in this group is of particular importance. Furthermore, prior research has not considered the effect of acculturation on the relationship between nocturnal BP dipping and MetS. Acculturation (the process of cultural exchange that occurs when two people from distinct cultures come in contact over an extended period of time) has been shown to be related to a variety of sociocultural and behavioral factors affecting disease risk in ethnic minority populations and has been shown to alter relationships between other factors associated with CVD risk.

The aims of the current paper were (i) to examine the association between BP dipping and MetS in Hispanic women and (ii) to determine whether the BP dipping–MetS association differs by acculturation status.

METHODS

Participants and recruitment

This study is part of a larger evaluation of sociocultural factors related to CVD risk in Mexican American women. Participants were randomly selected and recruited through targeted telephone and mail procedures. Women were invited to participate if they were aged 40–65 years, of Mexican descent, literate in English or Spanish, and free of major health conditions (CVDs, treated type 2 diabetes, any treated hypertension or stage 2 or greater untreated hypertension, liver disease, kidney disease, chronic inflammatory conditions, cancer other than nonmalignant skin cancers, major mental health problems) and medications with autonomic effects (e.g., stimulants, steroids, major tranquilizers). Of 321 women in the cohort, 300 (93.4%) provided ambulatory BP monitoring (ABPM) data. Individuals with <3 nighttime BP readings (n = 7), on antihypertensives for the treatment of conditions other than hypertension (n = 2), without waist circumference data (n = 2), and reporting the use of sedatives/hypnotics on the night of BP measurement (n = 3) were also excluded, resulting in a final sample of 286 subjects.

Procedures

A detailed description of the methods has been provided elsewhere. In brief, assessments were conducted during 2 consecutive home visits by trained, bilingual research technicians. Self-report measures of sociodemographic, psychosocial, and behavioral factors were administered in the participant’s preferred language, and a physical exam with fasting blood draw was performed. Participants underwent a 36-hour ABPM protocol as described below. The San Diego State University and University of California–San Diego institutional review boards approved all study procedures.

Blood pressure dipping

ABPM was conducted over 2 consecutive days during the workweek for a period of 36 hours using an oscillometric monitor (90217, Spacelabs; Redmond, WA) that has been shown to meet standards for accuracy and reliability set forth by the Association for the Advancement of Medical Instrumentation. BP was measured every 30 minutes during the day and every 60 minutes during sleeping hours (according to participant-reported sleep and wake times) in dynamic inflation mode with 1 retry for erroneous readings. Artifacts were determined through standard Spacelab default and using commonly applied criteria outlined by Marler et al. Approximately 1% of the data were excluded, which resulted in an average of 52.29 (SD = 8.17) daytime and 7.32 (SD = 1.72) nighttime readings per participant. Participant noncompliance, equipment failure, and sleep and wake times contributed to the varied number of readings across participants. To accommodate the nested data structure (measures within individuals), Hierarchical Linear Modeling 6.06 (Scientific Software International, Lincolnwood, IL) with maximum likelihood estimation was used to compute average daytime and nighttime systolic BP (SBP) and diastolic BP (DBP) for each participant. Nocturnal BP dipping values were calculated according to the standard formula as: (average daytime BP – average nighttime BP)/average daytime BP) × 100. In exploratory analyses, this value was further categorized into those with a nocturnal BP decrease of <10% (nondippers) vs. ≥10% (dippers), according to the commonly employed categorical cutoff for dipping. BP dipping was analyzed continuously in main analyses, to provide a better indication of risk across the BP dipping spectrum, and because the categorical BP dipping cutoff (although predictive of CVD outcomes) has been somewhat arbitrarily defined.

Acculturation

Language of survey battery was used as a proxy for acculturation status. Although a simple representation of the complex, multidimensional acculturation process, language is a reliable indicator that correlates well with scores on more elaborate scales and is considered the strongest single (proxy) acculturation indicator. Those who chose to complete the battery in English were considered more acculturated to US society, whereas those who chose to complete the battery in Spanish were considered less acculturated to US society.

Metabolic Syndrome

Clinic BP and waist circumference were assessed using a standardized protocol based on published guidelines. Assays for lipids (high-density lipoprotein cholesterol and triglycerides) and plasma glucose were conducted by Quest Diagnostics (West Hills, CA), which adheres to guidelines set forth by the College of American Pathologists and the National Heart, Lung, and Blood Institute. MetS was defined according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP/ATP III) criteria, with modifications by the American Heart Association and the National Heart, Lung, and Blood Institute. MetS was defined as the presence of at least 3 of the following: waist circumference ≥ 88 cm; triglycerides ≥ 150 mg/dl; high-density lipoprotein cholesterol < 50 mg/dl; SBP ≥ 130 mm Hg or DBP ≥ 85 mm Hg; and glucose ≥ 100 mg/dl.
Covariables

Covariables were chosen based on their conceptual or biological relevance to predictor and outcomes. Age was calculated as the difference between self-reported date of birth and date of assessment. Educational attainment was categorized as (i) less than 9th grade; (ii) 9th –11th grade; (iii) high school diploma or equivalent; (iv) some college; (v) bachelors degree; and (vi) graduate or professional degree. Monthly gross household income was assessed on an ordinal scale in $500 increments, ranging from <$500 per month to >$8,000 per month. An education/income composite representing socioeconomic status was created by standardizing and summing the variables. For those participants with missing income data (n = 5), education only was used to represent socioeconomic status. Smoking status (i.e., current smoker or nonsmoker) and alcohol use (i.e., current drinker or nondrinker) were also included.

Statistical analyses

Analyses were conducted using SPSS version 17.0 for Macintosh (SPSS, Chicago, IL). All variables were standardized before analysis (mean = 0; SD = 1). BP dipping values were reverse coded, such that greater values represented less nocturnal BP dipping (i.e., greater risk). Binary logistic regression was used to test the relationship between BP dipping (both SBP and DBP), acculturation, and their multiplicative interactions with MetS. Two models were tested: Model 1 included the effects of BP dipping, acculturation, and their interaction, adjusting for age only. Model 2 added adjustment for socioeconomic status, smoking, and alcohol use. Significant BP dipping by acculturation interaction effects evident in the full sample were probed by simple slope analyses by examining relationships between BP dipping and MetS in high- and low-acculturated groups separately.

RESULTS

Table 1 displays descriptive statistics for all study variables, for the overall sample, and for the sample split by MetS status within acculturation groups. Mean age was 49.59 years (SD = 6.57). Prevalence of smoking was low, but greater than half the participants (57%) were current drinkers. The majority of participants (59%) were low in US acculturation (as defined by Spanish language preference). Within the high-acculturated group, individuals with MetS had higher diurnal and nocturnal SBP values, lower SBP dipping percent, and higher nocturnal DBP values (DBP dipping percent was marginally lower at P = 0.06) than those without MetS; no significant differences emerged on any demographic or behavioral variables. Within the low-acculturated group, those with MetS had greater diurnal and nocturnal SBP and DBP.

Table 1. Descriptive statistics for overall sample and by metabolic syndrome status within acculturation groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall (n = 286)</th>
<th>No MetS (n = 96)</th>
<th>MetS (n = 21)</th>
<th>P value</th>
<th>No MetS (n = 128)</th>
<th>MetS (n = 41)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y, mean (SD)</td>
<td>49.6 (6.6)</td>
<td>49 (6.3)</td>
<td>50.1 (5.1)</td>
<td>0.48</td>
<td>49.1 (7)</td>
<td>52.1 (6.3)</td>
<td>0.01</td>
</tr>
<tr>
<td>Educational attainment</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;High school/GED</td>
<td>100 (35)</td>
<td>9 (9.4)</td>
<td>2 (9.5)</td>
<td>0.98</td>
<td>62 (48.4)</td>
<td>27 (65.9)</td>
<td>0.05</td>
</tr>
<tr>
<td>≥High school diploma/GED</td>
<td>186 (65)</td>
<td>87 (90.6)</td>
<td>19 (90.5)</td>
<td></td>
<td>66 (51.6)</td>
<td>14 (34.1)</td>
<td></td>
</tr>
<tr>
<td>Household monthly income</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>&lt;$3,000</td>
<td>117 (41.6)</td>
<td>19 (20.2)</td>
<td>5 (23.8)</td>
<td>0.71</td>
<td>69 (54.8)</td>
<td>24 (60)</td>
<td>0.56</td>
</tr>
<tr>
<td>≥$3,000</td>
<td>164 (58.4)</td>
<td>75 (73.8)</td>
<td>16 (76.2)</td>
<td></td>
<td>57 (45.2)</td>
<td>16 (40)</td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>26 (9)</td>
<td>8 (8)</td>
<td>2 (9)</td>
<td>0.86</td>
<td>10 (8)</td>
<td>6 (15)</td>
<td>0.19</td>
</tr>
<tr>
<td>Current alcohol use</td>
<td>162 (57)</td>
<td>70 (73)</td>
<td>11 (52)</td>
<td>0.06</td>
<td>66 (52)</td>
<td>15 (37)</td>
<td>0.09</td>
</tr>
<tr>
<td>Heart rate</td>
<td>70 (8.4)</td>
<td>70 (8.7)</td>
<td>75 (7)</td>
<td>0.02</td>
<td>70 (8.6)</td>
<td>71 (7.2)</td>
<td>0.56</td>
</tr>
<tr>
<td>Hypertension</td>
<td>6 (2.1)</td>
<td>3 (1.3)</td>
<td>3 (4.8)</td>
<td>0.09</td>
<td>2 (1.2)</td>
<td>4 (3.4)</td>
<td>0.20</td>
</tr>
<tr>
<td>Ambulatory BP, mean (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daytime SBP, mm Hg</td>
<td>119 (11.5)</td>
<td>117 (10.4)</td>
<td>123 (11.6)</td>
<td>0.02</td>
<td>118 (11.7)</td>
<td>125 (11.6)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Daytime DBP mm Hg</td>
<td>74 (7)</td>
<td>75 (7.2)</td>
<td>76 (7.5)</td>
<td>0.34</td>
<td>73 (6.8)</td>
<td>75 (6.5)</td>
<td>0.12</td>
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<tr>
<td>Nighttime SBP mm Hg</td>
<td>103 (10.8)</td>
<td>100 (9)</td>
<td>110 (12.2)</td>
<td>&lt;0.001</td>
<td>103 (11)</td>
<td>107 (10.7)</td>
<td>0.03</td>
</tr>
<tr>
<td>Nighttime DBP mm Hg</td>
<td>62 (6.2)</td>
<td>62 (5.6)</td>
<td>66 (7.9)</td>
<td>&lt;0.01</td>
<td>62 (5.8)</td>
<td>64 (7.1)</td>
<td>0.02</td>
</tr>
<tr>
<td>SBP nocturnal dipping, %</td>
<td>13.2 (6.1)</td>
<td>14.4 (5.6)</td>
<td>10.6 (5.5)</td>
<td>&lt;0.01</td>
<td>12.4 (6)</td>
<td>13.8 (7.1)</td>
<td>0.25</td>
</tr>
<tr>
<td>DBP nocturnal dipping, %</td>
<td>15.6 (6.7)</td>
<td>16.7 (6.6)</td>
<td>13.6 (7)</td>
<td>0.06</td>
<td>15.6 (6.2)</td>
<td>14.3 (7.9)</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Data are No. (%) unless otherwise indicated. Distributions of income and education presented for descriptive purposes; composite of income and education (i.e., socioeconomic status) was used in analyses. Hypertension is defined according to stage 1 hypertension criteria (i.e., systolic blood pressure/diastolic blood pressure ≥140/90 mmHg).

Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; GED, general educational development; MetS, metabolic syndrome; SBP, systolic blood pressure.
greater nocturnal DBP than those without MetS. Those with MetS were also older than those without MetS, and they also tended to have lower educational attainment (P = 0.05).

### Nocturnal BP dipping, acculturation, and MetS

As shown in Table 2, there was no significant association between BP dipping percent (SBP or DBP) or acculturation with MetS (P > 0.05). This was true in both the age-adjusted (model 1) and fully adjusted (model 2) models. However, a significant BP dipping by acculturation interaction was observed for SBP (but not DBP) in relation to the odds of MetS in both models (P < 0.01). To explore this interaction effect, associations between SBP dipping percent and odds of MetS were examined in high- and low-acculturated groups separately (Table 3). In high-acculturated women, each SD decrease in SBP dipping was associated with more than triple the odds of MetS (OR = 3.54; 95% CI = 1.38–9.09). In low-acculturated women, SBP dipping was unassociated with MetS (OR = 0.81; 95% CI = 0.54–1.22). In follow-up exploratory analyses (data not shown), we repeated the analysis presented in Table 3 but examined SBP dipping status categorically (i.e., dippers vs. nondippers). High-acculturated SBP nondippers had almost 4 times the odds of MetS vs. dippers (OR = 3.88; 95% CI = 1.38–10.92; fully-adjusted model). No significant SBP dipping–MetS association was found for low-acculturated women. We also evaluated whether SBP dipping was associated with individual MetS components (i.e., waist circumference, triglycerides, high-density lipoprotein cholesterol, glucose, clinic BP) in high-acculturated women. Results showed that each SD decrease in SBP dipping was associated with greater risk (as defined by increased odds of meeting MetS criteria per NCEP/ATP III guidelines) for waist circumference (OR = 1.80; 95% CI = 1.15–2.81; fully-adjusted model) and high-density lipoprotein cholesterol (OR = 1.82; 95% CI = 1.09–3.03; fully-adjusted model), but SBP dipping was unassociated with other MetS components (see Supplementary Appendix A).

### DISCUSSION

This study is the first (to our knowledge) to examine the relationship between nocturnal BP dipping and MetS in Hispanics. The associations found between blunted SBP dipping and MetS in Hispanics are consistent with previous studies that have suggested a...
dipping and greater MetS risk in high-acculturated women in this study are consistent with findings in other studies conducted in non-Hispanic, hypertensive subjects. Notably, had we only examined associations between SBP dipping and MetS without consideration of acculturation, results would have pointed to no null association. Consequently, the lack of an association found in some previous studies may be because of unmeasured effect modifiers (e.g., acculturation, hypertension status, age, definitional criteria for MetS).

The null association found between DBP dipping and MetS parallels results in some previous work. In general, DBP is less predictive of a variety of CVD outcomes than is SBP. Moreover, DBP levels that are too low have recently been linked to increased CVD risk, perhaps because of decreases in DBP and increases in SBP that occur with aging. Thus, DBP dipping may not have the same linear relationship with CVD risk or risk factors, including MetS, as SBP dipping; however, additional research is needed because the relationship between DBP dipping and CVD risk has been relatively understudied to date.

Effect modification of the BP dipping–MetS relationship by acculturation has not been explored previously. However, acculturation has been shown to alter relationships between other factors associated with CVD risk. For example, as length of residency in the United States increased, the strength of the association between family history of diabetes and MetS prevalence increased in 205 Mexican American patients of a health clinic. In another study, socioeconomic status was negatively related to coronary artery calcification for high-acculturated Mexican Americans but positively related to calcification for low-acculturated Mexican Americans. A positive relationship between psychological stress and insulin resistance was absent for more-acculturated residents of the US Virgin Islands (i.e., native-born African Americans) but present for less-acculturated residents (i.e., African Caribbean immigrants). Consequently, associations between various psychosocial and biological CVD risk factors have been shown to differ by acculturation in complex ways.

Although it is not clear what led to the differing relationship of BP dipping with MetS according to acculturation status in this study, several factors may be relevant. Less BP dipping could be an indicator of increased nocturnal sympathetivae nervous system activity resulting from greater levels of chronic psychological stress. Psychosocial and behavioral factors (e.g., social support, diet, smoking) linked to acculturation could differentially affect the physiological impact of chronic stress on metabolic outcomes, such as MetS. Influences that may differ by acculturation but are unrelated to the pathophysiology of the BP dipping–MetS relationship could also account for observed variations by acculturation status (e.g., physical activity, dietary sodium and potassium, and poorer sleep quality have all been linked with the degree of nocturnal BP dipping). It is important to note that these explanatory mechanisms are speculative. Future research is needed to clarify whether the observed associations among SBP dipping, acculturation, and MetS are stable and, if so, what factors contribute to them.

Findings from the current study signal a complex relationship between nocturnal BP dipping and MetS that requires further study. Despite limited research in the area, several postulated mechanisms for this relationship have been proposed. Hyperinsulinemia has been advanced as a common etiopathogenetic factor in both MetS and BP nondipping. Sympathetic overactivation, which has been implicated in the pathogenesis of blunted BP dipping and is found to be prevalent in individuals with MetS, has also been proposed as an explanatory mechanism. Others have suggested that the link between BP dipping and MetS is due to their common association with morbidities such as obesity and sleep apnea.

Although results of this study are novel, there are limitations to consider. The cross-sectional nature of the design prohibits conclusions regarding directionality. Thus, whether nocturnal SBP dipping leads to greater MetS risk or vice versa cannot be determined. Indeed, the association is likely to be bidirectional in that they may share common etiopathogenetic mechanisms, as noted above. Clarifying the nature and direction of the relationship between BP dipping and MetS will be in the purview of future research using prospective designs. Daytime and nighttime periods were defined based on self-report; more objective methods of specifying sleep/wake periods, such as the use of activity and posture monitoring using actigraphy data, would increase accuracy. Ambulatory BP readings were obtained over a 36-hour time frame that included only 1 sleep period, with nighttime BP readings obtained hourly. The assessment period is greater than the 24-hour duration commonly employed for ambulatory measurement. However, because of the time frame and frequency of BP measurements, the average number of nighttime BP readings obtained was 7, which, although within the number recommended for nocturnal ABPM measurement by the European Society of Hypertension, is on the low end. A 48-hour protocol including 2 sleep periods and/or more frequent BP nighttime assessments would have been preferable to increase the reliability of the nighttime BP average and ABPM dipping calculations. Whether results generalize to men cannot be ascertained because only women were enrolled in this study. Level of acculturation was assessed with a single, commonly used proxy marker. A more nuanced consideration of the association between acculturation and BP dipping/MetS using more detailed measures is an important direction for future work. Although covariables were selectively chosen, it is possible that the small size of the sample in comparison with number of predictors may have led to attenuated power to detect effects. In addition, this study focused on BP dipping; however, other BP information obtained from ambulatory monitoring, such as absolute diurnal and nocturnal BP values, masked hypertension, and white-coat hypertension could be relevant to understanding MetS risk.

In conclusion, findings suggest that blunted nocturnal dipping is associated with greater prevalence of MetS in Hispanic women but only in those who are more highly acculturated to the United States. Results also indicate that this relationship is present even in normotensive, healthy women. Whether the combination of nondipping and MetS confers compounded CVD risk remains to be determined in future research. If the association between BP dipping and MetS is found to be causal in nature or if the combination...
of the two is found to lead to augmented CVD risk in future work, this may eventually inform how and to whom interventions should be targeted to reduce deleterious CVD outcomes for individuals at risk.

**SUPPLEMENTARY MATERIAL**


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**DISCLOSURE**

The authors declared no conflict of interest.

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