Do Cardiovascular and Neuroendocrine Measures Mediate the Association between Trait Hostility and the Metabolic Syndrome?

by

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Objective: A consistent body of evidence links trait hostility with the metabolic syndrome (MS), a clustering of cardiometabolic risk factors. Previous research has suggested a three-factor solution for trait hostility involving cognitive, affective, and behavioral components, however, few studies have assessed which component is most important in the prediction of health outcomes. The mechanisms linking hostility with metabolic syndrome are also relatively unexplored, although biological pathways have been implicated. The purpose of this study is to address each of these two gaps in the existing literature. ***Methods***: Four hundred and ninety-three adults from a community sample completed trait hostility questionnaires. Participants collected biological samples and wore ambulatory devices during a four-day monitoring period. ***Results***: Contrary to prior work, we failed to show a three-factor solution using hostility questionnaire subscales. Exploratory factor analyses yielded a revised 4-factor solution using 21 items of the Buss-Perry Aggression Questionnaire (BPAQ), a multidimensional hostility questionnaire. Path analyses adjusted for demographic variates demonstrated that Physical Aggression (b = .019, 95% CI [.005 to .033], p = .041) was significantly associated with the standardized MS (zMS) but not dichotomous MS (diMS). This association became non-significant when controlling for lifestyle variables and BMI. Interaction tests reveal that these results may be limited to women. No associations emerged between Verbal Aggression, Hostility, or Anger. Standardized, aggregated lifestyle variables but not psychophysiological markers significantly mediated the

four BPAQ subscales and MS outcomes. ***Conclusions***: The original factor solution may have failed to replicate because this is the first known attempt to exhibit a hostility factor solution in a healthy, community adult sample. Physical aggression in healthy women may be associated with an increased risk for the metabolic syndrome, although further research is necessary to understand this relationship. Our findings advance the field by showing that aggregated lifestyle behaviors but not psychophysiological reactivity markers may mediate the association between hostility and MS. Future research may assess the relationship between the hostility components to other health outcomes (e.g., IMT, mortality) and other mediation effects (e.g., social support).

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1.0 BACKGROUND AND SIGNIFICANCE

1.1 HOSTILITY AND THE METABOLIC SYNDROME

Growing evidence suggests that individuals high in hostility, defined as a psychological characteristic which involves behavioral tendencies (aggression), cognitive biases (cynicism), and affective states (experience of frequent and intense anger), are at higher risk for metabolic syndrome, a cluster of cardiovascular risk symptoms including insulin resistance, hyperinsulinemia, glucose intolerance, dyslipidemia, central obesity, and hypertension that is estimated to be present in up to 40% of the adult population (Goldbacher & Matthews, 2007). A meta-analysis of 27 studies found that those with higher hostility scores from the frequently used Cook-Medley Hostility Scale had elevated triglycerides (Hedges' g = .10), blood glucose concentrations (g = .14), waist-to-hip ratio (g = .25), and lipid ratio (g = .20; Bunde & Suls, 2005). The metabolic syndrome is a strong correlate of the increased cardiovascular risk shown among hostile individuals. Past research has shown that hostility and metabolic syndrome are each associated with cardiovascular disease (CVD) occurrence and mortality (Lakka et al, 2002; Miller et al., 1996; Wilson et al, 2005; Malik et al, 2004, Rozanski, Iumenthal, & Kaplan, 1999; Smith & Ruiz, 2002; Barefoot et al., 1983), and although the literature is not entirely consistent in this respect (Niaura et al, 2002), some evidence suggests metabolic syndrome may, in fact,

partially mediate the association between hostility and cardiovascular disease as well (Nelson, Palmer, & Pedersen, 2004; Räikkönen et al, 2004).

Although this relationship between hostility and metabolic syndrome is well established, the mechanisms linking these two constructs are less well understood. The psychophysiological reactivity model is one compelling model that outlines possible biological pathways linking hostility and health (Smith et al., 2004). The psychophysiological reactivity model posits that, as hostile individuals are prone to experience more frequent and intense anger than their nonhostile counterparts, they may consequently show heightened cardiovascular (e.g., blood pressure) and neuroendocrine (e.g., epinephrine, cortisol) responses to potential stressors, with these responses, in turn, being linked with increased health risk.

1.2 HOSTILITY AND PSYCHOPHYSIOLOGICAL MARKERS

Cardiovascular reactivity, defined as the physiological changes from a resting or baseline state to a psychological or physical challenge or stressor, has been the most frequent source of evidence used to test the psychophysiological reactivity hypothesis. Numerous laboratory studies involving populations ranging from undergraduates to middle age subjects have shown that high hostile subjects exhibit exaggerated systolic blood pressure (SBP) and diastolic blood pressure (DBP) during interpersonal provocation compared to their low hostile counterparts (Frederickson et al., 2000; Smith & Allred, 1989; Hardy & Smith, 1988). Early research also found that the type of stressor exposure is important, such that responses to nonsocial stressors between high and low hostile groups (i.e., cold pressor and mental arithmetic stressor tasks) appear to be

equivalent (Sallis et al., 1987; Suarez et al, 1998). For instance, hostility individuals show larger cardiovascular responses to conflictual marital interactions, a frequently employed interpersonal stressor, relative to their nonhostile counterparts, especially among men (Miller et al, 1999; Malarkey et al, 1994).

In addition to the work showing elevated responding among hostile individuals in laboratory settings, patterns of elevated physiological reactivity among high hostile individuals have also been demonstrated in field studies through ambulatory assessments. In this work, individuals high in hostility have shown elevated systolic blood pressure in response to daily social interactions (Brondolo et al, 2009; Guyl & Contrada, 1998) relative to their low hostile counterparts. This exaggerated blood pressure reactivity during daily life may be especially relevant to the hypothesized relationship between hostility and disease development.

Measures of stress-related reactivity in these literatures are believed to be mediated by the two stress systems of the body: the hypothalamus-pituitary-adrenal (HPA) axis and the sympathetic-adrenomedullary (SAM) axis. The HPA axis is involved in a complex negative feedback loop regulating a neurochemical product of the HPA, glucocorticoids (Nicolson, pg. 38). Found in most cells of the body, glucocorticoid receptors are involved in widespread homeostatic effects on bodily functions, ranging from metabolism (e.g., elevating blood glucose levels following food ingestion), blood pressure regulation, inflammation, and neurogenesis (Dickerson & Kemeny, 2004; Herbert et al., 2006). The most frequently studied neuroendocrine marker of the HPA axis is the glucocorticoid cortisol. Although increased cortisol secretion is considered to be an adaptive mechanism when stressed, chronically abnormal levels, such as elevated daytime secretion or a flat decrease trajectory across the waking day, are believed to be indicative of negative health states or disease. Dysregulation of the HPA axis has been associated

with clinical endpoints such as atherosclerosis (Matthews, Schwartz, Cohen, and Seeman, 2006), and CVD and all-cause mortality (Kumari, Shipley, Stafford, & Kivimaki, 2011). Consistent with the psychophysiological reactivity model, cortisol may be another biomediator linking hostility to health. Hostile individuals have been shown to have elevated urinary cortisol collected across daytime hours (Pope & Smith, 1992) and flattened slope of cortisol across the day (Sjogren, Leanderson, & Kristenson, 2006). Hostile individuals may have altered HPA profiles that predict health outcomes.

In addition to the HPA axis, another regulatory stress system is believed to be the sympathetic-adrenomedullary (SAM) axis, which is the structural pathway of the autonomic nervous system that responds acutely to stressors and homeostatic changes through regulation of cardiovascular, respiratory, gastrointestinal, retinal, endocrine and other systems (Tsigos & Chrousos, 2002). The adrenomedullary hormones epinephrine and norepinephrine activate at alpha and beta adrenoreceptors found throughout the body, and these circulating catecholamines stimulate short-term, adaptive physiological changes, including increases in blood pressure, heart rate, and glucose levels. However, excessive and prolonged SAM activation is believed to have maladaptive health consequences. Animal models have shown that increased SAM activity contributes to the development of atherosclerosis through endothelial damage and increased platelet accumulation, whereas these effects were inhibited by beta-adrenergic blocking agents (Kaplan et al., 1991). Higher risk for mortality and functional decline across seven years was found among subjects with high baseline urinary excretion of epinephrine and norepinephrine in a sample of 765 high-functioning, older adults (Reuben et al., 2000). It is believed that heightened catecholamine levels, markers of SAM activation, contribute to these risk factors and later disease development. To our knowledge, there is no published evidence linking trait

hostility with circulating catecholamines in adults. Nevertheless, evidence from studies of hemodynamic reactivity and circulating cortisol, cited above, is thought to be consistent with the psychophysiological reactivity model linking hostility and health.

1.3 PSYCHOPHYSIOLOGICAL MARKERS AND THE METABOLIC SYNDROME

The explanatory variables depicted in the psychophysiological reactivity model have been shown to be associated with the metabolic syndrome, thus providing some support for these models in explaining the link between hostility and the metabolic syndrome. The strongest evidence links cortisol secretion with the metabolic syndrome. Cushing's syndrome, an endocrine disorder resulting from endogenous or exogenous hypercortisolism, usually due to prolonged use of steroid medications or adrenal gland abnormality, has characteristics that resemble the metabolic syndrome, including abdominal obesity, high triglycerides, low HDL cholesterol, hypertension, and hyperglycemia (Anagnostis, 2009, Walker, 2006). Given these similarities, we might extrapolate that heightened cortisol in the general population may also contribute to the pathogenesis of the metabolic syndrome. Indeed, research has shown that in a sample of 183 midlife adults, individuals with metabolic syndrome have higher levels of urinary cortisol metabolites when compared to normal individuals (Brunner et al, 2002), and in another a study of 205 older adult males, those with higher peak urinary cortisol concentrations had a 28% increased risk for having the metabolic syndrome (Reynolds et al, 2001). The endocrine function of cortisol secretion is thought to explain its impact on the metabolic syndrome. Cortisol has been demonstrated to be important in glucose neogenesis (Khani & Tayek, 2001), blood

pressure, and lipid deposition (Fraser et al, 1999). A study of 284 Swedish men showed that altered salivary cortisol patterns (low morning levels and flatter diurnal slopes) had consistent, strongly positive relationships to central obesity (BMI and waist-hip circumference) as well as insulin, glucose, lipids, SBP, DBP, and heart rate (Rosmond & Bjorntorp, 2000). These findings are consistent with the possibility that altered cortisol secretion may partially explain the relationship between hostility and the metabolic syndrome.

In addition to cortisol, research suggests a relationship between catecholamines and the metabolic syndrome components. Excessive or prolonged SAM activation has been implicated in the development of hypertension (Kjeldsen et al, 1989), though these effects are most consistent in among those younger than age 40 (Floras, 1992). Studies on glucose have supported a relationship between epinephrine and glucose intolerance in laboratory experiments (Stumvoll et al., 1995) and hyperglycemia in 24-hour urinary norepinephrine collection (Troisi et al., 1991), suggesting that high levels of catecholamines may promote heightened glucose levels. Human experimental data have shown that elevated catecholamines may play a significant role in regulating lipid levels in conditions of acute stress (McCann et al., 1995, Stoney et al. 1999), though one observational study found that high 24-hour urinary epinephrine excretion has been correlated with the favorable pattern of high HDL (Ward et al., 1994). The final component of the metabolic syndrome linked with catecholamines is central obesity. Although the direction of catecholamine concentrations in obesity studies have been inconsistent (Tentolouris, Liatis, & Katsilambros, 2006), there may exist a more consistent relationship of catecholamines with abdominal obesity compared to the overall BMI measure. Though one large adult study showed waist circumference to have an independent, positive association with 24-hour urinary norepinephrine concentrations (De Pergola, 2008), another adult study found an inverse

relationship with 24-hour urinary epinephrine (Leonetti et al., 1991). Although these studies suggest that there are relationships of catecholamines with metabolic syndrome components, further research is necessary to understand the expected direction of these relationships in outside of the laboratory setting.

In addition to examining the relationship between catecholamines and metabolic components, studies have looked at metabolic syndrome as a whole. In the previously cited De Pergola (2008) study, patients with the metabolic syndrome showed higher 24-hour urinary norepinephrine than subjects without this syndrome, and incremental increases in the metabolic syndrome components were directly associated with increased norepinephrine. However, 24-hour urinary epinephrine was not significantly different between patients with or without the metabolic syndrome. In a study of 557 Chinese subjects (average age 38 years, 68% with Type II diabetes mellitus), the authors found lower 24-hour urinary epinephrine excretion and higher urinary norepinephrine excretion among subjects with an increasing number of the metabolic syndrome components (Lee et al, 2001). However, whether these results reflect the metabolic syndrome or diabetes in this sample complicates the interpretability of these results. Further research is needed to examine the relationship and direction of effects between epinephrine and norepinephrine and the metabolic syndrome in a well-designed study of midlife adults.

In addition to cortisol and catecholamines, published evidence suggests a relationship between cardiovascular reactivity and metabolic syndrome components. In a small sample of older African Americans, participants with high waist circumferences exhibited greater SBP and DBP responses to stress than did participants with low waist circumferences (Waldstein et al., 1999), and these findings on DBP reactivity were consistent in a small sample of midlife women (Davis et al., 1999). Additionally, these pattern of findings have been consistent for waist

circumference and triglycerides in adolescent samples (e.g., Goldbacher et al., 2005, Countryman et al., 2014). These data across the lifespan suggest that cardiovascular reactivity to laboratory stressors may be a stable predictor of the metabolic syndrome components. However, it remains unknown to what degree cardiovascular reactivity in daily life might contribute to the metabolic syndrome.

1.4 PRESENT STUDY

To address this gap in the literature, the present study assesses ambulatory cardiovascular reactivity as it relates to the metabolic syndrome. Recent work involving ecological momentary assessment (EMA), collection of real-time data in the natural environment designed to capture daily experiences, has allowed us to examine how links between hostility and negative patterns of social interaction may unfold in the course of daily life. Past use of EMA in hostility studies have shown that trait hostility is reflected in momentary reports of state hostility (Edmondson, 2013), and that trait hostility measures moderate the relationship between daily social interaction and ambulatory blood pressure (Vella et al, 2008). Although the Vella et al. study may suggest that hostile individuals are more reactive to all social interactions irrespective of positive or negative quality, the current study focuses on negative daily social interactions to remain consistent with the previous laboratory literature. Continued research into the role of daily negative interactions may provide insight into what degree reactivity to this daily strain may mediate the relationship between hostility and negative health outcomes. EMA assessments

across multiple days may offer representative data from daily life to test the role of blood pressure responses to social conflict as a link between hostility and the metabolic syndrome.

Psychophysiological responding, through ambulatory blood pressure, cortisol, and catecholamines, is a promising explanation for the link between hostility and health outcomes. Although the available research supports that these physiological markers generally relate to hostility and metabolic syndrome, no study to date has tested the psychophysiological model as a plausible mediator between hostility and the metabolic syndrome. This was the goal of the present study.

In addition to testing this mechanistic model, the present study may provide us with an opportunity to examine which facet of hostility may be more strongly associated with the metabolic syndrome. Commonly used global self-report hostility scales are relatively homogeneous in terms of the facets of hostility they appear to represent (Smith, 1992). For example, the Cook-Medley Hostility Scale, a widely employed hostility measure consisting of 50 true/false questions, focuses predominantly on the cognitive aspect of hostility, whereas the 29-item Buss-Perry is a more balanced multidimensional assessment of hostility, which has surprisingly not been widely used in the literature linking hostility and physical health outcomes. Recent evidence has shown that hostility may consist of three components: Hostile Affect, Hostile Behavior, and Hostile Cognition, each of which may potentially hold independent predictive value in health research (Martin, Waton, & Wan, 2000; Kamarck et al., 2009). In one of the few investigations that has compared the predictive value of each of these three dimensions, Vella et al (2012) found that only cognitive hostility was a significant independent correlate of the daily experience of social conflict with others by diary report. Cognitive hostility may be the strongest independent predictor of daily social strain. It remains to be seen whether

this component of hostility may also be the primary driver in the relationship between hostility and health outcomes. One of the goals of this study was to assess which of these hostility components is most strongly associated with the metabolic syndrome.

1.5 SEX DIFFERENCES

Hostility expressions may differ by gender. The most consistent findings that employ well-established hostility measures (i.e., Cook-Medley) suggest that men exhibit higher levels of hostility relative to women (Barefoot et al, 1991; Scherwitz et al, 1991). In addition to differences in the overall magnitude of hostility scores, there may be gender differences in the way hostility is manifested. A study of 263 undergraduates who completed the Cook-Medley showed that among men, hostility was associated with a tendency to openly express anger (hostile behavior), whereas female hostility was associated with higher Anger/In (hostile affect or cognition), suggesting that females are more likely to turn their angry feelings inwards and males are more likely to behave in an openly aggressive way toward others (Greenglass & Julkunen, 1989). It remains unknown what influence these gender differences on hostility scores and dimensions may have on the metabolic syndrome.

In addition to gender differences in hostility, evidence suggests that there may exist gender differences in the association between the relationship of hostility and the metabolic syndrome. A prospective, longitudinal study of 6,484 participants aged 33-55 at baseline found that higher scores on the Cook-Medley hostility scale were associated with higher BMI at

baseline for women, and this effect remained consistent at the 19-year follow-up. The same hostility-BMI association was found for men, but unlike in the case of women, the strength of this association increased over time (Nabi et al., 2009). In another study, higher Cook-Medley scores were associated with higher insulin resistance and levels of fasting insulin in young women but not young men (mean age of 24; Suarez, 2006). Third, another study found that high baseline aggression, defined here as a factor loading of the Hunter Wolf A-B Rating Scale, predicted an increase insulin, triglycerides and BMI as well as the clustered metabolic syndrome among male but not female adolescents and young adults at a three-year follow-up (Ravaja et al, 1996). The above studies suggest that gender may be an important moderator in the relationship between hostility and metabolic syndrome. Such moderation effects remain to be explored in a middle-aged sample and using multidimensional scales.

The present study involved an assessment of the psychophysiological reactivity model as an explanation for the relationship between hostility measures and health outcomes. Specifically, this work tested how measures of psychophysiological reactivity may account for the relationship between hostility, derived from a factor analysis score of previously collected hostility scores, and metabolic syndrome, a well-established cluster of cardiovascular disease risk factors, among a large, community-based sample of healthy, middle-aged adults (ages 35-55). This is the first study to the author's knowledge that has A) incorporated a multifaceted trait hostility measure with the metabolic syndrome as well as salivary cortisol and B) examined the extent that trait hostility relates to metabolic syndrome via these proposed biological pathways.

2.0 METHOD

2.1 PARTICIPANTS

Participants were drawn from the Adult Health and Behavior Project – Phase 2 (AHAB-II), a study of psychosocial factors, behavioral, and biological risk factors, and subclinical CVD. AHAB-II participants were recruited between March 2008 – October 2011 through mass mailings of recruitment letters to individuals randomly selected from voter registration lists and other public domain lists. To be eligible to participate in AHAB-II, individuals had to be between the ages of 30 and 55 years and working at least 25 hours per week outside the home. Individuals were excluded from participation if they a) had a history of CVD, schizophrenia or bipolar disorder, chronic hepatitis, renal failure, neurological disorder, lung disease requiring drug treatment, or Stage 2 hypertension b) excessively consumed alcohol c) used fish oil supplements (because of the requirements for another substudy); d) were prescribed medications with autonomic effects or used insulin, glucocorticoid, antiarrhythmic, antihypertensive, lipid-lowering, psychotropic, or prescription weight loss medications; e) were pregnant; f) had less than eighth grade reading skills; or g) were shift workers. Participants signed an informed consent form when enrolled. Participants received compensation up to US$410, depending on extent of participation in visits and compliance with the protocol. The overall sample consisted of 494 participants.

2.2 PROCEDURE

Participants completed seven visits, some of which are not relevant to the current study. Demographic variables were assessed at Visit 1. A fasting blood draw was completed at Visit 1 to assess blood levels of physiological risk factors, including glucose and lipids. Participants were instructed by the research assistants in urine collection procedures during Visit 1. Respondents were asked to void urine at 5 PM, which was discarded, and to collect all subsequent samples in the provided collection container until 8 AM the following day. After each urination, participants were instructed to keep the collection container tightly closed and refrigerated until the Visit 2. The participants repeated the collection procedure after the Visit 2 and returned the collection container during Visit 3. One of these collection periods followed a workday, and the other followed a non-workday. Clinic blood pressure was assessed at Visits 2 and 3. EMAs and ambulatory blood pressure (ABP) assessments were completed between Visits 2 and 3 using a 4-day monitoring protocol (3 working days and 1 nonworking day) that consisted of two 2-day periods during the course of a week, including the beginning and end of the work week, and one entire nonworking day. During monitoring, participants wore an ABP device and carried a PDA (Palm Z22, software: Satellite Forms) in addition to an actigraphy watch. During waking hours on monitoring days, ABP was automatically assessed hourly by inflation of the ABP cuff, which signaled participants to initiate a 43-item EMA questionnaire on the PDA. Participants received extensive training and practice on the use of the ABP device and PDA before entering the field for ambulatory monitoring. While in the field, participants received four scheduled telephone calls from study staff, and staff was always available by cell phone for technical support.

2.3 MEASURES

2.3.1 Hostility Measure.

The multidimensional factor analysis was performed using subscales collected from three hostility self-report questionnaires: the 50-item Cook-Medley Hostility Scale, the 29-item Buss Perry Aggression Questionnaire (BPAQ), and the 44-item Spielberger State-Trait Anger Expression Inventory (STAXI). The Cook-Medley, expressed as a total score, has been shown to have high reliability (internal consistency of nearly .80; T. W. Smith, 1992) and is quite stable over periods of several years among adult samples (1-4 year test-retest correlations > .8; (J.C. Barefoot, Dahlstrom, & Williams, 1983; Shekelle, Gale, Ostfeld, & Paul, 1983). The BPAQ has been shown to have high internal consistency of .89 for the total score, and test-retest reliability over nine weeks is sufficient (.80 for the total score) (Buss & Perry, 1992). Subscales of the BPAQ include Physical Aggression, Verbal Aggression, Anger, and Hostility. Five independent subscales comprise the STAXI, including State Anger, Trait Anger, Anger-in, Anger-out, and Anger Control, although state anger was excluded from these analyses to remain consistent with the other trait measures. The coefficient alphas for the internal consistency of the STAXI subscales are above 0.70, and test-retest reliability for the subscales range from 0.74-0.82 (Bishop & Quah, 1998).

A factor analysis of these three questionnaires' subscales (4 BPAQ, 4 STAXI, and 1 CMHS) is expected to yield three hostility dimensions consistent with the previously reported evidence (Martin et al, 2000; Kamarck et al, 2009), involving cognitive, affective, and behavioral responses. As the author's intention is to confirm existing analyses, we performed a confirmatory factor analysis (CFA), which seeks to represent the structure of correlations among measured variables using relatively small set of latent variables (Fabrigar et al., 1999), to replicate the three-factor hostility loading. To determine the adequacy of the CFA solution, several fit statistics and indicates are available to determine the adequacy of model fit to the data. In this study fit was determined based on the chi-square tests (p values < .05 indicating good fit), root mean square error of approximation (values < .05 indicating good fit), comparative fit index (CFI) and Tucker-Lewis index (TLI; values of .95 and greater indicating good fit), and standardized root mean square residual (SRMR; values <.05 indicating good fit; Brown 2015). Should the model fit be poor, we would respecify the parameters of the model. Once the model fit is acceptable, we would use the resulting parameter estimates to generate factor scores for each individual. The factor loadings found in the CFA were expected to be used as independent, continuous predictors in one simultaneous step as part of the path analysis linking hostility with the metabolic syndrome in the statistical software MPlus (Version 6.1).

2.3.2 Mean Arterial Pressure Reactivity

We used a diary measure of social conflict to assess reactivity to real-time social stressor. As part of the hourly diary, participants were asked if they had been in a social interaction at present or in the past 10 minutes; if endorsed, they were asked to identify the type of social interaction

(e.g., spouse, coworker, family). Interaction quality was assessed using four Likert scale items. Two items assessed positive aspects of interactions ("agreeable interaction?" and "pleasant interaction?") and two items assessed negative aspects of interactions (''someone in conflict with you?" and "someone treated you badly?"). Item responses (NO! No no yes Yes YES!) were converted to a 1- to 6-point rating. The presence of social conflict was operationalized as the mean value of the two negative items.

Two primary measures of blood pressure collected in this study are systolic and diastolic blood pressure. ABP readings that were determined to be outside of the normal physiological range (systolic readings of > 260 mm HG or 70 mm Hg; diastolic readings of >150 mm Hg or 40 mm Hg; Verdecchia 1992) were counted as invalid and discarded. To reduce the number of analyses, ambulatory blood pressure reactivity (ABPR) was be assessed using mean arterial pressure (MAP; 1/3 systolic blood pressure and 2/3 diastolic blood pressure) as an index of ABP.

Values for ambulatory blood pressure reactivity were derived by regressing repeated measures of MAP on social conflict using a multilevel model (SAS PROC MIXED). We specified in the model that these coefficients linking social conflict with MAP be treated as random effects to permit the model to estimate individual differences in this association. All models included a series of time-varying covariates derived from the hourly diary that have previously been shown to be associated with fluctuations in cardiovascular activity: posture, physical activity, temperature, any recent meal, snack, caffeine, or alcohol within past hour, use of antihistamine or decongestant within past 4 hour, talking during the cuff inflation, cigarette smoking within past 5 min, and number of cigarettes within past hour (Kamarck et al, 2003). The model also included statistical adjustment for age, sex, race (white vs nonwhite). Coefficients

were outputted and used as scores in the overall regression models. Higher partial regression coefficients from the within-person association between social conflict and MAP reflect higher reactivity. We did not include in the model participants who reported no social conflict during the EMA period, and these participants were considered as having missing values.

2.3.3 Salivary Cortisol

Cortisol levels can be assessed through multiple means, however, ambulatory studies most frequently employ salivary cortisol for its ease and non-invasive nature of sample collection across multiple time points and its "free" state, meaning it is unbound by corticosteroid-binding globulin (CBG); free cortisol represents the biologically active fraction of the hormone (Nicolson, 2007, pg. 29). There are three primary indices of salivary cortisol secretion: area under the curve (AUC), diurnal slope, and the cortisol awakening response (CAR). AUC is the total secretion of cortisol across waking hours. Diurnal slope is the gradual decline of cortisol levels across the day that is believed to reflect dysregulated diurnal rhythms. The CAR is the rapid increase in cortisol secretion in the 30-40 minutes following awakening that may be an index of anticipated stress (Saxbe, 2008). Although the metabolic syndrome literature does not provide empirical support for the use of one cortisol index over another, theory and evidence from the existing cortisol literature suggests that day-level AUC and diurnal slope are more consistently predictive of health outcomes than CAR (e.g., Kumari et al., 2011). Therefore, cortisol AUC and slope were analyzed exclusively in this sample.

The present study had four monitoring days with five saliva samples collected on each monitoring day at 0 mins, 30 mins, 4 hours, 9 hours after wakening, and at bedtime. Area under the curve (with respect to ground) was calculated as described by Pruessner et al., (2003). This AUC measure accounts for number of hours since awakening and excludes the 30-minute time point to eliminate influence of the CAR. The AUC variable was defined at a day level and then averaged across the four days of the monitoring period to increase reliability. To calculate slope, each participant's log-transformed cortisol values were regressed on number of minutes since awakening. Slope values were calculated for days that had non-missing data for beginning of day and either 9th hour or bedtime cortisol samples. The resulting slope values were averaged across the available monitoring days.

2.3.4 Urinary Catecholamines

For the present study, participants collected urine during two overnight 15-hour collection periods (following one work day and following one non-work day) in opaque containers containing hydrochloric acid as a preservative. All assays were performed at the Endocrinology Laboratory at the University of Pittsburgh Cancer Institute. To increase reliability, all assays were measured twice, using high-performance liquid chromatography (HPLC) with electrochemical detection. Epinephrine samples that were under the lowest level of detection (0.18 ng/mL) were assigned values of 0.17 ng/mL. To account for individual differences in body size and hydration status, epinephrine and norepinephrine were each expressed as a ratio of catecholamines to urinary creatinine, a time-varying secretion of the kidneys used as an indicator

of completeness of collection. To be consistent with the cortisol measures, values for the two samples were averaged to reflect trait-like epinephrine and norepinephrine secretion.

2.3.5 Metabolic Syndrome

For the purposes of this study, metabolic syndrome was defined according to the National Cholesterol Education Program – Adult Treatment Panel III (2005 Revision; NCEP – ATP III), as opposed to the definitions used in the World Health Organization (WHO) or International Diabetes Foundation (IDF), due to its wide use in research and clinical value for its readily available measurements to physicians (Grundy et al., 2005, Huang, 2009). The NCEP – ATP III defines metabolic syndrome as including three or more of the following features: fasting plasma glucose of at least 110 mg/dL (6.1 mmol/L); serum triglycerides of at least 150 mg/dL (1.7 mmol/L); serum HDL cholesterol less than 40 mg/dL (1.04 mmol/L) in men and 50 mg/dL in women; blood pressure of at least 130/85 mm Hg; waist girth of more than 102 cm in men and 88 cm in women (Grundy et al., 2005). In the present study, metabolic syndrome was defined as a dichotomous variable according to the above criteria, such at 0 = 2 or less symptoms and 1 = 3 or more symptoms.

In addition to a dichotomous definition, we standardized the five metabolic syndrome components individually, with cholesterol and waist circumference standardized by gender. The z-scores produced for each component was averaged across participant to create a standardized metabolic syndrome score as the outcome variable in the analyses. Consistent with the NCEP definition of equally important components, the weighting of each individual variable to the final

score was considered equal in the z-score approach. Continuous metabolic syndrome scores appear to be a suitable index with high discriminant validity as evidenced by high sensitivity and specificity to the NCEP-ATP definition (e.g, Okosun et al., 2010). One advantage of this standardization approach is a continuous measure of the metabolic syndrome risk yields greater variability and greater statistical power. The present study uses the standardized metabolic syndrome score and the dichotomous NCEP – ATP III definition as outcomes.

2.3.6 Health Behaviors

Smoker status was operationalized as a self-report, dichotomized variable (current tobacco use = 1, no current tobacco use = 0). Alcohol consumption was a self-report of number of alcoholic drinks in the past 7 days. Energy expenditure was measured as an average level of continuous metabolic expenditure during waking hours using Sensewear armband devices (BodyMedia, Pittsburgh, PA). Body mass index (BMI) was calculated based on weight (in kilograms) over height squared (in centimeters) measured in the clinic. Two additional health behavior measures were examined in exploratory analyses: sleep duration and caloric intake.

Sleep duration was measured as the average of actigraphy-scored sleep duration following continuous monitoring via Actiwatch-16 devices (Bend, OR: Philips Electronics; Wong et al., 2015), with over 92% of participants providing five or more nights of valid data (range: 1-11 days). Caloric intake was measured using the Block Food Frequency Questionnaire,

a frequently used semi-quantitative questionnaire in this literature shown to be reasonably valid (Block et al., 1990).

2.4 ANALYSIS PLAN

Overall, this study aims to determine the extent to which the psychophysiological markers (ABP reactivity, cortisol, catecholamines) explain the relationship between a multidimensional measure of hostility and the metabolic syndrome, and if there exist gender differences in these relationships. A factor analysis was performed for the available hostility measures (Cook-Medley, Buss-Perry, and STAXI), and standardized scores were used for the metabolic syndrome components, including fasting plasma glucose, serum triglycerides, serum HDL cholesterol, resting clinic blood pressure, waist circumference. Hostility factor scores represented the predictor variables, and the metabolic factor standard score and dichotomous metabolic syndrome definition represented the two outcome variables.

Path analyses were performed to assess the direct effects of the hostility measures on MS variables and the indirect effects through the psychophysiological variables. To test significance of the indirect effects, the author created bias-corrected bootstrap confidence intervals. Bootstrapping is a nonparametric resampling procedure that involves repeatedly sampling from the data set and estimating the indirect effect in each resampled data set to derive an empirical approximation of the sampling distribution of $\alpha \times \beta$ (Preacher & Hayes, 2008). Bias-corrected confidence intervals that do not include zero values were considered significant. Logistic regression models were used for the dichotomous metabolic syndrome variable. The software

MPlus affords these regression models assessing the five psychophysiological markers to be calculated simultaneously and to calculate bootstrap confidence intervals. These analyses were performed in separate models for each subscale predictor.

Covariates include known confounders of these physiological and metabolic factors, including demographic variables (sex, age, race, and education) and lifestyle variables (physical activity, smoking status, alcohol consumption, and BMI; Everson et al., 1997). To inform the influence of lifestyle variables on these mediation pathways independent of demographics, these covariates were accounted for in three separate models. Model 1 controls only for demographics. Model 2 additionally controls for lifestyle variables (physical activity, smoking status, and alcohol consumption). Model 3 adds BMI, which highly correlates with waist circumference, in its separate model to not overcontrol for adiposity.

3.0 RESULTS

3.1 SELECT SAMPLE CHARACTERISTICS

Of the total sample of N=494, one subject was removed based upon a continuous metabolic syndrome (zMS) score that was more than three standard deviations from the mean, leaving a total sample on which analyses were conducted of N=493. Selected characteristics of the study population are listed in Table 1. Missing data of at least one biological or hostility variable occurred in 95 cases, with most cases attributed to missing conflict reactivity (n=56) and catecholamines (n=29). However, missingness was not substantially correlated with demographic, personality, or, in the case of catecholamine data, urine collection information variables, leaving us to conclude these data were missing completely at random (MCAR). As such, we decided to retain the non-missing data for all participants and to use full-information maximum likelihood (FIML) estimation in the path analysis. Epinephrine, norepinephrine, AUC, and energy expenditure values were log-transformed to reduce skewness, and these log-transformed values were used for all analyses. Descriptive statistics on hostility scores are displayed in Table 2 and on metabolic syndrome components in Tables 3 and 4. These descriptive statistic tables may reflect missing data in their sample sizes.

Table 1. Demographic Characteristics of Analytic Sample

Characteristic	Men (n = 230)	Women (n = 263)	Total (N = 493)
	Mean (SD) or % (n)		
Age, M (SD)	41.5 (7.41)	43.9 (7.11)	42.7 (7.34)
African American race, % (n)	11.6 (27)	21.1 (55)	16.6 (82)
Bachelor's degree or higher, % (n)	76.8 (179)	66.5 (173)	71.4 (352)
Current smoker, % (n)	16.3 (38)	14.6 (38)	15.4 (76)
Alcohol consumption, 7 days, M (SD)	3.5 (5.04)	2.6 (3.92)	3.1 (4.99)
Energy Expenditure, Log-transformed mean METS, M (SD)	.49 (.16)	.45 (.18)	.47 (.17)
BMI, kg/M^2, M (SD)	27.1 (4.55)	26.8 (5.85)	26.9 (5.27)

Note. BMI = Body-Mass Index

Table 2. Hostility Scores in the Full Sample and by Sex

Scale	*n*	*M*	*SD*	Range: Potential	Range: Actual	Median
Physical Aggression						
Whole Sample	479	12.57	3.38	6-30	6-25	12
Men	224	13.22	3.34	6-30	6-25	13
Women	255	12.00	3.31	6-30	6-25	11
Verbal Aggression						
Whole Sample	479	6.23	2.65	3-15	3-14	6
Men	224	6.71	2.72	3-16	3-14	6
Women	255	5.81	2.51	3-17	3-13	5
Anger						
Whole Sample	479	14.09	2.83	6-30	6-24	14
Men	224	13.99	2.76	6-30	6-22	14
Women	255	14.19	2.89	6-30	8-24	14
Hostility						
Whole Sample	479	10.95	4.68	6-30	6-26	10
Men	224	11.07	4.72	6-30	6-26	10
Women	255	10.85	4.65	6-30	6-25	10
Total Score						
Whole Sample	479	43.85	10.02	21-105	25-80	42

Men	224	44.87	10.1	21-106	26-80	43
Women	255	42.85	9.86	21-107	25-80	41

Note. Questionnaire data were lost on 14 subjects.

Table 3. Descriptive Statistics on Metabolic Syndrome Components

	Men (n = 233)	Women (n = 260)	Total (n = 493)
Characteristic		*Mean (SD)*	
Systolic Blood Pressure, mmHg	117.64 (9.98)	113.31 (10.94)	115.36 (10.71)
Diastolic Blood Pressure, mmHg	73.47 (7.18)	71.76 (8.10)	72.57 (7.72)
Glucose, mg/dl	100.36 (9.38)	96.56 (10.96)	98.35 (10.41)
Triglycerides, mg/dl	122.95 (74.02)	96.06 (56.19)	108.74 (66.51)
HDL, mg/dl	47.98 (10.95)	62.84 (14.78)	55.83 (15.06)
Waist Circumference, cm	95.23 (11.35)	85.95 (14.83)	90.31 (14.09)

Table 4. Distribution of Metabolic Syndrome Components for the Full Sample and by Sex

	Men (n = 233)	Women (n = 260)	Total (N = 493)
Risk Factor		n (%)	
Waist Circumference	50 (21.5%)	97 (37.3%)	147 (29.8%)
Glucose	116 (49.8%)	90 (34.6%)	206 (41.8%)
HDL Cholesterol	59 (25.3%)	54 (20.8%)	113 (22.9%)
Triglycerides	60 (25.8%)	33 (12.7%)	93 (18.9%)
Blood Pressure	28 (12.0%)	29 (11.2%)	57 (11.6%)
Metabolic Syndrome	40 (17.2%)	36 (13.8%)	76 (15.4%)
Number of Components		n (%)	
0	60 (25.8%)	99 (38.1%)	159 (32.3%)
1	87 (37.3%)	74 (28.5%)	161 (32.7%)
2	46 (19.7%)	51 (19.6%)	97 (19.7%)

3	26 (11.2%)	21 (8.1%)	47 (9.5%)
4	14 (6.0%)	11 (4.2%)	25 (5.1%)
5	0 (0.0%)	4 (1.5%)	4 (0.8%)

3.2 FACTOR ANALYSIS

3.2.1 Confirmatory Factor Analysis

A primary interest of this project was to replicate the three-factor solution for hostility shown in prior work. As inputs, we included 9 subscales derived from three common Hostility self-report questionnaires (4 BPAQ, 4 STAXI, and 1 CMHS), which consisted of the following structure: Affective (BPAQ Anger, STAXI Trait Anger, STAXI Anger-Control), Behavioral (BPAQ Physical Aggression, BPAQ Verbal Aggression, STAXI Anger-Out) and Cognitive (BPAQ Hostility, Cook-Medley, and STAXI Anger-In). A three-factor confirmatory factor analysis yielded a poor fit (CFI = .880, TLI = .821, RMSEA = .142). Because Kamarck et al (2009) found significant cross-loading for the STAXI Anger-Out subscale on the Hostile affect (factor loading of .61) and behavior (.51) factors, two respecified three-factor CFAs were performed. First, STAXI Anger-Out was respecified onto the affective subscale, but this respecified model had poor fit (CFI = .883, TLI = .825, RMSEA = .140). Second, STAXI Anger-Out was removed entirely from the three-factor CFA. Again, the overall model again had a weak fit (CFI = .907, TLI = .847, RMSEA = .135).

A two-factor CFA of hostility assessing Cynicism and Aggression factors, supported by Martin et al. (2000), was next tested. This solution collapsed the affective and behavioral scales

(BPAQ Anger, STAXI Trait Anger, STAXI Anger-Control, BPAQ Physical Aggression, BPAQ Verbal Aggression, STAXI Anger-Out) into one factor and retained the original cognitive factor structure. However, the fit indices remained weak (CFI = .872, TLI = .822, RMSEA = .141). To increase the number of indicators for each factor, the available Structured Interview for Type A Behavioral Pattern (SI-TABP), a brief interview designed to elicit and assess components of Type behavior, and three CMHS subscales (Cynicism, Hostile Affect, and Aggressive Responding) derived by John Barefoot (Barefoot et al., 1989) shown to have strong relationships with cardiovascular outcomes, were added as indicators. However, the inclusion of these subscales did not substantially improve the model fit for the above CFA combinations (data not reported). Overall, the CFAs failed to replicate a multidimensional hostility solution.

3.2.2 Exploratory Factor Analysis

The above a priori, theory-driven confirmatory factor analyses noted above did not support a two- or three-factor hostility solution in this sample. As the primary interest remained to identify latent variables to represent the structure of correlations among measured variables, a series of data-driven exploratory factor analyses (EFAs) were employed. These EFAs, separately utilizing geomin, oblimin, varimax, and equamax rotations, suggested a moderate fit for a three-factor solution. However, significant cross-loadings of scales across factors obscured the interpretability of these findings. In addition to discordance with the theoretical rationale, the removal of these cross-loaded subscales rendered too few indicators (seven) to produce a three-factor solution. Therefore, EFAs failed produce a satisfactory multidimensional hostility solution.

3.2.3 Buss-Perry Aggression Questionnaire Replication

Because hostility dimensions could not be derived from multiple hostility scales, the author decided to attempt to derive hostility factor scores from a single scale instead: the 29-item multidimensional Buss-Perry Aggression Questionnaire (BPAQ) and its four empirically-derived subscales: Physical Aggression, Verbal Aggression, Anger, and Hostility (Buss & Perry, 1992). A four-factor item-level CFA failed to replicate the four factor structure for BPAQ subscales (CFI = .869, TLI = .857, RMSEA = .076). It is common practice to remove items with weak or cross-loadings in order to improve factor structure. However, there is a lack of consensus in the literature about which of the Buss Perry items should be removed to replicate a four-factor structure. Harris (1995) found in her CFA of the BPAQ that two items from the Hostility subscale dealing with suspicion ("I am suspicious of overly friend strangers" and "When people are especially nice, I wonder what they want.") had relatively low standardized factor loadings (.357 and .378, respectively). Further, Meesters et al. (1996) proposed removing an additional item from the Verbal Aggression subscale, and Bryant and Smith (2001) removed a total of 17 items with weak or cross-loadings to achieve a four-factor measurement model with acceptable goodness-of-fit. Given this heterogeneity in the literature, a series of EFAs were performed to achieve a four-factor solution with good fit and no low or cross-loaded items. Ultimately, eight items were removed (see Appendix A) to achieve good fit (CFI = .971, TLI = .954, SRMR = .046) with a four-factor solution from 21 items that aligned with the broader literature (See Table 5 and Table 6). Unit-weighted scores using this four-factor solution were calculated from these items. These four subscales, along with an aggregated BPAQ measure summing the four

subscales, were used in the following analyses as the best approximation of multidimensional and overall measures of hostility, respectively.

Table 5. Factor Loadings for Exploratory Factor Analysis with Geomin Rotation of 21-Item Buss Perry Aggression Questionnaire Replication

Factor Item	Physical Aggression	Hostility	Anger	Verbal Aggression
Physical Aggression				
1. Given enough provocation, I may hit another person.	**.81**	-.01	.06	-.05
2. If somebody hits me, I hit back.	**.79**	-.10	-.03	.02
3. If I have to resort to violence to protect my rights, I will.	**.67**	.03	-.20	.25
4. There are people who pushed me so far that we came to blows.	**.56**	.11	.21	-.01
5. I can think of no good reason for ever hitting a person.	**.61**	-.12	.07	-.08
6. I have threatened people I know.	**.47**	.17	.25	.12
Hostility				
1. I am sometimes eaten up with jealousy.	-.03	**.61**	.19	-.05
2. At times I feel like I have gotten a raw deal out of life.	.15	**.71**	-.09	.04
3. Other people always seem to get the breaks.	.10	**.75**	-.05	-.07
4. I wonder why sometimes I feel so bitter about things.	-.01	**.71**	.06	.00
5. I know that "friends" talk about me behind my back.	.02	**.58**	.11	.18
6. I sometimes feel that people are laughing at me behind my back.	-.05	**.67**	.22	.03
Anger				
1. I flare up quickly but get over it quickly.	.06	.00	**.35**	.07
2. When frustrated, I let my irritation show.	.06	-.09	**.43**	.25
3. I get into fights a little more than the average person.[a]	.19	.08	**.52**	.12
4. I am an even tempered person.	.01	.04	**.78**	-.09
5. Sometimes I fly off the handle for no good reason.	-.02	.25	**.66**	.01
6. I have trouble controlling my temper.	.01	.00	**.85**	.07
Verbal Aggression				
1. I often find myself disagreeing with people.	.06	.13	.05	**.56**
2. I can't help getting into arguments when people disagree with me.	.02	-.05	.27	**.58**
3. My friends say that I'm somewhat argumentative.	-.06	.03	.01	**.87**

Note. Factor loadings ≥ .35 are in boldface. [a]Denotes that this item originally loaded onto the Physical Aggression subscale.

Table 6. Factor Correlations from the Factor Analytic Model for Exploratory Factor Analysis with Geomin Rotation of 21-Item Buss Perry Aggression Questionnaire Replication

	Physical Aggression	Verbal Aggression	Hostility	Anger
Physical Aggression	1.00			
Verbal Aggression	0.38	1.00		
Hostility	0.35	0.34	1.00	
Anger	0.39	0.51	0.47	1.00

3.3 HOSTILITY AND THE METABOLIC SYNDROME

3.3.1 Standardized Metabolic Syndrome

After controlling for demographic variables (Model 1), Physical Aggression (b= .019, 95% CI [.005 to .033], p = .041) was significantly associated with the standardized MS (zMS). Anger was marginally associated with zMS (b = .016, 95% CI [.001 to .031], p = .084). The above associations became non-significant after controlling for lifestyle variables (Model 2) and BMI (Model 3). No significant associations emerged for Verbal, Hostility, or Total scores on zMS in any model (see Table 7).

Table 7. Associations between Hostility Scales and Metabolic Syndrome Outcomes

	Model 1		Model 2		Model 3	
Subscale	*b*	95% CI	*b*	95% CI	*b*	95% CI
Physical Aggression						
zMS	0.019*	[0.005, 0.033]	0.010	[-0.002, 0.024]	0.009	[0.000, 0.020]
diMS	0.046	[-0.027, 0.117]	0.027	[-0.063, 0.117]	0.043	[-0.066, 0.142]
Verbal Aggression						
zMS	0.003	[-0.013, 0.020]	-0.008	[-0.022, 0.006]	-0.002	[-0.014, 0.010]
diMS	-0.001	[-0.090, 0.091]	-0.030	[-0.140, 0.085]	-0.005	[-0.142, 0.111]
Anger						
zMS	0.016†	[0.001, 0.031]	0.009	[-0.004, 0.023]	0.009	[-0.001, 0.020]
diMS	0.110†	[0.015, 0.203]	0.107	[-0.003, 0.220]	0.139†	[0.019, 0.248]
Hostility						
zMS	0.002	[-0.006, 0.011]	-0.005	[-0.012, 0.003]	-0.002	[-0.008, 0.004]
diMS	-0.014	[-0.065, 0.036]	-0.037	[-0.092, 0.021]	-0.028	[-0.090, 0.030]
Total Score						
zMS	0.004	[0.000, 0.009]	0.000	[-0.004, 0.004]	0.001	[-0.002, 0.004]
diMS	0.010	[-0.014, 0.034]	0.001	[-0.028, 0.053]	0.009	[-0.026, 0.039]

Note. Model 1 = adjusted for sex, age, race, and education. Model 2 = adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure. Model 3 = adjusted for adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure, and BMI. CI = Confidence Interval. zMS = Standardized Metabolic Syndrome. diMS = Dichotomous Metabolic Syndrome.

†p<.10 *p< .05 **p<.01 ***p<.001

To test for significant differences in the magnitude of associations between zMS and Physical Aggression compared to the other BPAQ scales, Hotelling's t-statistics (Steiger, 1980) were calculated for each of these correlations after partialling out the effects of sex, age, race, and education. The magnitude of the differences between zMS-Physical Aggression correlations and correlations between zMS and Verbal Aggression ($T^2(479) = .864$, $p > .05$), Hostility ($T^2(479) = .1.17$, $p > .05$), Anger ($T^2(479) = .209$, $p > .05$), and Total ($T^2(479) = .685$, $p > .05$) were not significant.

3.3.2 Dichotomous Metabolic Syndrome

Anger was marginally associated with the NCEP-defined dichotomous MS (diMS; b = .110, 95% CI [0.015 to 0.203], p = .058) in Model 1, but became non-significant in Model 2 (b = 0.107, 95% CI [-0.003 to 0.220], p =.118). Anger was marginally significant again in Model 3 (b = .139, 95% CI [.019 to .248], p = .056). None of the other BPAQ scales or Total score were significantly associated with diMS (see Table 7). In light of the current findings showing links between Physical Aggression and zMS, we found partial support for Hypothesis 1b that higher levels of hostility are associated with the metabolic syndrome.

3.4 HOSTILITY AND PSYCHOPHYSIOLOGICAL MARKERS

None of the four Buss Perry subscales nor the total score were significantly associated with the five psychophysiological markers (see Table 8) Surprisingly, none of these five markers significantly correlated with the five BPAQ measures using zero-order correlation coefficients or partial correlations controlling for the effects of sex, age, race, and education. Therefore, we failed to support the Hypothesis 2a that hostility is significantly related to psychophysiological measures. Descriptive statistics of the psychophysiological markers are displayed in Table 9.

Table 8. Associations between Hostility Scales and Psychophysiological Measures

Scales		Epinephrine		Norepinephrine		Slope Cortisol		AUC Cortisol		MAP Reactivity	
Physical Aggression		*b*	95% CI	*b*	95% CI	*b*	95% CI	*b*	95% CI	*b*	95% CI
	Model 1	0.009	[-.007, .027]	0.002	[-.011, .015]	0.000	[-.001, .001]	0.006	[-.001, .013]	-0.002	[-.007, .004]
	Model 2	0.000	[-.018, .018]	-0.004	[-.019, .009]	0.000	[-.001, .001]	0.005	[-.002, .013]	-0.004	[-.009, .002]
	Model 3	0.000	[-.017, .018]	-0.004	[-.018, .009]	0.000	[-.001, .001]	0.005	[-.002, .013]	-0.004	[-.009, .002]
Verbal Aggression											
	Model 1	0.003	[-.020, .026]	0.007	[-.011, .025]	0.001	[.000, .002]	0.000	[-.009, .008]	0.001	[-.006, .008]
	Model 2	-0.002	[-.027, .023]	0.005	[-.014, .024]	0.001	[.000, .003]	0.000	[-.009, .008]	-0.001	[-.007, .006]
	Model 3	-0.003	[-.029, .022]	0.004	[-.015, .023]	0.001	[.000, .003]	-0.001	[-.009, .009]	0.000	[-.007, .007]
Anger											
	Model 1	0.004	[-.016, .025]	-0.002	[-.018, .012]	0.001	[.000, .002]	0.005	[-.003, .012]	0.000	[-.007, .007]
	Model 2	-0.004	[-.027, .018]	-0.006	[-.022, .011]	0.001	[.000, .002]	0.003	[-.005, .011]	0.000	[-.007, .006]
	Model 3	-0.005	[-.027, .019]	-0.006	[-.023, .010]	0.001	[.000, .002]	0.003	[-.005, .011]	0.000	[-.007, .007]
Hostility											
	Model 1	0.003	[-.003, .009]	0.003	[-.002, .007]	0.000	[.000, .001]	0.002	[-.001, .004]	0.000	[-.002, .001]
	Model 2	0.000	[-.007, .007]	0.002	[-.003, .006]	0.000	[.000, .001]	0.002	[-.001, .004]	-0.001	[-.003, .001]
	Model 3	0.000	[-.007, .007]	0.002	[-.003, .006]	0.000	[.000, .001]	0.002	[-.001, .004]	-0.001	[-.003, .001]
Total											
	Model 1	0.003	[-.003, .009]	0.003	[-.002, .007]	0.000	[.000, .001]	0.002	[-.001, .004]	0.000	[-.002, .001]
	Model 2	0.000	[-.007, .007]	0.002	[-.003, .006]	0.000	[.000, .001]	0.002	[-.001, .004]	-0.001	[-.003, .001]
	Model 3	0.000	[-.007, .007]	0.002	[-.003, .006]	0.000	[.000, .001]	0.002	[-.001, .004]	-0.001	[-.003, .002]

Note. Model 1 = adjusted for sex, age, race, and education. Model 2 = adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure. Model 3 = adjusted for adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure, and BMI. CI = Confidence Interval. zMS = Standardized Metabolic Syndrome. diMS = Dichotomous Metabolic Syndrome. MAP = Mean Arterial Pressure Reactivity

†p<.10 *p< .05 **p<.01 ***p<.001

Table 9. Descriptive Statistics for Psychophysiological Markers

	Men		Women		Total	
Characteristic	*n*	*Mean (SD)*	*n*	*Mean (SD)*	*n*	*Mean (SD)*
Epinephrine, log-transformed	218	-4.83 (.67)	246	-4.65 (.75)	464	-4.74 (.72)
Norepinephrine, log-transformed	218	-3.37 (.56)	246	-3.00 (.53)	464	-3.17 (.58)
Cortisol AUC , log-transformed	231	4.83 (.28)	258	4.75 (.32)	489	4.79 (.30)
Cortisol slope	233	-0.13 (.05)	260	-0.11 (.04)	493	-0.12 (.04)
MAPR	206	-0.0094 (.213)	231	0.006 (.247)	437	-0.0012 (.231)

Note. AUC = Area-Under-the-Curve. MAPR = Mean Arterial Pressure Reactivity

3.5 PSYCHOPHYSIOLOGICAL MARKERS AND THE METABOLIC SYNDROME

In analyses with the zMS outcome, mean arterial pressure reactivity to social stress (MAPR) showed a significant association in Model 1 (b = .986, 95% CI [.750 to 1.215], p<.001. This association continued when adjusting for additional covariates in Models 2 and 3 (see Table 10). Epinephrine was significantly associated with zMS in Model 1 (b=-.079, 95% CI [-.140 to -.016], p=.038), however, this association became marginally significant in Models 2 and 3. Interestingly, no significant association emerged for norepinephrine on zMS in Models 1 or 2; norepinephrine only was significantly associated with zMS in Model 3 (b = .076, 95 % CI [.013 to .136], p = .044) but not Models 1 or 2. AUC was significantly associated with zMS in Model 1 (b=-.226, 95% CI [-.140 to -.016], p=.006) but not in Models 2 or 3.

In analyses with the diMS outcome, MAPR showed a significant association in Model 1 and Model 2 but a marginal association in Model 3 (see Table 10). Epinephrine showed a significant association in Model 1, a marginal association in Model 2, and no significant association in Model 3. Norepinephrine, on the other hand, showed a marginally significant in Model 1 but significant associations in Models 2 and 3. Neither of the cortisol indices significantly predicted diMS in any three models. Overall, these findings suggest that catecholamines, AUC, and MAPR associate with MS, with the epinephrine and AUC associations potentially accounted for by lifestyle and anthropometric variables. MAPR has a more robust association across models and outcomes.

Table 10. Associations between Psychophysiological Markers and Metabolic Syndrome Outcomes

	Model 1		Model 2		Model 3	
Marker	*b*	95% CI	*b*	95% CI	*b*	95% CI
Epinephrine						
zMS	-0.079*	[-0.140,-0.016]	-0.066†	[-0.122,-0.005]	-0.041	[-0.082,0.010]
diMS	-0.551*	[-0.951,-0.230]	-0.490†	[-0.900,-0.072]	-0.440	[-1.006,-0.063]
Norepinephrine						
zMS	0.057	[-0.031,-0.144]	0.074	[-0.004,0.152]	0.076*	[0.013,0.136]
diMS	0.519†	[0.073,1.022]	0.709*	[0.139,1.286]	0.803*	[0.243,1.529]
Slope						
zMS	-0.544	[-1.524,0.436]	-0.422	[-1.230,0.437]	-0.393	[-1.083,0.288]
diMS	-0.238	[-7.682,6.846]	1.945	[-5.984,9.134]	1.706	[-7.429,10.230]
AUC						
zMS	-0.226**	[-0.361,-0.092]	-0.071	[-0.200,0.060]	-0.034	[-0.142,0.077]
diMS	-0.497	[-1.306,0.283]	0.158	[-0.765,1.106]	0.379	[-0.658,1.472]
MAPR						
zMS	0.986***	[0.750,1.215]	0.905***	[0.706,1.094]	0.814***	[0.664,0.966]
diMS	1.723**	[0.811,2.910]	1.891*	[0.475,3.154]	2.011†	[0.418,3.816]

Note. Model 1 = adjusted for sex, age, race, and education. Model 2 = adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure. Model 3 = adjusted for adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure, and BMI. CI = Confidence Interval. zMS = Standardized Metabolic Syndrome. diMS = Dichotomous Metabolic Syndrome. AUC = Area-Under-the-Curve. MAPR = Mean Arterial Pressure Reactivity

†p<.10 *p< .05 **p<.01 ***p<.001

3.6 PSYCHOPHYSIOLOGICAL MARKERS AND MEDIATORS

We explored the possibility that psychophysiological processes might explain some of the observed associations between measures of hostility and MS. Using the five BPAQ predictors and two MS outcomes, none of these five psychophysiological markers were associated with significant indirect effects between BPAQ subscales and MS across all three models (Table 11).

Therefore, we failed to support Hypothesis 2b that indirect (mediating) effects of hostility on metabolic syndrome may be mediated by these psychophysiological measures.

Table 11. Indirect Effects of Hostility Measures through Psychophysiological Markers on the Metabolic Syndrome Outcomes

Scales	Epinephrine		Norepinephrine		Slope Cortisol		AUC Cortisol		MAP Reactivity	
Physical Aggression	*b*	95% CI	*b*	95% CI	*b*	95% CI	*b*	95% CI	*b*	95% CI
zMS										
Model 1	-0.001	[-0.003, 0.000]	0.000	[-0.001, 0.002]	0.000	[-0.002, 0.000]	-0.001	[-0.004, 0.000]	-0.002	[-0.007, 0.004]
Model 2	0.000	[-0.001, 0.001]	0.000	[-0.002, 0.000]	0.000	[-0.001, 0.000]	0.000	[-0.002, 0.000]	-0.003	[-0.008, 0.002]
Model 3	0.000	[-0.001, 0.001]	0.000	[-0.002, 0.001]	0.000	[-0.001, 0.000]	0.000	[-0.002, 0.000]	-0.003	[-0.008, 0.001]
diMS										
Model 1	-0.005	[-0.020, 0.004]	0.001	[-0.005, 0.011]	0.000	[-0.008, 0.004]	-0.003	[-0.014, 0.001]	-0.003	[-0.015, 0.006]
Model 2	0.000	[-0.009, 0.012]	-0.003	[-0.019, 0.005]	0.000	[-0.004, 0.007]	0.001	[-0.003, 0.012]	-0.007	[-0.024, 0.002]
Model 3	0.000	[-0.010, 0.010]	-0.003	[-0.019, 0.007]	0.000	[-0.004, 0.007]	0.002	[-0.002, 0.016]	-0.008	[-0.030, 0.002]
Verbal Aggression										
zMS										
Model 1	0.000	[-0.003, 0.002]	0.000	[0.000, 0.003]	-0.001	[-0.003, 0.000]	0.002	[-0.002, 0.002]	-0.008	[-0.006, 0.008]
Model 2	0.000	[-0.002, 0.002]	0.000	[-0.001, 0.003]	0.000	[-0.003, 0.000]	0.000	[-0.001, 0.001]	-0.001	[-0.007, 0.005]
Model 3	0.000	[-0.001, 0.002]	0.000	[-0.001, 0.003]	0.000	[-0.002, 0.000]	0.000	[0.000, 0.001]	0.000	[-0.006, 0.005]
diMS										
Model 1	-0.002	[-0.017, 0.012]	0.003	[-0.004, 0.019]	0.000	[-0.002, 0.008]	0.000	[-0.005, 0.007]	0.001	[-0.010, 0.016]
Model 2	0.001	[-0.011, 0.019]	0.004	[-0.009, 0.023]	0.003	[-0.005, 0.008]	0.000	[-0.007, 0.004]	-0.001	[-0.017, 0.011]
Model 3	0.001	[-0.010, 0.020]	0.003	[-0.013, 0.024]	0.002	[-0.007, 0.019]	0.000	[-0.009, 0.005]	0.000	[-0.018, 0.014]
Anger										
zMS										
Model 1	0.000	[-0.003, 0.001]	0.000	[-0.002, 0.001]	-0.001	[-0.003, 0.000]	-0.001	[-0.003, 0.000]	0.000	[-0.007, 0.007]
Model 2	0.000	[-0.001, 0.002]	0.000	[-0.003, 0.000]	0.000	[-0.002, 0.000]	0.000	[-0.002, 0.000]	0.000	[-0.007, 0.006]
Model 3	0.000	[-0.001, 0.002]	0.000	[-0.002, 0.001]	0.000	[-0.002, 0.000]	0.000	[-0.001, 0.000]	0.000	[-0.006, 0.005]
diMS										
Model 1	-0.002	[-0.018, 0.010]	-0.001	[-0.013, 0.007]	-0.001	[-0.012, 0.006]	-0.003	[-0.015, 0.001]	-0.001	[-0.015, 0.013]
Model 2	0.003	[-0.008, 0.021]	-0.004	[-0.023, 0.006]	-0.002	[-0.004, 0.017]	-0.001	[-0.002, 0.010]	0.000	[-0.017, 0.014]
Model 3	0.003	[-0.009, 0.021]	-0.005	[-0.024, 0.008]	0.001	[-0.007, 0.017]	0.002	[-0.002, 0.016]	0.000	[-0.020, 0.015]
Hostility										
zMS										
Model 1	0.000	[-0.002, 0.000]	0.000	[0.000, 0.002]	0.000	[-0.002, 0.000]	-0.001	[-0.002, 0.000]	-0.001	[-0.005, 0.002]
Model 2	0.000	[-0.002, 0.000]	0.001	[0.000, 0.003]	0.000	[-0.001, 0.000]	0.000	[-0.001, 0.000]	-0.002	[-0.005, 0.002]
Model 3	0.000	[-0.001, 0.000]	0.001	[0.000, 0.002]	0.000	[-0.001, 0.000]	0.000	[-0.001, 0.000]	-0.001	[-0.005, 0.001]
diMS										
Model 1	-0.002	[-0.012, 0.003]	0.005	[0.000, 0.016]	0.000	[-0.005, 0.003]	-0.001	[-0.009, 0.001]	-0.002	[-0.010, 0.004]
Model 2	-0.002	[-0.012, 0.004]	0.007	[0.000, 0.021]	0.000	[-0.002, 0.007]	0.001	[-0.002, 0.008]	-0.003	[-0.014, 0.003]
Model 3	-0.002	[-0.012, 0.003]	0.008	[0.000, 0.023]	0.000	[-0.002, 0.007]	0.002	[-0.002, 0.011]	-0.003	[-0.016, 0.003]
Total										
zMS										
Model 1	0.000	[-0.001, 0.000]	0.000	[0.000, 0.001]	0.000	[-0.001, 0.000]	0.000	[-0.001, 0.000]	0.000	[-0.002, 0.001]
Model 2	0.000	[-0.001, 0.000]	0.000	[0.000, 0.001]	0.000	[-0.001, 0.000]	0.000	[-0.001, 0.000]	-0.001	[-0.003, 0.001]
Model 3	0.000	[0.000, 0.000]	0.000	[0.000, 0.001]	0.000	[-0.001, 0.000]	0.000	[-0.001, 0.000]	-0.001	[-0.002, 0.001]
diMS										
Model 1	-0.001	[-0.006, 0.002]	0.001	[0.000, 0.006]	0.000	[-0.003, 0.002]	-0.001	[-0.004, 0.000]	-0.001	[-0.005, 0.003]
Model 2	0.000	[-0.005, 0.004]	0.001	[-0.002, 0.007]	0.000	[-0.001, 0.004]	0.000	[-0.001, 0.004]	-0.002	[-0.008, 0.001]
Model 3	0.000	[-0.004, 0.004]	0.001	[-0.002, 0.007]	0.000	[-0.001, 0.005]	0.001	[-0.001, 0.005]	-0.002	[-0.009, 0.002]

Note. Model 1 = adjusted for sex, age, race, and education. Model 2 = adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure. Model 3 = adjusted for adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure, and BMI. CI = Confidence Interval. zMS = Standardized Metabolic Syndrome. diMS = Dichotomous Metabolic Syndrome. MAP = Mean Arterial Pressure Reactivity

†p<.10 *p< .05 **p<.01 ***p<.001

3.7 EXPLORATORY FINDINGS

3.7.1 Sex Differences

We examined sex differences in hostility, metabolic syndrome, and in our psychophysiological marker measurements. Due to overrepresentation of certain sex and ethnic groups (e.g., higher rates of Black women than Black men; see Table 1), least-square means, adjusted for demographics, are reported. Results show that Physical Aggression, Verbal Aggression, and Total BPAQ are significantly higher for men relative to women (see Table 12). No significant sex differences emerged for Hostility or Anger. Results also revealed significantly higher zMS scores and higher diMS adjusted rates (19.1%) among men than among women (12.1%). These findings partially support Hypothesis 3 that sex differences exist in BPAQ scales and both MS outcomes.

Table 12. Least-Square Means for Hostility Scales and Metabolic Syndrome Controlling for Demographic Variables.

	Mean		df	F	p
Characteristic	Men	Women			
Physical Aggression	13.3	11.93	478	17.97	<.0001
Verbal Aggression	6.69	5.83	478	4.97	0.0005
Anger	13.92	14.24	478	2.34	0.2312
Hostility	11.11	10.82	478	6.70	0.4929
Total BPAQ	45.02	42.82	478	9.09	0.0157
Cook-Medley	18.46	15.62	478	15.71	<.0001
Standardized MS	0.153	-0.151	492	17.34	<.0001
Dichotomous MS	0.191	0.121	492	8.2	0.0306

Note. BPAQ = Buss-Perry Aggression Questionnaire. MS = Metabolic Syndrome. Demographic variables include sex, age, race, and education.

A formal test of interaction found sex differences in the relationship between Physical Aggression and zMS across all three models (see Table 13). Subgroup analyses reveal that there was a significant relationship between Physical Aggression (b = .034, 95% CI [.013 to .054], p = .005) and zMS for women, and this association persisted in Models 2 and 3. Men do not exhibit a significant association. Hotelling's t-statistics did not reveal any significant differences between the Physical Aggression-zMS association and other associations with zMS involving the other BPAQ scales. The interaction between Total BPAQ and sex was marginally significant in Model 1. A significant sex-by-hostility interaction emerged for Total BPAQ in Model 2, however, this effect became marginal in Model 3. No significant interactions with sex emerged for any BPAQ scale on diMS in any of the three models. These findings partially support Hypothesis 2A by suggesting that sex may moderate the association only between Physical Aggression and zMS but not diMS.

Table 13. Revised Buss Perry Aggression Questionnaire Scales with Metabolic Syndrome Outcomes: Sex-by-Subscale Interaction Effects

	Model 1		Model 2		Model 3	
Subscale	*b*	95% CI	*b*	95% CI	*b*	95% CI
Physical Aggression						
zMS	0.036*	[0.009, 0.065]	0.043**	[0.017, 0.068]	0.030*	[0.010, 0.050]
diMS	0.022	[-0.105, 0.147]	0.078	[-0.077, 0.239]	0.052	[-0.132, 0.238]
Verbal Aggression						
zMS	0.027	[-0.007, 0.061]	0.02	[-0.010, 0.050]	0.006	[-0.018, 0.030]
diMS	0.072	[-0.111, 0.248]	0.092	[-0.173, 0.092]	0.08	[-0.170, 0.308]
Anger						
zMS	0.016	[-0.017, 0.047]	0.021	[-0.008, 0.049]	0.019	[-0.005, 0.042]
diMS	-0.018	[-0.190, 0.144]	0.023	[-0.185, 0.223]	0.014	[-0.230, 0.248]
Hostility						
zMS	0.014	[-0.019, 0.005]	0.018†	[0.002, 0.035]	0.010	[-0.004, 0.022]
diMS	0.009	[-0.088, 0.099]	0.052	[-0.062, 0.151]	0.040	[-0.077, 0.156]
Total Score						
zMS	0.010†	[0.001, 0.019]	0.012*	[0.004, 0.020]	0.008†	[0.001, 0.014]
diMS	0.009	[-0.033, 0.056]	0.03	[-0.021, 0.094]	0.023	[-0.042, 0.081]

Note. Model 1 = adjusted for sex, age, race, and education. Model 2 = adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure. Model 3 = adjusted for adjusted for sex, age, race, education, smoking status, alcohol consumption, and energy expenditure, and BMI. CI = Confidence Interval. zMS = Standardized Metabolic Syndrome. diMS = Dichotomous Metabolic Syndrome. MAP = Mean Arterial Pressure Reactivity
†p<.10 *p< .05 **p<.01 ***p<.001

Given the consistently significant interaction effect of sex and Physical Aggression on zMS, mediation analyses were performed for only this relationship. None of the hypothesized mediation effects involving psychophysiological variables were significant either for men or for women. We conclude that only women exhibit the relationship between Physical Aggression and zMS, although the psychophysiological variables of interest do not account for this association. These findings fail to support Hypothesis 2b.

3.7.2 BPAQ Scales and Individual Metabolic Syndrome Components

Components of the metabolic syndrome (SBP, DBP, glucose, triglycerides, waist circumference, and HDL cholesterol) were examined as independent outcomes. Regression models, adjusting for demographic covariates, revealed only marginal effects of Hostility on triglycerides (b = .009, 95% CI [.001 to .017], p = .051), Physical Aggression on waist circumference (b = .394, 95% CI [.047 to .747], p = .066), and Anger on waist circumference (b = .370, 95% CI [.003 to .724] p = .097). Significant sex-by-hostility interactions emerged for Physical Aggression on DBP (b = .506, 95% CI [.181 to .842], p = .012) and Verbal Aggression on glucose (b = .009, 95% CI [.003 to .015], p = .011). Marginally significant sex interactions emerged for Physical Aggression on SBP (b = .547, 95% CI [.096 to 1.031], p=.055) and Total Scores on DBP (b = .122, 95% CI [.013 to .231], p = .068) and waist circumference (b = .217, 95% CI [.002 to .415], p = .084). Subgroup analyses revealed significant effects for women but not men for both DBP and glucose for Physical and Verbal Aggression, respectively. Blood pressure and glucose appear to be associated with aggressive behavior for women but not for men.

3.7.3 Cook-Medley Hostility Scale and the Metabolic Syndrome

Analyses were conducted with the Cook-Medley Hostility Scale (CMHS), a more commonly used measure of hostility in this literature. Mean scores were 18.34 (SD = 8.19) for men and 15.72 (SD = 7.48) for women. Men exhibited significantly higher CMHS scores than women (see Table 11). However, no significant associations emerged in the relationship between CMHS and either MS outcome, psychophysiological variables as mediators, or sex differences. Analyses

with individual components reveal a significant main effect of CMHS scores only on waist circumference (b = .162, 95% CI [.037 to .293], p = .039), and no significant sex-by-CMHS interactions emerged for any metabolic component. The psychophysiological variables did not explain the relationship between CMHS scores and waist circumference.

3.7.4 Health Behaviors and Standardized Mediators

In addition to BMI and the three health behaviors included in Model 2, actigraphy-measured mean sleep duration and caloric intake were tested as potential mediators in the relationship between the BPAQ scales and zMS. When tested as individual mediators, no significant indirect effects were shown for BMI nor these five health behaviors in the relationship between revised scales and zMS. Additionally, no sex differences emerged in these patterns (see Table 14).

Table 14. Indirect Effects of Hostility Measures through Health Behaviors on the Continuous Metabolic Syndrome Score

Subscale	Smoking Status	Alcohol Consumption	Energy Expenditure	BMI	Sleep Duration	Caloric Intake
	b	*b*	*b*	*b*	*b*	*b*
Physical Aggression						
Full Sample	0.000	0.001	0.000	0.007	0.000	0.001
Men	-0.001	0.000	0.002	0.002	0.000	0.000
Women	0.003	-0.001	0.000	0.012	-0.001	0.001
Verbal Aggression						
Full Sample	0.000	0.001	0.001	0.003	0.000	0.001
Men	0.000	-0.001	0.000	-0.009	0.000	0.000
Women	0.000	0.001	0.000	0.016	0.000	0.001
Anger						
Full Sample	0.000	0.000	0.000	0.003	0.000	0.000
Men	-0.001	0.000	0.000	-0.001	0.000	0.000
Women	0.002	0.000	0.000	0.007	0.002	0.001
Hostility						
Full Sample	0.000	0.000	0.000	0.002	0.000	0.000
Men	0.000	0.000	0.001	-0.003	0.000	0.000
Women	0.002	0.000	0.001	0.006	0.000	0.002
Total Score						
Full Sample	0.000	0.000	0.000	0.002	0.000	0.000
Men	0.000	0.000	0.000	-0.001	0.000	0.000
Women	0.001	0.000	0.000	0.004	0.000	0.001

†p<.10 *p< .05 **p<.01 ***p<.001

We hypothesized that perhaps lifestyle variables, much like the metabolic syndrome components, tend to co-occur. To support this hypothesis, we found that partial correlations (controlling for demographic covariates) suggest that smoking status significantly correlates with alcohol consumption (r = .18, p = .0002) and caloric intake (r = .18, p <.0001) and energy expenditure marginally correlates with alcohol consumption (r = .056, p = .069) and sleep duration (r = -.09, p = .065). To test this hypothesis, we first re-analyzed the models using the average of z-scores for the three lifestyle variables originally proposed in this project: smoking

status, alcohol consumption, and energy expenditure (reverse-scored so that higher values reflect less physical activity). We found that standardized lifestyle variables were significant mediators in relationship between all four BPAQ subscales and Total score with zMS when controlling for demographic variables. However, these relationships became non-significant when controlling for BMI (See Table 14).

Further, we created a second standardized lifestyle variable with caloric intake and sleep duration (reverse-scored) included in the mean value. Again, this lifestyle variable had significant indirect effects for all five BPAQ variables. These patterns of associations were also found for diMS (See Table 15). Following this strategy, the five psychophysiological variables were standardized and used as a composite psychophysiological variable. Unlike the health behavior composite, this psychophysiological composite variable failed to show an indirect effect of BPAQ variable on either zMS or diMS. These findings suggest that a combination of health behaviors, rather than individual behaviors or combined psychophysiological variables, may explain the relationship between hostility and the metabolic syndrome.

Table 15. Indirect Effects of Hostility Measures through Aggregated Mediators on the Metabolic Syndrome Outcomes

Scales	Health Behaviors[a]		Revised Health Behaviors [a]		Biological[a]		Health Behaviors[b]		Revised Health Behaviors[b]		Biological[b]	
Physical Aggression	*b*	95% CI	*b*	95% CI	*b*	95% CI	*b*	95% CI	*b*	95% CI	*b*	95% CI
zMS	0.014***	[0.008, 0.021]	0.012**	[0.006, 0.019]	0.001	[-0.001, 0.001]	0.006	[-0.002, 0.004]	0.002	[0.000, 0.005]	0.000	[0.000, 0.002]
diMS	0.028*	[0.011, 0.050]	0.026*	[0.009, 0.047]	-0.001	[-0.010, 0.002]	-0.004	[-0.026, 0.016]	0.005	[-0.014, 0.024]	0.001	[-0.004, 0.009]
Verbal Aggression												
zMS	0.013**	[0.007, 0.021]	0.053**	[0.007, 0.020]	0.000	[-0.001, 0.002]	0.002	[-0.001, 0.005]	0.003	[0.000, 0.006]	0.001	[0.000, 0.003]
diMS	0.027*	[0.012, 0.049]	0.029*	[0.012, 0.050]	-0.001	[-0.012, 0.003]	-0.002	[-0.022, 0.017]	0.007	[-0.012, 0.026]	0.001	[-0.004, 0.012]
Anger												
zMS	0.008**	[0.004, 0.014]	0.008**	[0.004, 0.014]	0.000	[-0.001, 0.001]	0.001	[-0.001, 0.003]	0.001	[0.000, 0.004]	0.001	[0.000, 0.003]
diMS	0.015†	[0.005, 0.031]	0.016†	[0.005, 0.032]	-0.001	[-0.012, 0.002]	-0.005	[-0.020, 0.006]	0.001	[-0.013, 0.015]	0.000	[-0.004, 0.009]
Hostility												
zMS	0.006**	[0.003, 0.010]	0.007**	[0.004, 0.011]	0.000	[-0.001, 0.001]	0.001	[0.000, 0.003]	0.001	[0.000, 0.003]	0.001	[0.000, 0.002]
diMS	0.014*	[0.006, 0.024]	0.015*	[0.007, 0.028]	-0.001	[-0.007, 0.002]	0.000	[-0.011, 0.009]	0.004	[-0.006, 0.015]	0.001	[-0.002, 0.002]
Total												
zMS	0.005***	[0.003, 0.007]	0.004***	[0.003, 0.007]	0.000	[0.000, 0.000]	0.008	[-0.001, 0.002]	0.001	[0.000, 0.002]	0.000	[0.000, 0.001]
diMS	0.009*	[0.004, 0.016]	0.010*	[0.004, 0.017]	0.000	[-0.004, 0.001]	0.000	[-0.008, 0.006]	0.002	[-0.005, 0.009]	0.000	[-0.002, 0.003]

Note. zMS = Standardized Metabolic Syndrome. diMS = Dichotomous Metabolic Syndrome. Health Behaviors = average of z-scores for smoking status, alcohol consumption, and energy expenditure (reverse scored). Revised Health Behaviors = average of z-scores for smoking status, alcohol consumption, energy expenditure (reverse scored), caloric intake, and sleep duration (reverse scored). Biological = average of z-scores for coritosl area-under-the-curve, slope, mean arterial pressure reactivity, epinephrine, and norepinephrine. [a]unadjusted for BMI. [b]adjusted for BMI

†p<.10 *p< .05 **p<.01 ***p<.001

3.7.5 Sensitivity Analysis for BMI

To examine whether the association between physical aggression and zMS varied by BMI, a strong correlate of waist circumference (r = .86, p<.0001) and zMS (r = .71, p <.0001), sensitivity analyses were performed by BMI. Subjects were divided into two categories: BMI less than 30, or normal BMI, and BMI greater than or equal to 30, or elevated BMI. Regression models, controlling for demographic variables, reveal that the relationship between Physical Aggression and zMS was statistically significant among the normal BMI group but only marginally significant among the elevated BMI group (see Table 16). However, subgroup analyses by sex reveal that women exhibited a significant Physical Aggression-zMS relationship across both BMI groups. This relationship was not true for men in either BMI classification. The data suggest that the association between Physical Aggression and zMS persisted among women regardless of BMI classification.

Table 16. Associations between the BPAQ Physical Aggression Subscale and Continuous Metabolic Syndrome Outcomeby BMI Category and Sex

	Normal BMI (n = 368)		Elevated BMI (n = 124)	
Characteristic	*b*	95% CI	*b*	95% CI
Full Sample	0.041**	[0.017, 0.067]	0.063†	[0.008, 0.119]
Women	0.043*	[0.013, 0.081]	0.105*	[0.029, 0.181]
Men	0.072†	[0.005, 0.078]	0.008	[-0.073, 0.088]

Note. BPAQ = Buss-Perry Aggression Questionnaire. BMI = Body-Mass Index. Normal BMI represents individuals with BMI scores less than 30. Elevated BMI represents individuals with BMI scores greater than or equal to 30.

†p<.10 *p< .05 **p<.01 ***p<.001

4.0 DISCUSSION

4.1 SUMMARY

The current investigation is the first study to test the psychophysiological reactivity hypothesis in the context of the relationship between multi-dimensional hostility measures and the metabolic syndrome in a sample of middle-aged, healthy adults. We failed to replicate a two or three-factor structure for hostility when we used subscales scores from several trait hostility questionnaires, however, after eliminating some items, we replicated the four factor structure that has previously been shown to characterize the Buss Perry Aggression Questionnaire. Using subscales derived from this Buss Perry factor analysis, we found that BPAQ Physical Aggression predicts standardized metabolic syndrome scores, and BPAQ Anger marginally predicts both MS outcomes. Sex differences did emerge with women, but not men, showing associations between Physical Aggression and MS. Neither psychophysiological markers nor several individual measures of health behavior were putative individual mediators, but health behaviors as a whole appeared to account for these effects.

4.2 METHODOLOGICAL CONSIDERATIONS

Contrary to the existing literature, a factor structure for hostility involving two- or three- factors utilizing existing hostility questionnaires failed to replicate. This failure may be attributed to differences between our replication sample and the original samples from which numerous multidimensional factor structures have been derived. In a previous study showing a three-factor model derived from multiple hostility scales (Kamarck et al., 2009), the authors used some scales that were not available in this sample, and subjects that were explicitly selected to be high in hostility, unlike in the current sample, suggesting that differences in sample characteristics might account, in part, for these inconsistent effects. Second, the inclusion criteria in our study may have resulted in a biased sample. One inclusion criterion for our study was employment of greater than 25 hours a week, yet prior work has shown that hostile individuals are more likely to be unemployed. For example, Hakulinen and colleagues (2013) found in a large, longitudinal study of Finnish adults that hostility was associated with higher risk of unemployment and longer unemployment duration. Therefore, sample characteristics in the current study may differ from those seen in prior factor analytic investigations (e.g., Martin et al., 200; Kamarck et al., 2009).

Regarding the failure to replicate the factor structure for the original 29-item BPAQ in this sample, most of the previous published psychometric data on this scale has been derived from younger samples. For instance, the original BPAQ publication (Buss & Perry, 1992) and follow-up replications (Harris, 1995; Bernstein & Gesn, 1997; Bryant & Smith, 2001, Martin et al., 2000) all used samples of young, college-level students (weighted mean = 19.9 years). Prior work has shown a curvilinear relationship between age and hostility, such that scores are higher in college years, lower in midlife (Siegler et al., 2003), and higher again in late life (Barefoot et

al., 1993). It is possible that developmental changes affect not only mean scores but factor structures as well. To the author's knowledge, this study is the first to attempt a factor solution for the BPAQ in a healthy, midlife American sample not recruited for elevated hostility scores.

The main findings suggest that the revised Physical Aggression and Anger factors are associated with MS, whereas no significant findings emerged for Verbal Aggression and Hostility. Importantly, this multidimensional assessment of hostility showed that though the overall score did not relate to MS, affective and behavioral components of hostility may be most pertinent to the metabolic syndrome. Although the literature is mixed in study design quality and measurements of hostility and metabolic syndrome, the most noteworthy finding linking hostility with the metabolic syndrome in adults have been shown with the STAXI, which is most aligned with the affective component (see Räikkönen et al., 2004 and Goldbacher et al., 2007). However, the relationship between Anger and MS in this sample failed to reach statistical significance, and these findings should be interpreted with caution.

Of the significant findings, it remains unclear why Physical Aggression in particular was associated with MS. Our sex interaction finding, which revealed that this behavioral component of hostility poses a risk factor to MS among women and not among men, may provide a clue. One interpretation for this sex disparity, a surprise finding that is generally discordant with the literature, is that physical aggression, a more socially acceptable behavior in men, may adversely influence the social network in women. For instance, highly physically aggressive women may have fewer social relationships than women with low physical aggression scores that may, in turn, increase their risk for the metabolic syndrome. This interpretation would be consistent with prior work showing a relationship between social relationships and health risk (Lundstad, Smith, & Layton, 2010), particularly the metabolic syndrome (Horsten et al., 1999). These effects for

Physical Aggression on the metabolic syndrome for women may not have been evident in the literature because prior studies have typically used aggregated hostility measures. This work illustrates the importance of a multidimensional assessment of hostility, especially in comparisons between men and women.

Another possible reason that unexpected effects emerged in this study is the low prevalence of MS. Unadjusted rates of NCEP-defined MS occurred in 17.2% of men and 13.8% of women in our sample, whereas one epidemiological report found that approximately 40.8% of men and 37.2% of women in the midlife age group meet the NCEP criteria (Ervin, 2009). The reduced MS prevalence seen in our sample may be explained by our exclusion criteria of antihypertensive medication use, a history of CVD, and Stage 2 hypertension (≥160 mmHg/ ≥100 mmHg), which qualifies for the blood pressure component of MS (130 mmHg/ 85 mmHg). Likewise, highly hostile individuals, known to have higher CVD risk, may have been excluded from the study based upon these criteria. The other BPAQ scales may have emerged as significant predictors of the metabolic syndrome in a less healthy sample, especially among males.

Despite the aforementioned limitations, this study advances the field in multiple ways. First, we demonstrated that even in a healthy, employed community sample, physical aggression is associated with an increased risk for the metabolic syndrome, and these effects may be limited to women. Second, our findings elucidate the relationship between psychophysiological markers and the metabolic syndrome. Recall from the introduction that there are no published studies examining the association between multidimensional measures of hostility and ABP, salivary cortisol, or catecholamines. Using sophisticated biological sample collection protocols, we showed a relationship between MAPR, AUC, and epinephrine excretion on MS. In particular,

these findings may clarify the expected direction of catecholamine excretion and MS in an adult sample free of confounding health conditions (e.g., diabetes, antihypertensive medications). Despite demonstrating these effects, these biological markers may not be the primary link between hostility and the metabolic syndrome.

Perhaps most importantly, our findings advance the field by showing that though neither individual psychophysiological markers nor health behaviors mediate the relationship between hostility and the metabolic syndrome, particularly Physical Aggression on zMS, these aggregate measures of health behavior have significant indirect effects on all hostility measures with both MS outcomes. Much like the metabolic syndrome components, poor health behaviors are likely to co-occur and may pose their greatest risk when co-occurring. Although numerous studies have shown hostility is related to poor health behaviors, only the previously cited Everson (1997) paper has examined whether health behaviors explain the relationship between hostility and health outcomes. In their prospective, longitudinal study of 2125 men, the authors found that behavioral risk factors (smoking status, alcohol consumption, physical activity, and BMI) significantly reduced the association of cynical hostility and cardiovascular mortality at the nine-year follow-up. Though no mediation analyses were performed, the authors controlled for these health behaviors as a whole rather than individually. The current investigation is the first study to show formal mediation of the cumulative role of health behaviors in the relationship between hostility and the metabolic syndrome.

4.2.1 Future Directions

Further work is needed assessing hostility dimensions in a sample with less stringent inclusion criteria. This work would aim to replicate the physical aggression findings shown in this sample to help determine if these findings are unique to this current study or if they are representative of effects shown in the general population. Likewise, reproducing sex differences observed here would suggest that our findings for physical aggression in women are not spurious findings limited only to the current investigation. Such work may inform which specific dimensions of hostility may pose the greatest risk of the metabolic syndrome and to whom. Further, future work may examine how hostility relates to a bevy of other health pathways, such as intima media thickness (IMT), inflammation, platelet aggregation, coronary artery calcification, as well as directly assessing coronary heart disease, including myocardial infarction, angina, and sudden cardiac death. The demonstration of an association of multiple hostility dimensions with other clinical markers may substantiate the call for multidimensional hostility assessments in future work and inform which specific hostility components pose the greatest health risk.

Another area of recommended future work is to test the psychosocial vulnerability model, which posits that negative health outcomes among hostile individuals are mediated by perceived interpersonal threat and insufficient support, and the transactional model, a related model that that hostile individuals provoke interpersonal conflict and lower social support (Smith et al., 2004). These conceptually overlapping models place the relationship of negative health and hostility in an interpersonal context. EMA methods could assess social interaction quality to inform how conflict and isolation in daily life, as well as daily health behaviors and

physiological reactivity, may explain the increased health risk for hostile individuals. The psychosocial vulnerability model may be another link by which hostility relates to health.

In addition to its research relevance, the current findings may inform clinical efforts to reduce hostility and metabolic syndrome. In a meta-analysis of 50 studies, cognitive-behavioral therapy (CBT) has been shown to have moderate efficacy (weighted mean effect size of .70) in anger reduction among adolescents and adults (Beck & Fernandez, 1998). Reducing hostility, especially the anger component, may have health benefits. A small clinical trial featuring a hostility intervention showed reduction in hostility among recent CHD patients (Gidron et al., 1999). Using a pharmacological intervention, Kamarck and colleagues (2011) demonstrated that reduction in hostility may result in correlated changes in metabolic syndrome components, with some of those changes (glucose) being mediated by the hostility reductions induced by treatment. Clinical interventions, especially CBT, that highlight physical aggression and anger reduction as well as improved healthy lifestyle may be efficacious strategies in reducing metabolic syndrome and/or prevalence. The development of such interventions may be guided, in part, by the research linking hostility factors with health risk.

APPENDIX A

A.1 APPENDIX A. FINAL LIST OF REVISED BUSS PERRY AGGRESSION QUESTIONNAIRE ITEMS

Physical Aggression. (6 items)

BPAQ5	Given enough provocation, I may hit another person.
BPAQ9	If somebody hits me, I hit back.
BPAQ17	If I have to resort to violence to protect my rights, I will.
BPAQ21	There are people who pushed me so far that we came to blows.
BPAQ24	I can think of no good reason for ever hitting a person.
BPAQ27	I have threatened people I know.

Hostility (6 items)

BPAQ4	I am sometimes eaten up with jealousy.
BPAQ8	At times I feel like I have gotten a raw deal out of life.
BPAQ12	Other people always seem to get the breaks.
BPAQ16	I wonder why sometimes I feel so bitter about things.
BPAQ20	I know that “friends” talk about me behind my back.
BPAQ26	I sometimes feel that people are laughing at me behind my back.

Anger (6 items)

BPAQ3 I flare up quickly but get over it quickly.

BPAQ7 When frustrated, I let my irritation show.

BPAQ13 I get into fights a little more than the average person (originally Physical Aggression).

BPAQ15 I am an even tempered person.

BPAQ22 Sometimes I fly off the handle for no good reason.

BPAQ25 I have trouble controlling my temper.

Verbal (3 items)

BPAQ6 I often find myself disagreeing with people.

BPAQ14 I can't help getting into arguments when people disagree with me.

BPAQ18 My friends say that I'm somewhat argumentative.

Removed:

BPAQ1 Once in a while I can't control the urge to strike another person (originally Physical Aggression).

BPAQ2 I tell my friends openly when I disagree with them (Verbal).

BPAQ10 When people annoy me, I may tell them what I think of them (Verbal).

BPAQ11 I sometimes feel like a powder keg ready to explode (Anger).

BPAQ19 Some of my friends think I'm a hothead (Anger).

BPAQ23 I am suspicious of overly friendly strangers (Hostility).

BPAQ28 When people are especially nice, I wonder what they want (Hostility).

BPAQ29 I have become so mad that I have broken things (Physical).

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