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Hostility, Social Support and Nighttime Blood Pressure Dipping

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Abstract

Background: Individuals whose blood pressure (BP) does not drop by 10-20% when asleep are at increased risk for future cardiovascular events and mortality. Psychosocial variables may contribute to non-dipping of BP.

Purpose: To investigate the concurrent and three-year prospective associations of hostility and social support with BP dipping status in healthy, working adult men and women. Whether sex or age moderated these relations was also examined.

Methods: 191 participants at Time 1 and 128 at Time 2 underwent 24-hour ambulatory BP monitoring after completing psychosocial questionnaires and Ecological Momentary Assessments (EMA) over a 3-week period.

Results: Hostility was negatively correlated with systolic BP dipping at both time points in univariate associations only. A Sex by Social Support interaction emerged (β = -.152, p = .037) in the concurrent analyses at Time 1, while an Age by Social Support interaction emerged in the prospective analyses at Time 2 (β = .181, p = .047).

Conclusion: The current results suggest that hostility and social support may influence BP dipping, though the effects appear modest. The impact of social support on BP dipping was particularly dependent on sex and age, such that at Time 1, men appeared to benefit most from social support, while at Time 2, older individuals did. The implications of these findings are unclear at this time and require replication.

Key words: hostility, social support, blood pressure dipping, nondipping, anger, quarrelsome behaviour, rumination, ecological momentary assessments, prospective, ambulatory blood pressure monitors/cuffs, sex differences.

Résumé

Contexte: Les personnes dont la tension artérielle (TA) ne diminue pas de 10 à 20% en période de sommeil présentent un risque accru d'événements cardiovasculaires et de mortalité à venir. Les variables psychosociales peuvent contribuer à un non-diminution de la TA.

Objectif: Étudier les associations simultanées et prospectives triennales d'hostilité et de soutien social avec le statut de TA non-diminuée chez les hommes et les femmes en santé et actifs. Les relations modérées par le sexe ou l'âge ont également été examinée.

Méthodes: 191 participants au temps 1 et 128 au temps 2 ont subi une surveillance ambulatoire de la TA pendant 24 heures après avoir rempli des questionnaires psychosociaux et des évaluations momentanées écologiques (EMA) lors d'une période de 3 semaines.

Résultats: L'hostilité était négativement corrélée avec une baisse de la TA systolique aux temps 1 et 2 dans les associations univariées seulement. Une interaction du Sexe par le Soutien Social a émergé (β = -.152, p = .037) dans les analyses simultanées au temps 1, alors qu'une interaction de l'Âge par le Soutien Social a émergé dans les analyses prospectives au temps 2 (β = .181, p =. 047).

Conclusion: Les résultats suggèrent que l'hostilité et le soutien social peuvent influencer la diminution de la TA, bien que les effets semblent modestes. L'impact du soutien social sur l'abaissement de la TA était particulièrement dépendant du sexe et de l'âge, de telle sorte qu'au temps 1, les hommes semblaient bénéficier davantage du soutien social, tandis qu'au temps 2, c'était les personnes plus âgées. Les implications de ces résultats ne sont pas claires à ce stade et nécessitent d'être reproduits.

Mots clés: hostilité, soutien social, pression artérielle, colère, comportement querelleur, rumination, évaluations écologiques momentanées, moniteurs / poignets de tension artérielle, prospectifs, différences sexuelles.

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List of Abbreviations

ABPM	Ambulatory Blood Pressure Monitors
BARQ	Behavioral Anger Response Questionnaire
BP	Blood Pressure
BMI	Body Mass Index
CAD	Coronary Artery Disease
CVD	Cardiovascular Disease
CMHo	Cook-Medley Hostility Inventory
DAB-VR	Destructive Anger Behavior–Verbal Rumination Questionnaire
EMA	Ecological Momentary Assessments
ND	Nondipping (blood pressure pattern/status)
PSQI	Pittsburgh Sleep Quality Index
SBP	Systolic Blood Pressure
TA	Tension Artérielle

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Introduction

During sleep, blood pressure (BP) typically drops by 10-20% compared to daytime (Fagard, 2009). In some individuals, this reduction in BP is not observed, with hypertensive individuals being 25% more likely than normotensives to show nondipping (ND) BP patterns (Routledge, McFetridge-Durdle, & Dean, 2007). ND increases risk for future target organ damage, cardiovascular events, and mortality in both normotensive and hypertensive (two to five times more likely, respectively) individuals (Ohkubo et al., 2002).

Ambulatory blood pressure monitors (ABPM) make it possible to monitor circadian blood pressure (BP) patterns and evaluate BP dipping status in the day-to-day lives of individuals outside of clinical settings (Wang et al., 2006). Now considered the gold standard approach in the diagnosis and management of hypertension (Pickering, Shimbo, & Haas, 2006), ABPMs minimize measurement errors, and are better predictors of health outcomes compared to those measured in a clinical setting (Sherwood et al., 2002; Verdecchia et al., 1995; 1994; Khattar, Senior, & Lahiri, 1998; Redon et al., 1998; Clement et al., 2003).

The underlying causes of ND remain unclear (Kario, 1996; Routledge, McFetridge-Durdle, & Dean, 2007; Koroboki et al., 2011), though likely reflect contributions from genetic, biological, environmental (Harshfield et al., 2002), and sociodemographic (Campbell et al., 2013) domains. Psychosocial factors (Routledge & McFetridge-Durdle, 2007), such as hostility and social support, may also be involved.

Trait hostility is defined as a three-part construct consisting of cognitive, affective, and behavioural components (Barefoot, 1992). Hostile individuals may show cynical and mistrustful attitudes towards others, experience frequent and intense feelings of anger, and/or exhibit quarrelsome or overt hostile behaviour (Haukkala et al., 2010). Research has shown that

hostility is implicated in the development and progression of cardiovascular disease (CVD; Miller et al., 1996; Everson et al., 1997; Stuart-Shor et al., 2003; Chida & Steptoe, 2009) and hypertension (Diamond, 1982; Rutledge & Hogan, 2002). However, there is far less data on the association between hostility and BP dipping, particularly as it pertains to healthy individuals. Thomas, Nelesen, and Dimsdale (2004) examined the concurrent relationships between BP dipping, hostility, and anger expression in 86 hypertensive men and women of Caucasian and African American descent, weaned off their medication for the study. Anger expression was composed of three subscales; anger-out (expressed toward other people/objects), anger-in (suppressed or held in), and anger control (extent to which individuals attempt to control their anger). Individuals reporting greater hostility, anger expression and anger experience (resentment, suspiciousness) showed less BP dipping compared to other participants, while participants with greater anger control showed more BP dipping. More recently, Mezick and colleagues' (2010) examined sleep-wake BP ratios over 48-hours in 224 participants (m_{age} = 60) with no known life-threatening conditions. Greater hostility was associated with higher sleep-wake MAP ratios (less dipping), independently of age, sex, body mass index (BMI), race, and hypertensive status. In contrast, Linden and colleagues (2008) found no association between cynical hostility and BP dipping (as measured by a difference score between mean nighttime and mean daytime BP) in 62 un-medicated hypertensives.

The few studies that have examined the association of BP dipping status with anger and/or anger management style have obtained mixed findings (Routledge & McFetridge-Durdle, 2007; Linden, Klassen, & Phillips, 2008; Koroboki et al., 2011). For example, letting go of anger and using it constructively (Linden, Klassen, & Phillips, 2008), as well as letting go of guilt or putting the blame on someone else (expressing anger extrapunitively; Koroboki et al., 2011)

were both associated with greater BP dipping; whereas, yelling and overtly fighting with others was not (Pavek & Taube, 2009). Helmers and colleagues (2000) similarly found that holding on to anger, or taking it out on something or someone else had no impact on BP dipping.

Social support has received greater attention in the BP dipping literature compared to hostility. Social support is often examined along two dimensions (Cohen & Wills, 1985). Structural support reflects two key features of an individual's social network: the existence of interpersonal relationships and their degree and frequency of interaction, while functional support reflects the types of interactions or exchanges experienced or perceived with people in their network. Low levels of support, especially functional support, have been shown to predict higher cardiac and all-cause mortality (for a review, see Barth and colleagues; 2010). In a recent systematic review of 11 cross-sectional studies on the associations between structural and/or functional support and nocturnal BP dipping measures, studies examining functional support (five out of seven) generally observed moderate to large positive associations with BP dipping *(*range of *Cohen's d effect sizes*: MAP: 0.58 – 1.43; SBP: 0.41 – 2.01; DBP: 0.65 – 1.22; Fortmann & Gallo, 2013). The findings on structural support are mixed. Results were less consistent when marital status was used as the structural support indicator (Fortmann and Gallo, 2013). According to Fortmann and Gallo (2013), these inconsistencies may reflect differences in how dipping status is measured (with continuous measures such as ratios, yielding stronger associations than dichotomous measures) (Holt-Lunstad, Jones, & Birmingham, 2009; Holt-Lunstad, Birmingham, & Jones, 2008), as well as the quality of the relationships available. Indeed, while married individuals do show slightly more BP dipping than their non-married counterparts overall (Spruill et al., 2009), the reverse can be observed when they appraise their relationship as low quality (Holt-Lunstad, Birmingham, & Jones, 2008).

Hostility and social support are typically examined separately. However, they can influence each other and moderate their effects on cardiovascular outcomes. For example, more hostile individuals may elicit less social support from others (Holt-Lunstad, Smith, & Uchino, 2008; Vella, Kamarck, & Schiffman, 2008). They may also benefit less from the stress-reducing/cardioprotective effects of social support (Holt-Lunstad, Smith, & Uchino, 2008; Uchino & Garvey, 1997), given their difficulty trusting others and worry about being negatively evaluated (Sarafino & Smith, 2014), as well as their tendency to perceive their friends as less friendly (Hold-Lunstad, Smith, & Uchino, 2008).

Although nondippers sometimes show a tendency to manage their anger less effectively, to react more to stress in their environment, and to have less social support (Routledge and McFetridge-Durdle, 2007), to our knowledge, the main and interactive effects of hostility and social support on BP dipping have not yet been examined. Moreover, to date, research in this area has been cross-sectional, limiting the extent to which directionality of effects can be inferred. Samples have typically included only hypertensive individuals, making it difficult to exclude the possibility that the hypertension is contributing to their ND. Investigations have used one-time questionnaires in which individuals are asked to self-report, which can be subject to memory and recall bias (Hassan, 2005), as well as social desirability (Crowne & Marlowe, 1964).

The aim of the current study was to investigate the concurrent and three-year prospective associations between hostility, social support, and BP dipping status in healthy, working adult men and women. The influence of age and sex on the observed relations were examined given mixed findings regarding their respective influences on BP dipping (see review by Routledge & McFetridge-Durdle, 2007) including the differential associations with hostility and BP dipping

(Koroboki et al., 2011) or anger and BP dipping (Helmers, et al., 2000), and social support and dipping (Holt-Lunstad, Jones, & Birmingham, 2009; Rodriguez et al., 2008). Hostility was measured using the Cook-Medley Hostility Scale as well as with ecological momentary assessments (EMA) of quarrelsome behaviour and anger in the participants' day to day living. EMA data enhance ecological validity, and may be a more reliable approach to measuring hostile behaviour and affect during interpersonal interactions (Moskowitz, 1994). We hypothesized that individuals who are more hostile and/or low in support would demonstrate less BP dipping compared to other participants. There is insufficient information in the literature to posit on the direction of influences of age or sex at this time.

Methods

This study was part of a larger project examining the cross-sectional and prospective association of psychological and psychophysiological variables with intermediary coronary artery disease risk factors.

Time 1

Participants. One hundred and ninety-nine healthy working men ($N = 81$) and women ($N = 118$) aged 20-64 years ($M_{age} = 41 \pm 11$ years) were recruited through newspaper and community centre advertisements in the greater Montreal area between 2005 - 2007. Individuals were pre-screened by telephone and invited to participate if they had: (a) not received mental health services 12 months prior, (b) no diagnosed health problems (e.g. asthma, auto-immune disorders, disorders of the adrenal gland, cancer, diabetes, heart disease, hypertension) or use of medication (e.g. anti-inflammatory, statins) capable of affecting cardiovascular, neuroendocrine, and immune functions, (c) no cognitive impairments that could impede their ability to understand instructions or complete questionnaires, (d) not received hormone replacement therapy.

Participants were selected to ensure a broad age distribution for approximately three equal age groups (18-34 years; 35-44 years; 45-65 years). Women were oversampled to ensure a substantial number of post-menopausal participants for a separate part of the larger study not discussed here.

Procedure. Eligible participants were scheduled for 8:00 am weekday laboratory appointments to control for circadian rhythms. Participants were asked to refrain from eating, drinking (save for water), smoking, and strenuous exercising for 12 hours prior to their appointment. They were also asked to refrain from drinking alcohol or other drug use for 24 hours preceding testing. Appointments were rescheduled if participants were unable to adhere to the instructions. Participants were paired with research assistants of the same sex who were trained to maintain a neutral expression and tone throughout testing. After obtaining informed consent, questionnaires were administered to collect sociodemographic, psychological, and medical information. Height, weight, and waist circumference were measured. A blood sample was obtained following a 10-minute rest period. Participants then underwent a stress protocol involving four five-minute interpersonal stressors for a separate component of the study not addressed here (for description of stressors – see Lévesque et al., 2010). Participants were then fitted with an ambulatory blood pressure cuff and ABPM measures were obtained for 24 hours (ABPM schedule described below). A holter was also fitted, and ECG measures obtained over that time period. Participants were further provided with a palm pilot device for 21 consecutive days, and asked to complete electronic forms following any significant interpersonal interactions of at least five minutes in duration, for up to a maximum of 10 interactions per day. Participants were encouraged to sample across various social contexts (home, work, leisure) and times.

Participants were compensated 200$. The study was approved by the research ethics board of the Montreal Heart Institute.

Measures. Data on sex, age, ethnicity, waist circumference, height, body mass index (BMI), years of schooling, personal/family income, marital status, alcohol/tobacco consumption, and physical activity were collected.

BP measures were taken every 20 minutes from 6:00 am - 10:00pm, and every 60 minutes from 10:00pm – 6:00am using Spacelabs Inc. Ambulatory Blood Pressure Monitors (Model 90207-30; Redmond, WA) which use an oscillometric method. Data analyses were conducted on cases for whom at least 70% of recorded BP readings were satisfactory for each period, as per recommendations of the European Society of Hypertension and the European Society of Cardiology Task Force (2013). For nighttime dipping, this represented a minimum of six out of eight hourly measures.

Psychosocial Questionnaires.

Cook-Medley Hostility Inventory (CMHo; Cook & Medley, 1954). The CMHo is a well validated, 50-item true/false questionnaire derived from the MMPI (Smith & Frohm, 1985) and designed to measure the hostile cognitive trait which includes: cynical, mistrustful attitudes, aggression, and anger responses towards others. The CMHo has strong internal consistency (α = .82 -.86) and test-retest reliability (rs > .84). In our sample, the internal consistency was α = .83.

Ecological Momentary Assessments (EMA). This is a well validated method of sampling behaviours from daily interpersonal interactions (Moskowitz, 1994). Computerized, event-contingent forms requested information about context, behaviour, and affect in the social interactions reported. Quarrelsome behaviour and angry affect were of interest for this study.

EMA of interpersonal behaviour. Forty-eight items from the *Social Behavior Inventory* (SBI; Moskowitz, 1994) were used to assess four dimensions of participants' behaviour: dominance, agreeableness, submissiveness, and quarrelsomeness. Each dimension was represented by 12 items. Four forms containing three items for each dimension were rotated on a four-day cycle for the entire three-week duration to guard against developing a response set. Participants were asked to endorse the behaviours that occurred during their social interactions from a list (on the event-contingent form). An example of quarrelsome behaviour is, "I made a sarcastic comment". Frequency scores were then tallied for each behaviour prior to constructing ipsatized scores across the four dimensions. Ipsatizing was used to guard against individual differences in the tendency to endorse all items. Mean ipsatized scores for quarrelsomeness are typically negative suggesting that this event-contingent behaviour is typically lower that mean ipsatized scores of all other interpersonal behaviours taken together.

EMA of angry affect. Participants reported on how they felt at the time of their interpersonal interactions. Nine items (e.g. angry/hostile) were rated on a 7-point Likert style scale from 0 (not at all) to 7 (extremely). Mean intensity scores for the "angry/hostile" affect item averaged over all events and the recording period were used.

Social Support Questionnaire (using an adaptation of the *MOS Social Support Survey*; Czajkowski et al., 1997). The questionnaire was adapted from the MOS (Medical Outcomes Study) Social Support Survey published in 1991and involves seven statements reflecting general examples of functional support. Sample items include: "Someone who shows you love and affection" [or] "Someone you can count on to listen to you when you need to talk". Using a 5-point Likert-style response format, item endorsement level of agreement ranged from "none of the time" to "all of the time". The internal consistency for our sample was .86.

Time 2

Participants. Of the initial sample, 141 participants were re-tested approximately 3 years later (*M*=34.4 ± 3.59 months). Attrition at follow-up was due to the inability to reach the participant (*N*=15), expressed disinterest (*N*=16), perception that testing was too demanding (*N*=4), and conflicting schedules (*N*=15). Moreover, six individuals were excluded for medical reasons including breastfeeding, pregnancy, postpartum, cancer, and sleep apnea. Of the 141 participants, 134 had data necessary for analyses; 128 had valid BP dipping percents at both time points.

Procedure. The protocol was as per Time 1, with the exception that two additional questionnaires were completed.

Destructive Anger Behavior–Verbal Rumination Questionnaire (DAB-VR; Gerin et al., 2006). The DAB-VR is a five-item scale designed to assess individuals' tendencies to engage in angry ruminative thoughts. Sample items include: "After discussing my anger, I hold a grudge" [or] "I continue to dwell on it". The questionnaire has acceptable internal reliability (Cronbach's alpha = .69), and test-retest reliability over a 12-week period. The internal consistency for our sample was .75.

Pittsburgh Sleep Quality Index (PSQI; Buysse, et al., 1989). The PSQI is designed to assess sleep quality during the past month and was added as a control measure for the confounding effects of sleep quality on BP dipping (Loredo et al., 2004). The PSQI is comprised of 19 self-rated questions, combined to form seven component scores. A four-item response scale from "0" (no difficulty) ranging to "3" (extreme difficulty) is used to qualify participants' experience. The seven component scores yield a global score ranging from 0-21 points, where higher scores indicate more severe difficulties with sleep. The PSQI has a high degree of internal

consistency (Cronbach's alpha = .83), and the global and component scores have shown stability over time. The internal consistency for our sample was .89. Sample items include: "During the past month, how many hours of actual sleep did you get at night?" or "During the past month, how would you rate your sleep quality?"

Statistical Analyses

BP dipping was measured as a continuous score [1- (SBP_{night}/SBP_{day}) * 100] for analyses, and as a dichotomous score (<10% drop) for descriptive purposes.

EMA Anger data were square root transformed to meet normality postulates. Other variables were normally distributed.

Potential covariates (medical, sociodemographic, psychological) were drawn from the literature and included in multivariate analyses if they correlated with the SBP dipping ratios at $p \leq .20$. The covariates that were retained included age, sex, BMI, number of children, and number of alcoholic beverages per week.

Pearson correlations were performed to examine the univariate associations between the SBP dipping ratios and the hostility (Cook-Medley Hostility Scale, as well as quarrelsome behaviour and angry affect from EMAs) and social support measures.

To evaluate the moderating influence of age, sex, as well as the interaction of hostility with social support, hierarchical linear regressions was performed separately for the CMHo, Anger, and Quarrelsome behaviour measures of hostility. Age, sex, and other covariates were entered in the first block; hostility and social support were entered in the second block; and the 2-way and 3-way interactions (age, sex, hostility, and social support) were entered stepwise into the third block. Interaction terms were created in SPSS from centered means. Of the 191 valid

cases at Time 1, 184 individuals had complete EMA data for both anger and quarrelsome behaviour.

The same analytic approach was used for the prospective analyses to assess the associations between hostility and social support and dipping percent three years later, with the exception that 3-way interactions were omitted from the third block of the hierarchical analyses given the reduced N. Significant interactions were followed-up using simple slope analysis (Preacher, Curran, & Bauer, 2006). Significance was set at $p < .05$ for both time points.

Results

Sample characteristics are shown in Table 1. Sex differences were noted at both time points in the number of alcohol beverages consumed per week (Time 1: $p = .001$; Time 2: $p = .012$), and the number of hours exercised per week (Time 1: $p = .001$; Time 2: $p < .001$).

Slightly more than 50% of the sample had a non-dipping status in the current manuscript.

Univariate associations between SBP dipping status, hostility, and social support

Table 2 shows the correlations between the hostility dimensions, social support, and SBP dipping percent. In summary, more (cynically) hostile individuals showed less SBP dipping at Time 1 but not at Time 2. Anger experienced in daily life, was for its part, associated with more dipping three years later, but not at the first evaluation. SBP dipping was not significantly associated with quarrelsome behaviour or social support.

Examining the independent and interactive effects of hostility and social support, on SBP dipping status at Time 1

Cynical Hostility. The hierarchical analysis using the CMHo measure of hostility revealed a significant Sex by Social Support interaction (Figure 1). No main effects of hostility or social support emerged. Table 5 shows the final model details. Simple slope analyses

indicated that greater perceived social support was associated with more SBP dipping in men (β = 0.1796, t =1.4517, p = .148) but not in women, in whom the opposite relation was observed (β = -0.1816, t =-1.4678, p = .144).

Using EMA measures of Quarrelsome Behaviour and Anger produced identical results.

Quarrelsome Behaviour. The main effects of Quarrelsomeness (β = .014, t = .190, p = .849) and social support (β = .008, t =.111, p = .911) were non-significant, but the Sex by Social Support interaction was significant (β = -.149, t = -2.031, p = .044). The interaction was not explored further, as it was already described above.

Anger. The main effects of Anger (β = .045, t = .616, p = .539) and social support (β = .014, t = .194, p = .846) were non-significant, but the Sex by Social Support interaction was significant (β = -.148, t = -2.007, p = .046). The interaction was not explored further, as it was already described above. Results were unaltered in the absence of covariates.

Predicting SBP dipping percent at Time 2

Cynical Hostility. No main or interaction effects emerged for cynical hostility or social support.

Quarrelsome Behaviour. No main or interaction effects emerged for quarrelsome behaviour or social support.

Anger. A trend emerged for the Anger main effect (β = .170, t = 1.920, p = .057, r = .166). Individuals who reported more anger in their daily interactions at Time 1 tended to exhibit more SBP dipping three-years later.

Results were similar when no covariates, other than age and sex were added to the model.

Posthoc analyses

At follow-up evaluation, (angry) rumination and sleep quality were also measured. Rumination correlated with hostility (r = .446, p < .001), and daily anger (r = .168, p = .064). Sleep quality correlated with hostility (r = .242, p = .006), social support (r = -.196, p = .027), and daily anger (r = .198, p = .029). Sleep quality was not significantly related with Time 2 SBP dipping (r = .124, p = .163).

The hierarchical regressions predicting 3-year SBP dipping percent values were redone with rumination and sleep quality as additional covariates in block 1. Again, no main effects emerged for (cynical) hostility and social support. However, a significant Age by Social Support interaction emerged for SBP dipping. See Table 4 for details of the final model. Simple slope analyses revealed that greater perceived social support was associated with more SBP dipping in older participants (b = 0.2206, t =1.76, p = .080) but not in younger participants, in whom no relation was observed (b = -0.0926, t = -0.53, p = .599; Figure 2).

Discussion

The goal of the current study was to examine the concurrent and prospective associations of hostility (cynical hostility, quarrelsome behaviour, and daily anger) and social support with SBP dipping in a sample of healthy working men and women. While hostility was correlated with SBP dipping at both time points, the relations were not robust (no longer significant in multivariate analyses) and differed in the timing and direction of effect according to the dimension of hostility measured. The relation between social support and SBP dipping was dependent on sex in concurrent analyses and with age in prospective analyses.

Individuals who were more cynically hostile at the baseline evaluation showed less SBP dipping at night. However, in the multivariate analyses, cynical hostility was no longer a

significant predictor of SBP dipping. Linden and colleagues (2008) had similarly reported no significant association between cynical hostility (using the Cook-Medley Hostility Scale) and SBP dipping in diagnosed hypertensives weaned off medication for the purposes of their study. In contrast, using different hostility questionnaires, Thomas and colleagues (2004) and Koroboki and colleagues (2011) reported that individuals high in hostility showed less SBP dipping. Whether conflicting results represent methodological differences relating to the measure of hostility or sample characteristics is currently unclear.

In contrast with cynical hostility, anger predicted more SBP dipping three years later (but not concurrently) in the present study. This remained a trend in multivariate analyses. For their part, Thomas and colleagues (2004) reported that individuals high on reported anger showed less BP dipping using the anger expression styles inventory (Spielberger, Krasner, & Solomon, 1988). Pavek and Taube (2009) similarly found that healthy middle-aged men higher on verbal aggression demonstrated decreased SBP dipping. Linden and colleagues (2008) postulated that the way a person copes with their anger may be more influential to BP dipping than anger levels themselves. They utilized the Behavioral Anger Response Questionnaire (BARQ; Linden et al., 2003) to assess how anger is managed across six subscales, in a sample of 62 adults (30 nondippers), weaned off all medications for the study (*M*age = 57). They reported that individuals who are more proactive in working off their anger (high on the anger diffusion subscale) demonstrated more SBP dipping. In the current study, anger management style was examined to some extent using the anger rumination questionnaire (at Time 2). Individuals who described a greater tendency to ruminate over their anger showed less SBP dipping, though this relation did not reach significance in analyses. Given that anger is a charged emotion that can fluctuate with situational demands, as well as, how individuals feel, express, and/or manage their

anger, it appears to be an interesting target for intervention to help improve health outcomes. More specifically, anger management techniques and psychoeducation can help individuals to recognize their anger and have the choice to proactively work it off in a constructive manner (e.g. gardening, cooking, reading, etc.) rather than ruminating over what made one angry during the day. Channelling anger constructively can facilitate diffusion of the charged emotion (Linden, Klassen, & Phillips, 2008), likely resulting in reduced physiological arousal and a more rapid recovery, which could facilitate improved BP dipping later that night.

Findings relating to social support in the current study were also unexpected. A recent metanalytic review of the literature had shown consistent positive associations between social support and blood pressure dipping (Fortman & Gallo, 2013). For example, relationship closeness (depth of a relationship), a type of functional support, was shown to be a significant predictor of SBP dipping, in a similar sample size of healthy men and women (303 normotensive and un-medicated hypertensives, aged 20-68 years), independent of sleep quality, age, hypertensive status, marital status, and level of perceived network support (Holt-Lunstad, Jones, & Birmingham, 2009). However, in the current study, social support was found to predict SBP dipping only in subgroups of individuals. Specifically, sex moderated the association between social support and SBP dipping at baseline. The more social support the men reported having, the more SBP dipping they were likely to exhibit. Social support did not appear of additional benefit to BP dipping in women. A study by Spruill and colleagues (2009) also examined sex differences between SBP dipping and marital status (a structural social support indicator) in a sample of normotensive and mildly hypertensive individuals and found that being married was associated with significantly more dipping in men than in women irrespective of race.

Much of the social support and health literature has suggested that men tend to report less social support compared to women and, for men, their primary support often comes from their spouse or partner (Umbersom & Montez, 2010). On the other hand, in partnered relationships, men tend to experience fewer costs pertaining to childrearing, caring of aging parents, and spousal caregiving (Umbersom & Montez, 2010). While women may have wider support networks than men (Antonucci & Akiyama, 1987) they may also experience more strain resulting from the demands placed on them by their more extensive network, particularly when their personal resources become depleted (Walen & Lachman, 2000). Indeed, women often take on the burden of care in their networks (Rook, Dooley, & Catalano, 1991), which can lead to reduced benefits of social support on their health. Thus, it may be that men who report similar levels of available social support as women (as was observed in our sample), are reaping additional health benefits because of fewer demands placed on them. Finally, it may be possible that, while men and women rate the availability of support similarly, the actual support received may have differed considerably between the sexes and influenced the results obtained here.

Age further moderated the relation between social support measured at baseline and SBP dipping obtained at the three-year follow-up. To our knowledge, this is the first study to report the moderating effect of age between social support and SBP dipping. However, this was observed only when sleep quality and anger rumination were further controlled for in the post hoc analyses. In this case, social support at baseline was associated with more SBP dipping at follow-up among older participants. Given that increasing age has been associated with a greater likelihood of having a nondipping BP profile (Helmer et al., 2000; Staessen et al., 1997), the current results may suggest that having access to, or at least perceiving more social support in one's life may help guard against (or slow down) the age-related reduction in BP dipping among

older individuals. This is consistent with research showing that social support among older individuals is related to self-reports of greater physical and mental health compared to those with less social support (Umberson & Montez, 2010). Alternatively, younger individuals (under 45 years of age in the current sample) may be benefiting less from social support, given the professional and family demands that they may be exposed to during this phase of their life. In sum, they may benefit less from social support by having less time available to be social.

The findings obtained in the current manuscript may reflect the peculiarities of the sample that was recruited. Indeed, although non-dipping of blood pressure during sleep occurs within normotensive populations, it was unexpected to have a sample comprised of more nondippers (54.5%) than dippers at both the outset and at follow-up. Such a high prevalence of non-dipping may reflect a bias introduced by the methodology of the study. Specifically, participants were fitted with an ABPM and a holter (for a separate part of the study not addressed here) for the 24-hour period. It is possible the combined equipment was cumbersome and may have contributed to a less restful sleep. Sleep disruption and more frequent waking may have limited the extent to which BP could decrease at nighttime, particularly in individuals habituated to sleeping undisturbed. This may explain the unexpected finding in the posthoc analyses that better sleep quality was associated with less SBP dipping. Individuals who typically sleep well may have been more sensitive to the disruptive effects of the equipment on their sleep. Furthermore, the use of arbitrary sleep times (10pm – 6am rather than self-reported sleep times) to denote nighttime BP may have also contributed to the categorization of more participants into a non-dipping status. While comparisons of standardized sleep times versus self-reported sleep-awake times to measure BP dipping have found no significant prognostic differences for health outcomes (Verdecchia and colleagues, 2008; Hold-Lunstad and colleagues, 2009), the use of true

sleep times may result in fewer people being categorized as non-dippers (Hold-Lunstad and colleagues, 2009). Nonetheless, most research studies on BP dipping to date have reported using standardized times such as 10pm – 6am, or 12am – 6am which encompass the times most people are in bed.

In contrast to many investigations on BP dipping that have studied borderline and diagnosed/medicated hypertensives, the current study sought individuals who were very healthy. Consequently, our sample had BP values at the lower range of normal. Floor effects may have limited the extent to which BP could further decrease during the night. Moreover, the very healthy status of our sample, particularly our older participants, may have led to the inclusion of individuals who were more resilient to the effects of hostility and reduced social support on their health. In addition, participants were mostly French speaking and Caucasian. Generalizability may not be possible to other populations. The sample size at follow-up was relatively small and may have limited the power to detect significant associations. Finally, other variables which may impact BP dipping, such as undiagnosed sleep apnea (Routledge & McFetridge-Durdle, 2007), were not considered in the current study.

On the other hand, this study used rigorous methodology and is one of the first to draw upon a relatively large, heterogenous, and healthy population, defacto ruling out the possibility that health problems, including hypertension, are contributing to either hostility and/or nondipping. The multidimensional measurement of hostility, including angry rumination at Time 2, as well as, two measures of EMA data shown to be more ecologically valid, was assessed. Furthermore, dipping was examined at two time points, while controlling for numerous covariates to rule out their impact on the observed associations.

In conclusion, the current results suggest that hostility and social support may influence BP dipping, though the effects were modest and influenced by other variables, particularly, age and sex. These findings were consistent with some but not other studies on the topic. The research on BP dipping is very heterogeneous with respect to methodology, and would benefit from standardization of approach with respect to participant sampling, choice of questionnaires, ABP monitors, and manner of operationalizing nondipping. This may yield more consistent findings and contribute to improved guidelines for health care management. Given that for every 5% decrease in BP dipping (for both normotensive and hypertensive individuals), there is a 20% increase in cardiac mortality (Ohkubo et al., 2002), continued research in the area is warranted. Clinical interventions aimed to improve cardiac health outcomes by encouraging modifiable behaviours (e.g. reducing hostile interactions and effectively managing anger) and providing psychoeducation on the importance of social support to health across the lifespan can be provided. Educational pamphlets could be made available in doctors' and psychologists' offices with links to interactive websites that can teach individuals about what factors and behaviours can promote improved health and wellness.

Conflict of Interest Statement

The authors have no conflict of interest to report.

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Tables

Table 1. Participant characteristics at initial recruitment

	Mean (SD)
Demographic variables	
Age (years)	41.17 (11.56)
Female *n* (%)	111 (58.11%)
Caucasian *n* (%)	167 (87.43%)
Body Mass Index (kg/m^2)	24.95 (4.90)
Years of schooling	15.85 (3.42)
Marital Status *n* (%)	
Single	84 (43.98)
Married/living with someone	77 (40.31)
Separated/divorced/widowed	30 (15.71)
Annual family income *n* (%)	
≤ $29,999	84 (43.98%)
$30 000-59 999	86 (45.03%)
≥ $60 000	21 (10.99%)
Behavioural and medical variables	
Smoker *n* (%)	40 (20.94%)
Alcohol (beverages/week) *	3.64 (5.02)
Exercise (hours/week) *	3.43 (4.30)
Employed full-time *n* (%)	135 (70.68%)
Daytime SBP (mmHg)	117.16 (9.62)
Nighttime SBP (mmHg)	106.80 (10.59)
Psychological Variables	
Cook-Medley Hostility Score	18.96 (7.72)
Social Support	20.78 (5.13)
Anger (*n* = 184)	.51 (.53)
Quarrelsome (*n* = 184)	-.19 (.07)
Non-Dippers N (%)	
Time 1 (*n* = 191)	104 (54.45)
Time 2	75 (58.60)

N = 191 at Time 1; * statistically significant sex differences were noted.
Percentage of nondippers at Time 2 (58.60%) were from a total sample of *n* = 128.

Table 2. Univariate correlations (and p-values) between SBP dipping percents and the hostility and social support measures at Time 1 and Time 2

	Time 1 SBP Dipping %	**Time 2 SBP Dipping %**
Independent Variables	***r* (p-value)**	***r* (p-value)**
Cook-Medley Hostility	-.147 (.043)	-.088 (.321)
Social Support	.014 (.851)	.087 (.326)
Anger Daily [1]	.055 (.458)	.179 (.049)
Quarrelsome Behaviour [1]	-.025 (.738)	.026 (.780)

[1]Anger Daily and Quarrelsome Behaviour measures had fewer participants; T1: n =184 and T2: n =122, respectively.

Table 3. Details of the hierarchical regression analysis results of SBP dipping percent at Time 1

Final model	β	t	*p*	95% C.I.	semi-partial *r*
Age	.096	1.174	.242	-.034; .135	.082
Sex	.017	.229	.819	-1.564; 1.975	.016
BMI	-.203	-2.793	.006	-.428; -.074	-1.95
Number of children	.103	1.341	.182	-.280; 1.470	.094
Alcohol beverages/week	-.083	-.1.105	.271	-.277; .078	-.077
Cynical hostility	-.123	-1.642	.102	-.212; .019	-.115
Social Support	-.001	-.017	.987	-.173; .171	-.001
Sex * Social Support	-.152	-2.100	.037	-.709; -.022	-.147
$F_{model}(8, 182) = 2.844$, $p = .005$					
$R^2_{model} = .111$, $R^2_{adj} = .072$					

N = 191.

Table 4. Details of the hierarchical regression analysis results of SBP dipping percent at Time 2

Final model	β	t	*p*	95% C.I.	semi-partial *r*
Age	.083	.861	.391	-.058; .146	.073
Sex	-.004	-.043	.965	-2.302; 2.203	-.004
BMI	-.137	-1.527	.129	-.471; .061	-.129
Number of children	.163	1.743	.084	-.130; 2.048	.148
Alcohol beverages/week	-.141	-.1.593	.114	-.382; .041	-.135
Sleep quality	.184	2.042	.043	.011; .681	.173
Rumination	.017	.170	.865	-.390; .463	.014
Cynical hostility	-.073	-.707	.481	-.234; .111	-.060
Social Support	.073	.791	.430	-.127; .297	.067
Age * Social Support	.181	2.003	.047	.000; .038	.170
$F_{model}(10, 117) = 2.263$, $p = .019$					
$R^2_{model} = .162$, $R^2_{adj} = .090$					

N = 128.

Figure Legend

Figure 1. Sex by Social Support Interaction at Time 1. The concurrent association between SBP dipping and Social Support is moderated by Sex. $N = 191$; Greater perceived social support was associated with more SBP dipping in men ($b = 0.1796$, $t = 1.4517$, $p = .148$). The opposite relation was observed in women ($b = -0.1816$, $t = -1.4678$, $p = .144$). Interaction: $b = -.152$, $p = .037$.

Figure 2. Age by Social Support Interaction at 3-year Follow-up. The prospective association between SBP dipping and Social Support is moderated by Age. N = 128; Greater perceived social support was associated with more SBP dipping in participants ≥ 45 years ($b = 0.2206$, $t = 1.76$, $p = .080$). This was not observed in participants < 45 years ($\beta = -0.0926$, $t = -0.53$, $p = .599$). Interaction: $b = .181$, $p = .047$.

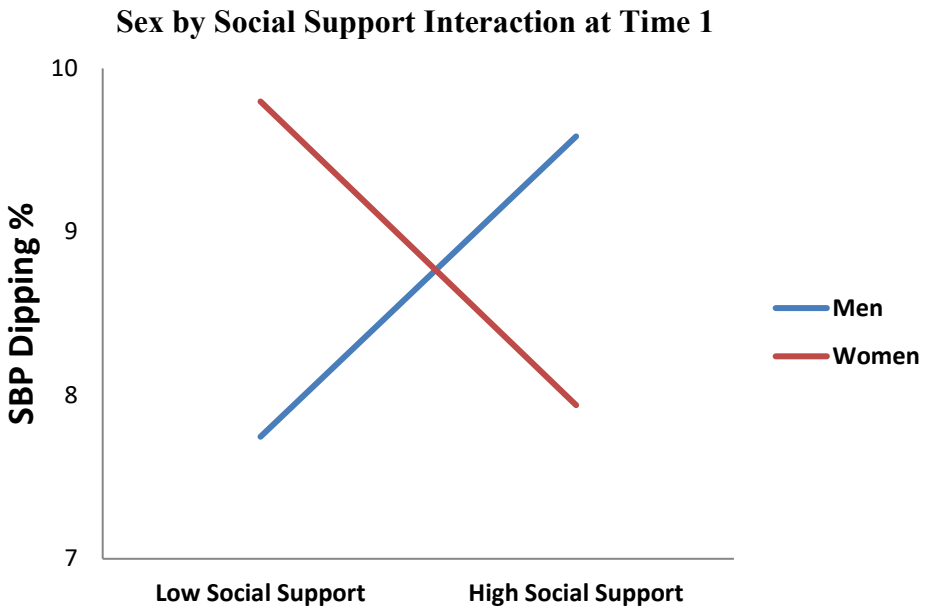

Fig. 1. $N = 191$; Greater perceived social support was associated with more SBP dipping in men ($b = 0.1796$, $t = 1.4517$, $p = .148$) at Time 1. The opposite relation was observed in women ($b = -0.1816$, $t = -1.4678$, $p = .144$). Interaction: $b = -.152$, $p = .037$.

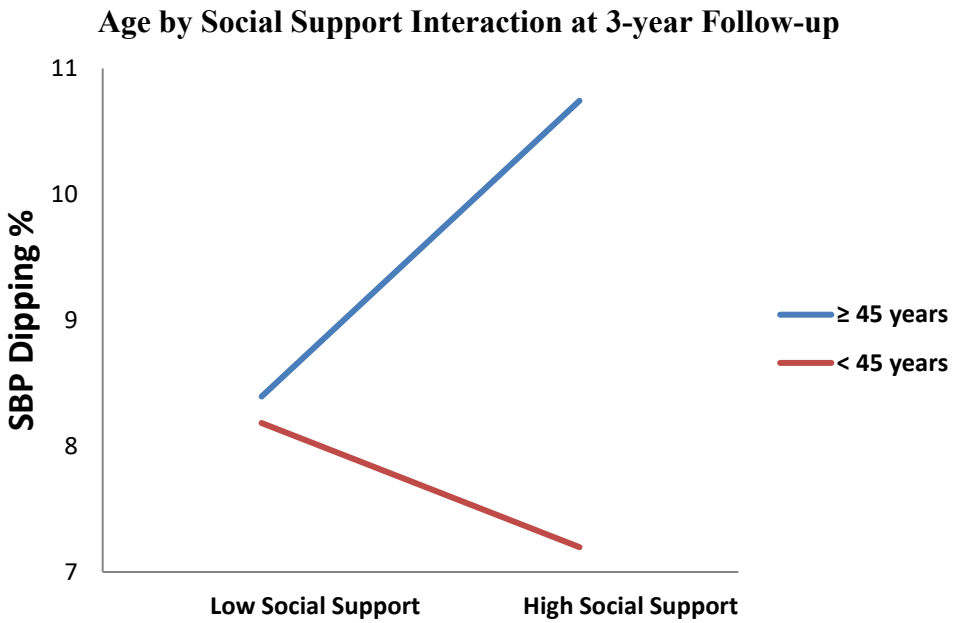

Fig. 2. N = 128. Greater perceived social support was associated with more SBP dipping in older participants (b = 0.2206, t =1.76, p = .080) at 3-year follow-up. This was not observed in younger participants (b = -0.0926, t = -0.53, p = .599). Interaction: b = .181, p = .047.