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Parenting Stress, Salivary Biomarkers, and Ambulatory Blood Pressure: A Comparison Between Mothers and Fathers of Children with Autism Spectrum Disorders

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Abstract Parents of children with autism spectrum disorders (ASD) may experience higher levels of stress and health problems than parents of children with typical development. However, most research has focused on mothers, with emphasis on parent-reported stress and wellbeing. This study compared parenting responsibility, distress, anxiety, depression, cortisol, alpha-amylase, and cardiovascular activity between 19 mother–father dyads of children with ASD. Mothers reported higher parenting responsibility, distress, anxiety, and depression than fathers, while fathers had higher blood pressure and heart rate variability. Mothers and fathers had lower than average morning cortisol levels, suggesting stress effects on the hypothalamic–pituitary–adrenal-axis. Parents of children with ASD may benefit from routine health screening (particularly adrenal and cardiovascular function) and referral for stress reduction interventions or supports.

Keywords Autism spectrum disorder · Parent stress · Cortisol · Alpha-amylase · Ambulatory blood pressure

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Introduction

Parents of children with autism spectrum disorders (ASD) often experience higher levels of stress than parents of children with typical development or other disabilities (e.g., Eisenhower et al. 2005), and may be at risk of health problems as a result. However, the majority of research to date has focused on mothers of children with ASD, with an emphasis on parental reports of stress and wellbeing. Consequently, the inclusion of fathers in stress research, in addition to investigating physiological markers of stress, has potential to advance our understanding of the health effects of stress related to parenting a child with ASD.

Stress

The term "stress" is often used interchangeably to refer to stressors and the stress-response. Stress is a process that consists of stressors (i.e., challenging events), mediators (i.e., constructs that enable us to evaluate the nature of a threat and the emotional and behavioral responses elicited by that threat), and the stress-response (i.e., physical and emotional responses elicited by a stressor; Vedhara et al. 2000). With respect to *parenting stress*, this has been defined as an aversive psychological reaction to the demands of being a parent, and has been theorized to include high levels of parental distress, child difficulty, and parent–child dysfunctional interactions (Zaidman-Zait et al. 2010). The Parenting Stress Index (PSI-SF; Abidin 1995) is an assessment tool that was developed to reflect this conceptualization of parenting stress. A number of studies have used the PSI as a measure of stress in parents of children with ASD (e.g., Davis and Carter 2008; Tomanik et al. 2004). However, a recent item analysis found that only the parental distress subscale of the PSI-SF was

valid for use with parents of children with ASD (Zaidman-Zait et al. 2010), so findings based on other subscales of the PSI should be interpreted with caution.

Depression and Anxiety

Depression and anxiety, which are both linked to stress, are more clearly defined constructs. Depression is characterized by anhedonia (i.e., loss of pleasure), psychomotor retardation (i.e., the individual moves and speaks slowly, with everything requiring extreme effort and concentration), grief and guilt, a distorted, negative view of the world, and elevated levels of glucocorticoids (Sapolsky 2004). The Hospital Anxiety and Depression Scale (Zigmond and Snaith 1983), which will be included in the present study, focuses on anhedonia, which is considered by many to be the best predictor of depressive mood disorders (Snaith 2003). Negative emotions, including depression, can accompany psychological stress (Lovallo 2005). Individuals who are prone to depression tend to experience an increased level of stressors, while individuals who are experiencing chronic stress are more prone to experience major depression (Sapolsky 2004). Close links have also been demonstrated between stress and anxiety, while there are also similarities between anxiety and depression. Anxiety, like depression, is associated with a cognitive distortion, and there is a great deal of overlap between anxiety and stress disorders. The degree of overlap that exists between stress, depression, and anxiety warrants the inclusion of depression and anxiety measures in studies of stress.

Comparisons of Stress Between Mothers and Fathers of Children with ASD

Extensive research has demonstrated that parents of children with ASD experience higher levels of stress than both the general population and parents of children with other developmental disabilities (e.g., Duarte et al. 2005; Eisenhower et al. 2005; Estes et al. 2009; Hayes and Watson 2013; Hoffman et al. 2009; Rao and Beidel 2009). However, the emphasis of most research has been on mothers of children with ASD. Research investigating stress among mothers of children with ASD may not be generalisable to fathers, considering common differences between mothers' and fathers' domestic roles. For instance, some studies have reported higher levels of stress among mothers than fathers (e.g., Tehee et al. 2009). Additionally, in studies that have included both mothers and fathers of children with ASD, different sources of stress have sometimes been identified for each. Hastings (2003) found that child behavior problems did not affect paternal stress, but did affect maternal stress levels.

There are a number of reasons why fathers may be under-represented in research into parenting stress. These include challenges in recruiting fathers into research (which may be due to factors such as male attitudes towards research, or the fact that fathers are most often the parent in full-time employment), or a lack of attention to the potential influence of fathers on their children (Phares et al. 2005). In addition, the focus on mothers may at least partly reflect the assumption, based on traditional societal norms, that fathers spend less time than mothers caring for their child, and that mothers are always the primary caregivers (Phares 1992). Some previous research has supported these assumptions, reporting higher levels of parental involvement for mothers than fathers (e.g., Heller et al. 1997; Konstantareas and Homatidis 1992). However, Simmerman et al. (2001) found that fathers of children with severe intellectual disabilities tended to be substantially involved in caregiving, and mothers reported high levels of satisfaction with the extent of fathers' help within the family. Given that relevant evidence suggests that many fathers are substantially involved in caring for their children, it is important that mother–father differences in parenting stress are researched and identified in order to facilitate the provision of appropriate supports.

Physiology of Stress

One neglected area of potential important difference between mothers and fathers concerns physiological markers of chronic stress. Chronic stress has potential to cause health problems. Psychological stressors typically relate to social role and context (e.g., social expectations regarding parenting responsibilities), and these psychological stressors can activate the same physiological stress-response that is triggered in response to physical crises (Sapolsky 2004). In order to maintain optimal bodily functioning, a process known as *homeostasis* regulates internal stability in response to environmental changes (Lovallo 2005). Attempts to maintain homeostasis long-term as a result of chronic psychological stress can produce wear and tear, damaging the body. Chronic activation of the stress-response can, for instance, increase the risk of developing fatigue, hypertension (i.e., high blood pressure; BP), cardiovascular (CV) disease, peptic ulcers, cognitive decline, and damage to immune function (Sapolsky 2004). However, physiological measures may not always correlate well with self-reported stress, and individuals who report the highest levels of stress are not necessarily those demonstrating the greatest negative outcomes (Romanczyk and Gillis 2006). Therefore, it is important to directly measure physiological parameters of stress to better understand parenting stress among carers of children with ASD.

Salivary Biomarkers of Stress

Salivary cortisol (Adam and Kumari 2009) and alpha-amylase (Rohleder and Nater 2009) can provide valuable information about hypothalamic–pituitary–adrenal (HPA) axis and sympathetic nervous system (SNS) activity, respectively, which are activated in response to stress. There is growing evidence that parents of children with ASD may experience blunted cortisol activity, or hypocortisolism (Lovell et al. 2012, 2014; Ruiz-Robledillo et al. 2014; Seltzer et al. 2010). However, previous studies have focused primarily on mothers. Seltzer et al. (2010) included mothers only, Lovell et al. (2014) included only one father (6 %) and 17 mothers, and Lovell et al. (2012) included only six (13 %) fathers and 39 mothers. Furthermore, no mother–father comparisons were conducted in those studies. Ruiz-Robledillo et al. (2014) included a similar number of mothers ($n = 7$) and fathers ($n = 5$) in their supported caregiver group, but a higher number of mothers ($n = 9$) than fathers ($n = 3$) in their non-supported group. They found no significant gender differences in cortisol levels, which may not be unexpected considering the likely low statistical power of their study. Additional research is necessary to investigate potential differences in cortisol activity between mothers and fathers of children with ASD. Furthermore, parents of children with ASD have been reported to experience levels of stress similar to individuals with post-traumatic stress disorder (PTSD; e.g., Casey et al. 2012), which is characterized by blunted cortisol activity and elevated levels of alpha-amylase (Fries et al. 2005). Therefore, measurement of alpha-amylase in addition to cortisol could identify any potential physiological similarities between parents of children with ASD and individuals experiencing PTSD.

Cardiovascular Assessment

When discussing health implications of chronic stress, the link between stress and CV activity is particularly relevant. Stress is a risk factor for the development of hypertension and CV diseases (including coronary heart disease and stroke), which are the main cause of mortality and morbidity worldwide (WHO 2013). Ambulatory blood pressure (ABP) monitoring, which enables repeated observations of BP and HR in the natural environment, can provide useful information about CV responses to chronic stressors experienced in real-life situations (Klaver et al. 1994). To our knowledge, only two studies (Foody et al. 2014; Gallagher and Whiteley 2012) have used ABP monitoring with parents of children with ASD. Foody et al. (2014) investigated predictors of CV activity among mothers of children with ASD. Gallagher and Whiteley (2012) used ABP monitoring to compare CV activity between caregivers of children with developmental disabilities (DD), including ASD, and a control group of caregivers of children with typical development. They reported that caregivers of children with DD had higher mean SBP than caregivers of children with typical development. However, only 13 of the 35 caregivers included in that study were caring for a child with ASD, and only four of the caregivers were fathers. Thus, CV responses to daily stressors among parents of children with ASD still remain relatively unexplored.

There are two particularly important aspects of ABP that to our knowledge have not yet been explored in parents of children with ASD. The first concerns the fact that the diurnal CV profile usually includes a 10–20 % fall in BP during sleep (known as "dipping"), and non-dipping (no fall in nocturnal BP), extreme dipping (a larger than 20 % fall in nocturnal BP), and reverse dipping (an increase in nocturnal BP) are reported to be associated with increased risk of end-organ damage, stroke, and CV complications (e.g., Kario et al. 2001; Kario and Shimada 2004; O'Brien et al. 2000). ABP monitoring is the only non-invasive way to measure dipping.

A second aspect, variability in BP and HR, is also of potential significance. BP and HR variability can be measured using standard deviations and variation coefficients based on invasive intra-arterial BP monitoring (Mancia et al. 1983). HR variability can also be measured by using 24-h electrocardiograms (ECGs) to measure beat-to-beat changes in HR (Ewing et al. 1991). Using these methods, higher BP variability and lower HR variability have been found to predict end-organ damage and CV mortality (Algra et al. 1993; Frattola et al. 1993; Tsuji et al. 1994). However, these findings have also been replicated with standard deviations of BP and HR measured by non-invasive ABP monitoring. Kikuya et al. (2000) found that higher BP variability and lower HR variability, using standard deviations measured every 30 min by ABP monitoring, predicted higher CV mortality. BP variability measured using non-invasive ABP monitoring has also been reported to be associated with hypertension-related target organ damage, and higher incidence of CV morbid complications of hypertension (Frattola et al. 1993; Verdecchia et al. 1996). Thus, using standard deviations based on readings from ABP monitoring provides a way to measure BP and HR variability that is less invasive than intra-arterial BP monitoring or ECG, but still has prognostic significance. Examining CV activity, particularly with respect to nocturnal dipping and CV variability, may provide useful insights into different physiological effects of parenting a child with ASD for mothers and fathers.

Aims of the Present Study

The present study was an exploratory study that attempted to address two key gaps in the literature: (1)

Table 1 Demographic and diagnostic information for parents ($N = 38$) and children ($N = 19$)

Parents	
Mothers' mean age (SD)	41.1 (4.6)
Mothers' mean number of illnesses (SD)	1.5 (1.6)
Mothers' employment (% employed full-time)	11 %
Fathers' mean age (SD)	42.2 (5.5)
Fathers' mean number of illnesses (SD)	0.4 (0.8)
Fathers' employment (% employed full-time)	79 %
Children	
Gender (% boys)	79 %
Mean age (SD) at testing (years)	7.3 (3.4)
Mean age (SD) at diagnosis (years)	3.7 (1.7)
Type of ASD diagnosis (% of sample)	
Autism	84 %
Asperger's syndrome	5 %
Pervasive developmental disorder-not otherwise specified	11 %
Mean number of diagnoses (SD)	2.6 (1.2)
Diagnoses (% of sample)	
Mild intellectual disability (ID)	26 %
Moderate ID	16 %
Severe ID	11 %
Attention-deficit hyperactivity disorder (ADHD)	11 %
Epilepsy	26 %
Physical disability	11 %
Gastrointestinal issues	42 %

the limited research comparing stress and health between mothers and fathers of children with ASD, and (2) the limited research linking physiological measures of stress and parent-reported stress, anxiety, and depression, in order to further understand physical effects associated with chronic parenting stress. In order to address these issues, a dyadic approach was employed to ensure that mothers and fathers were matched on all major child characteristics. Both parent-report and physiological measures of stress were included. In stress research, there is often an over-reliance on self-report measures, which may be influenced by factors such as respondent biases (Jones and Kinman 2001). Thus, combining both parent-report and physiological markers of stress has potential to contribute to our understanding of parental stress. In the present study, parent-reported parenting responsibility, parental distress, anxiety, depression, quantity of illnesses reported, employment status, and physiological markers (i.e., awakening cortisol levels, sAA, night-time BP dipping, and CV variability) were compared between mother–father dyads of children with ASD.

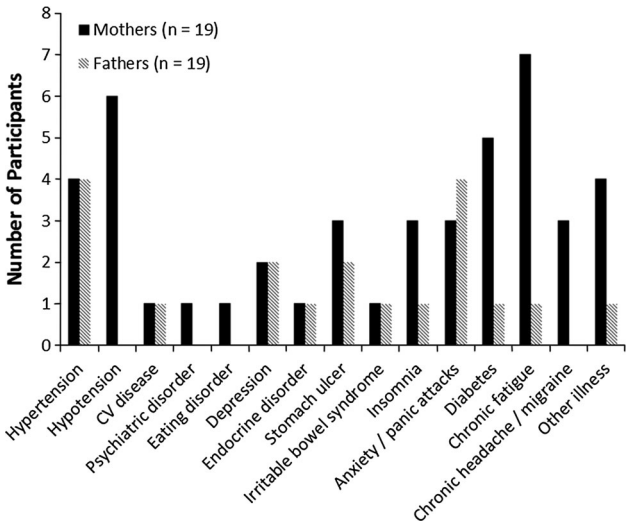

Fig. 1 Types of illnesses reported by mothers and fathers

Methods

Participants

The sample initially comprised 20 mother–father dyads of children with an ASD. Parents were eligible for inclusion if they reported that their child had received an official diagnosis of any ASD (autism, Asperger's syndrome, or pervasive developmental disorder-not otherwise specified; PDD-NOS). One dyad failed to return questionnaires within the allotted time and was excluded, leaving a final sample of 19 dyads. Participants voluntarily responded to a recruitment call issued through ASD schools, support groups, online forums, and conferences. Demographic and diagnostic information for parents and children are presented in Table 1 and Fig. 1.

Psychometric Measures

Parenting Stress Index-Short Form (Abidin 1995)

The PSI-SF is a 36-item, self-report instrument that measures stress related to the role of parenting. It contains statements related to parenting such as, "I feel trapped by my responsibilities as a parent". Individuals rate their level of agreement with each statement on a 5-point Likert scale from 1 (*strongly agree*) to 5 (*strongly disagree*). It yields an overall parenting stress score from three different subscales: parental distress (PD), parent–child dysfunctional interaction (PCDI), and difficult child (DC). However, because an item analysis has identified that PD is the only valid subscale for parents of children with ASD (Zaidman-Zait et al. 2010), only the PD subscale was included in the

present study. PD examines the extent to which the parent experiences stress in his/her role as a parent. Strong internal reliability was found for the PD subscale in the present study (Cronbach's $\alpha = .86$).

Hospital Anxiety and Depression Scale (Zigmond and Snaith 1983)

The HADS is a self-report instrument that comprises two 7-item subscales to measure perceived anxiety and depression. It was designed to assess the severity of anxiety and depression without contamination by reports of physical symptoms. Each item is rated on a 4-point Likert scale ranging from 0 to 3, with response options differing for each item. High internal consistency and validity have been reported (Moorey et al. 1991; Zigmond and Snaith 1983). Although some inconsistencies have been reported regarding the psychometric properties of the HADS, Mykletun et al. (2001) reported good factor structure, intercorrelation, homogeneity, and internal consistency. Furthermore, in the present study, good internal reliability was found for both the anxiety ($\alpha = .84$) and depression ($\alpha = .76$) subscales.

Parental Responsibility Scale (McBride and Mills 1993)

The PRS is a 14-item measure of parental responsibility. Common childcare tasks are listed (e.g., "Spending special time with the child at bedtime"). Respondents designate which parent has the primary responsibility for that task on a 5-point Likert scale ranging from 1 (*almost always completed by me*) to 5 (*almost always completed by my partner*). Responsibility was defined as remembering, planning, and scheduling the task, so it was possible for the parent to be responsible for a task without actually completing it. Moderate internal consistency, test–retest reliability, and validity have been reported (McBride and Mills 1993). A strong Cronbach's α of .91 was observed in the present study.

Demographic and Health Questionnaires

The questionnaire booklet included questions about participant age, employment status, and supports received (e.g., housekeeping assistance or caregiving support). Health-related details were also collected, including body mass index (BMI), oral health problems, smoking status, activity levels, alcohol and caffeine intake, illnesses, medication usage, weight loss, use of psychotherapy, and menopause status.

Saliva Collection

The use of salivary cortisol as a marker of HPA-axis activity has been widely documented, and further information can be obtained elsewhere (e.g., Adam and Kumari 2009; Clow et al. 2004; Pruessner et al. 2003). Similarly, the use of sAA as a marker of SNS activity has been reported in previous literature (e.g., Granger et al. 2007; Rohleder and Nater 2009). In the present study, saliva samples were collected from under the front of the tongue using Salimetrics Oral Swabs (SOS; Salimetrics Europe, Suffolk, UK). Participants were advised not to schedule data collection for at least 2 days after any dental work. Participants were also advised to avoid alcohol for 24 h before collecting saliva, and to avoid tooth-brushing, smoking, eating, drinking, and exercising in the 60 min before collecting saliva samples.

Cardiovascular Assessment

CV measures were taken using an Oscar 2^{TM} ABP monitor with an Orbit^{TM} cuff (SunTech Medical Ltd., Oxfordshire, England). The reliability and validity of this recorder have been demonstrated (Goodwin et al. 2007). The cuff was programmed to inflate every 20 min between 8:30 and 22:30 ("daytime"), and every 45 min between 22.30 and 8:30 ("night-time"). Systolic blood pressure (SBP), diastolic blood pressure (DBP), and HR were recorded for each reading. CV data were downloaded from the monitor using the SunTech AccuWin Pro v3 ABPM software (SunTech Medical Ltd., Oxfordshire, England). Participants were provided with a print-out of their ABP data and in the event that BP readings fell within the hypertensive range, participants were advised to visit their General Practitioner for further investigation.

Diaries

A diary was provided to each participant. Participants were asked to report their location, activity, and mood each time the BP cuff inflated. The rating of mood states used a 4-point scale, ranging from *not at all* (1) to *extremely* (4), and contained the following moods: "sad", "active", "interested", "stressed", "upset", "excited", "frustrated", and "alert". Diary entries were also completed after saliva samples were collected and when the ABP monitor was removed to obtain information on adherence to saliva collection guidelines, predicted and perceived stress, and ratings of child behavior problems. The summary diary also included questions about caffeine and alcohol intake, smoking, medication usage, exercise, and supports.

Procedure

Materials were posted to participants, and instructions were delivered individually by phone. The study was then carried out in the participant's natural environment, as the

participant continued his or her typical daily routine. On the morning of the study, the participant collected four saliva samples: immediately, 15, 30, and 45 min after waking. Completed samples were then placed by the participant into his or her domestic freezer, and a diary entry was completed. An additional saliva sample was collected at 12:00, and a corresponding diary entry was completed. After the morning saliva samples had been collected, the researcher met with the participant and attached an ABP monitor. When the cuff inflated during waking hours, the participant made relevant entries into the cuff-inflation diary. The ABP monitor was removed 24 h after it was attached, and the participant completed a summary diary entry. The participant was given a questionnaire booklet and asked to return the completed questionnaire within 1–2 months. Participants were given this time because of the length of the questionnaire booklet, and the sensitive nature of some of the questions. The information sheet contained contact details for participants if they wished to talk to someone as a result of any discomfort that may have been experienced while completing the questionnaires.

Analyzing Salivary Analytes

Saliva samples were retrieved from participants, and stored frozen at −20 °C until they were assayed for cortisol and sAA. On the day of testing, samples were thawed, vortexed, and centrifuged at 3,000 rpm for 15 min.

Cortisol

The four morning saliva samples were assayed in duplicate for salivary cortisol by enzyme immunoassay using the Salimetrics salivary cortisol assay kits (Salimetrics Europe, Suffolk, UK). The test requires 25 μL of saliva, and it has a range of sensitivity from .003 to 3.0 μg/dL. Average intra- and inter-assay coefficients of variability were less than 4 and 7 %, respectively. Two area under the curve calculations were made: area under the curve with respect to ground (AUC_G), and area under the curve with respect to increase (AUC_I), using Pruessner et al.'s (2003) formulas (see Clow et al. 2004 for further information). Both the AUC_G (which represents overall cortisol secretory activity), and the AUC_I (a measure of the dynamic increase in cortisol secretion), have been found to be differentially associated with psychological health and wellbeing (Clow et al. 2004).

To control for noncompliance, samples were excluded if there was more than a 10-min difference between reports of waking and collecting the first sample. Samples were also excluded if there was not enough saliva in the sample to perform the assay. Furthermore, given the dyadic nature of this study, dyads were only included in cortisol analyses if valid samples were available for both members of the dyad. Based on these inclusion criteria, seven dyads were included in the cortisol statistical analyses.

Alpha-Amylase

The 12:00 samples were assayed by kinetic measurement with the Salimetrics sAA assay kits (Salimetrics Europe, Suffolk, UK). The test used 10 μL of saliva. Average inter-assay coefficients of variability were less than 11 %. To control for noncompliance, samples were excluded if they were not reported as being collected within 60 min of the target time (i.e., 12:00; Rohleder et al. 2008). Samples were excluded if there was insufficient quantity of saliva to perform the assay, and dyads were only included in sAA analyses if valid samples were available for both members of a dyad. Based on these inclusion criteria, nine dyads were included in the sAA statistical analyses.

Data Analysis

Cortisol and sAA data were positively skewed, and were natural-log and square-root transformed, respectively (Adam and Kumari 2009; Granger et al. 2007). Outliers were then recoded to the next highest value in the distribution. Skewness statistics were less than .35 for all of the cortisol and sAA distributions after data transformation. For ease of interpretation, raw, unaltered values are presented in tables and graphs.

Because the statistical assumption of independence had been violated, group comparisons were not conducted. Instead, for each dependent variable, the father's score was subtracted from the mother's score for each dyad, providing a difference score for each. Dyad difference scores were then tested for significance of difference from zero, using one-sample *t* tests. Alpha values were corrected using family-wise Bonferroni adjustment (see Table 2). The quantity of parent-reported illnesses was also included in the dyad difference analyses. Comparisons between mothers and fathers with respect to health-relevant variables (e.g., BMI) and diary information (e.g., mood or location on the day of the study) showed that the two groups did not differ significantly on any of these variables, which therefore are not reported in the Results section. Furthermore, a Chi square test of association was conducted to test for an association between gender and employment status.

Results

Descriptive Analysis

Mean group scores for mothers and fathers are reported in Table 2. As can be seen in Table 2, mothers had clinically

Table 2 Mean (*SD*) for dependent variables for mothers and fathers, and summary of one-sample *t* tests to test dyad difference scores for significance of difference from zero

Measure	Mothers ($n = 19$)	Fathers ($n = 19$)	*t*	*df*	Adjusted α value[a]
Parental responsibility	44.6 (7.2)	29.7 (6.8)	4.64*	17	.05
Anxiety	10.2 (3.3)	6.4 (3.4)	4.34*	18	.025
Depression	7.3 (2.7)	5.0 (3.2)	2.64*	19	.025
Parental distress	34.2 (8.6)	29.9 (7.9)	2.11*	19	.05
SBP night-time reduction (%)	15.1 (6)	13.7 (7.3)	0.71	19	.025
DBP night-time reduction (%)	20.7 (6.9)	19.2 (8.9)	0.45	18	.025
Awake SBP variability	23.6 (5.5)	29.2 (5.5)	−3.14*	18	.008
Asleep SBP variability	22.5 (4.4)	29.1 (8.9)	−3.70*	17	.008
Awake DBP variability	22.9 (4.1)	27.9 (5.1)	−3.11*	19	.008
Asleep DBP variability	19.1 (4.2)	23.8 (6.2)	−2.81[b]	18	.008
Awake HR variability	23.0 (3.7)	28.7 (6.2)	−3.58*	19	.008
Asleep HR variability	19.3 (4.2)	24.8 (6.8)	−2.81[b]	18	.008
AUC_G[c]	–	–	0.72	7	.025
AUC_I[c]	–	–	−0.02	7	.025
Alpha-amylase[d]	116.9 (81)	169.5 (137.8)	−1.16	9	.05
Quantity of illnesses	1.5 (1.6)	0.4 (0.7)	3.75*	19	.05

* Significant at the adjusted α value denoted

[a] Alpha value adjusted using family-wise Bonferroni correction

[b] Approaching significance

[c] Non-transformed means not available for AUC_G and AUC_I. Dyad difference analysis based on a sample of 7 mother–father dyads

[d] Based on a sample of 9 mothers and 9 fathers

significant levels of parental distress, with mean scores falling above the 85th percentile (Abidin 1995). However, mean parental distress scores for fathers fell at the 70th percentile, indicating typical levels of parental distress.

As can be seen in Table 2, group anxiety and depression scores for fathers and group depression scores for mothers all fell within the normal range (0–7), and group anxiety scores for mothers fell within mild range (8–10; Zigmond and Snaith 1983). However, 11 mothers (58 %) had anxiety scores that fell within the moderate range (11–14).

Mean cortisol levels for both groups are illustrated in Fig. 2, alongside average cortisol values reported by Wust et al. (2000). Wust et al.'s (2000) reported "normal" cortisol values, which were based on 509 participants, were used in the present study as a comparison given that there was no control group of parents of children with typical

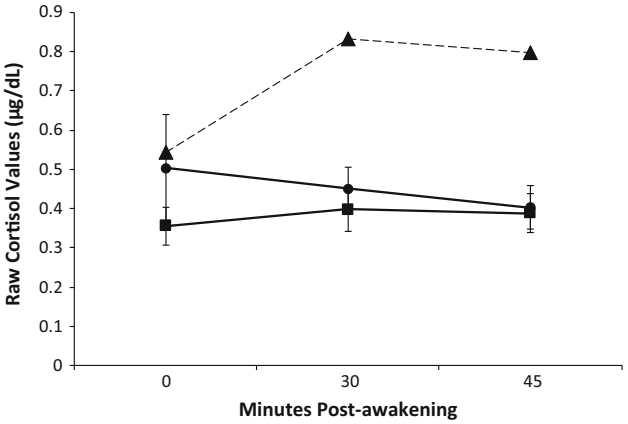

Fig. 2 Post-awakening mean group cortisol values (µg/dL) of mothers (*circles*) and fathers (*boxes*) of children with ASD in the present study and "normal" cortisol values based on Wust et al. (2000; $N = 509$) presented for comparison (*triangles* with *dashed line*). *Note* Standard *error bars* are shown for cortisol values of mothers and fathers in the present study, but are not available for results published by Wust et al. (2000)

development. This approach has some limitations (see "Discussion"), but provides a starting point for this exploratory study which can be built upon in future research. One-sample *t* tests were conducted to compare cortisol values of mothers and fathers of children with ASD to Wust et al.'s (2000) normal cortisol values. For mothers, cortisol values immediately after waking did not differ significantly from the reported averages, $t\ (15) = -0.24$, $p = .81$; however, cortisol values 30 min, $t\ (18) = -6.23$, $p < .001$, and 45 min, $t\ (18) = -6.16$, $p < .001$, after waking were significantly lower than the reported averages. For fathers, cortisol values immediately, $t\ (17) = -11.78$, $p < .001$, 30 min, $t\ (19) = -9.83$, $p < .001$, and 45 min, $t\ (16) = -11.20$, $p < .001$, after waking were significantly lower than the reported averages. Mean sAA levels were somewhat high for mothers ($M = 116.9$, $SD = 81.0$, range 34–308 U/mL) and fathers ($M = 169.5$, $SD = 137.8$, range 8–390 U/mL), falling above Salimetrics' expected adult mean of 92.4 U/mL (Salimetrics 2010). However, this difference did not reach statistical significance for mothers, $t\ (12) = 1.05$, $p = .32$, or fathers, $t\ (10) = 1.77$, $p = .11$.

Mean 24-h DBP for mothers ($M = 72.0$, $SD = 8.4$) and fathers ($M = 82.6$, $SD = 11.3$), and mean 24-h SBP for mothers ($M = 121.3$, $SD = 11.3$), fell within the normotensive range. The normotensive range was defined by O'Brien et al. (2000) as a 24-h SBP $\leq$ 135 mmHg and a 24-h DBP $\leq$ 85 mmHg. Mean 24-h SBP for fathers ($M = 138.3$, $SD = 15.3$) slightly exceeded the normotensive range, with mean 24-h SBP for 11 fathers (58 %) falling within the hypertensive range. DBP means were also more variable for fathers than mothers, with only one mother (5 %), but seven fathers (37 %) falling within the hypertensive DBP range.

Testing Dyad Difference Scores

As outlined in the Data Analysis, dyad difference scores were calculated for each of the dependent variables, and tested to see if they significantly differed from zero using one sample *t* tests with family-wise Bonferroni adjustments. Results are reported in Table 2. As shown in Table 2, mothers reported higher levels of parenting responsibility than fathers. Similarly, mothers reported significantly higher levels of parental distress, anxiety, and depression than fathers. However, there were no significant differences in AUC_G, AUC_I, or sAA levels between mothers and fathers. Mothers did, however, report experiencing a significantly higher number of illnesses at the time of the study than fathers.

With respect to CV measures, there were no significant differences in SBP or DBP dipping (see Table 2). Standard deviations from awake and asleep SBP, DBP, and HR measures were used as estimates of BP and HR variability (Kikuya et al. 2000). Fathers had higher awake SBP, DBP, and HR variability, and higher asleep SBP variability than mothers. Asleep DBP and HR variability did not significantly differ between mothers and fathers, although they were approaching significance, with higher variability for fathers than mothers.

Dipping Status

Because no significant differences were observed between the size of SBP or DBP dipping between mothers and fathers, dipping patterns were explored further, using the following criteria: dipping was defined as a $\geq$10 % but <20 % fall in nocturnal BP, non-dipping was defined as a <10 % but >0 % fall, extreme dipping was defined as a nocturnal BP fall $\geq$20 %, and reverse dipping was defined as a nocturnal BP > 0 % (Xu et al. 2013). A Chi square test for independence indicated no significant association between gender and dipping status for SBP, χ^2 (2, $n = 36$) = .66, $p = .72$, or DBP, χ^2 (2, $n = 36$) = .50, $p = .78$. Furthermore, a 2 (gender) × 4 (dipping status) way ANOVA was conducted to determine if there was an interaction between stress, gender, and dipping status, but no significant effects were observed ($p = ns$). The majority of mothers and fathers were normal SBP dippers. Only three mothers (16 %) and five fathers (26 %) were found to be non-dippers for SBP, and only two mothers (11 %) and three fathers (16 %) found to be non-dippers for DBP. However, five mothers (26 %) and four fathers (21 %) were found to be extreme SBP dippers, and 10 mothers (53 %) and eight fathers (42 %) were found to be extreme DBP dippers. No reverse dipping was observed.

Employment Status

A Chi square test for independence revealed a significant association between gender and employment status, χ^2 (2, $n = 38$) = 18.06, $p < .001$, with fathers (79 %) significantly more likely to be in full-time employment than mothers (11 %).

Discussion

This exploratory study compared parenting responsibility, parental distress, anxiety, depression, and physiological measures of stress between mother–father dyads that had children with ASD. Mothers reported significantly higher levels of parenting responsibility, parental distress, anxiety, and depression than fathers, while fathers had significantly higher BP and HR variability than mothers. However, there were no significant differences between mothers and fathers in relation to SBP or DBP dipping, AUC_G, AUC_I, or sAA levels.

Perceived Parenting Stress, Anxiety, and Depression

The findings that mothers reported significantly higher levels of parenting responsibility than fathers, and were significantly less likely than fathers to be in full-time employment, are consistent with previous findings that mothers are more often the primary caregiver (Heller et al. 1997; Konstantareas and Homatidis 1992). The higher level of maternal involvement in parenting may have contributed to their higher levels of parental distress, anxiety, and depression, as has been previously suggested (e.g., Hastings 2003; Moes et al. 1992). Interestingly, mothers also reported a significantly higher number of illnesses than fathers. This could suggest a link between negative health consequences and higher parental responsibility, anxiety, depression, and parental distress among mothers, although any results of the present study must be viewed cautiously due to the small sample size. The gender differences identified in parental involvement, anxiety, depression, and distress should be taken into consideration when assessing and screening parents, and when designing or allocating supports and services (see "Practical Implications"). Mothers, in particular, may benefit from greater access to respite, social support, or stress management interventions.

Salivary Biomarkers of Stress

Previous research has indicated that parents of children with ASD may experience hypocortisolism (Seltzer et al. 2010). Ruiz-Robledillo et al. (2014) also reported that non-supported caregivers of individuals with ASD had lower cortisol awakening responses than supported caregivers and non-caregivers. In the present study, there were no significant differences between mothers and fathers with

respect to AUC_G or AUC_I. Both groups of parents had lower than average post-awakening levels of cortisol (Wust et al. 2000). Although there are limitations to comparing the present sample to Wust et al.'s (2000) reported values (see "Limitations and Future Research"), these findings provide further, tentative evidence that parents of children with ASD may experience dysregulation of the HPA-axis and, importantly, that this risk of dysregulation may extend to fathers as well as mothers. A pattern of blunted cortisol activity, in addition to elevated sAA activity, has been reported among individuals with PTSD (Fries et al. 2005). Although sAA levels were not significantly higher than Salimetrics' expected adult means in the present study, this may have been due to the small sample size. Further research exploring cortisol and sAA activity among a larger sample of parents of children with ASD, in comparison to parents of children with typical development and individuals experiencing PTSD, could provide greater understanding of the mechanisms underlying hypocortisolism among parents of children with ASD.

Hypocortisolism is associated with an increased risk of health problems (Heim et al. 2000), and Ruiz-Robledillo et al. (2014) reported a link between lower cortisol awakening responses and higher somatic symptoms among caregivers. Fries et al. (2005) propose that hypocortisolism is a protective response that reduces the harmful effects of glucocorticoid responses to daily stressors, with the drawback of symptoms such as pain, fatigue, and high stress sensitivity. Consequently, preventing and managing chronic stress may be the most effective approach to dealing with hypocortisolism and preventing associated health problems among parents of children with ASD. Additionally, as Ruiz-Robledillo et al. (2014) found that awakening cortisol levels were blunted only for parents of children who were not receiving support, these findings highlight the importance of providing supports for parents of children with ASD. Thus, it may be beneficial for health practitioners to routinely monitor parents and make referrals for appropriate supports and service.

Moreover, further investigation is needed in relation to the fact that similar cortisol activity was found among mothers and fathers despite mothers having reported significantly higher levels of distress, anxiety, and depression than fathers. Greater dysregulation of the HPA-axis could have been expected among mothers than fathers if they were under greater distress, as reported. Previous research has indicated that gender differences may influence self-reports of psychological health status, with physiological symptoms such as depression more likely to be reported by woman than men (Cooper and Bright 2001). This gender difference could be due to actual differences in emotions between men and women, or could be influenced by cultural expectations for men and women. Consequently, it is possible that fathers in the present study may have under-reported their levels of distress, anxiety, and depression. Further research is needed to better understand the discrepancy between physiological outcomes and self-reports of stress, anxiety, and depression among mothers and fathers of children with ASD.

Blood Pressure and Heart Rate Variability

To our knowledge, only two studies (Foody et al. 2014; Gallagher and Whiteley 2012) have investigated ambulatory BP and HR in parents of children with ASD. High BP and low HR variability using standard deviations of readings obtained from ABP monitoring have been found to independently predict CV mortality (Kikuya et al. 2000; Pickering and James 1994). In the present study, fathers had significantly higher BP and HR variability than mothers. This suggests that fathers may be at higher risk of CV disease than mothers as a result of higher BP variability, but that mothers may be at higher CV risk than fathers as a result of reduced HR variability. Previous research has reported that, although antihypertensive medication may be effective in lowering BP, it may not be effective in regulating BP variability (Garcia-Vera et al. 2004). Garcia-Vera et al. (2004) found that stress management training could be effective in reducing BP variability. Such findings provide further support for the need for stress management for parents of children with ASD.

With respect to night-time reduction in SBP and DBP, there were no significant differences between mothers and fathers in terms of the extent of dipping or type of dipping pattern. Although the majority of mothers and fathers were normal dippers, three mothers and five fathers were found to be non-dippers for SBP, and two mothers and three fathers were non-dippers for DBP. Five mothers and four fathers were found to be extreme SBP dippers and ten mothers and eight fathers were found to be extreme DBP dippers. Extreme dipping has been found to be associated with increased risk of stroke and silent cerebrovascular disease (Hoshide et al. 2002; Kario and Shimada 2004). Antihypertensive medication has also been reported to be less effective for extreme dippers than normal dippers (Hoshide et al. 2002), and treatment of hypertension in individuals with extreme dipping may exacerbate night-time hypotension, increasing risk of stroke at night (Kario and Pickering 2000). Furthermore, higher BP variability and extreme dipping together may accelerate target-organ damage (Shimada and Kario 1997). These findings suggest that parents of children with ASD may be at increased risk of abnormal dipping patterns and CV variability. Given the associated health consequences, combining stress management training with routine health assessments, with a particular emphasis on ambulatory BP, may be beneficial in

assessing, treating, and possibly preventing CV health problems for parents of children with ASD. Additionally, given the limited research on CV activity in parents of children with ASD and small sample size in the present study, further large-scale research investigating ambulatory CV activity could be informative.

Practical Implications

The present study identified potential health risks for parents of children with ASD. Given the lower than average awakening cortisol levels found, further research is warranted to determine whether some parents of children with ASD might exhibit low cortisol production throughout the day (i.e., hypocortisolism), which could have important health implications (Heim et al. 2000). In addition, some abnormal CV activity was detected. As discussed previously, extreme BP dipping was found in a high number of mothers ($n = 15$) and fathers ($n = 12$), while fathers had significantly higher BP and HR variability than mothers. High BP variability and extreme dipping together may accelerate target-organ damage (Shimada and Kario 1997). Antihypertensive medication may not be effective in regulating BP variability, but stress management training has been shown to reduce BP variability (Garcia-Vera et al. 2004). The findings in the present study suggest the need for health practitioners to screen parents of children with ASD, and to make referrals to ensure access to necessary services and supports. Screening of mothers of children with ASD may be particularly important, given the findings that they are more involved and experience higher levels of distress, anxiety, and depression than fathers.

The management of high stress levels identified through such a screening process is likely to require a multi-faceted approach, in addition to treating any health issues identified. Stress reduction interventions (e.g., Blackledge and Hayes 2006), access to social support (e.g., Boyd 2002), access to required supports and services for their children (e.g., Smith 1997), and parent training (e.g., McConachie and Diggle 2007), for instance, all have the potential to reduce stress among parents of children with ASD. Dillenburger et al. (2010) also found that respite was rated as a future need by 93 % of parents of children with ASD surveyed, although only 38 % were in receipt of home or respite support. Potential differences in needs for mothers and fathers should be considered. For instance, mothers may be in greater need of respite services than fathers, given the greater levels of parent involvement, distress, anxiety, and depression, in addition to lower levels of employment. Unemployed parents do not experience the respite associated with employment, and may have less of a reprieve from the demands of caregiving (Gray and Holden 1992). During the screening process, the needs of the parents should be considered to ensure the most appropriate supports and services are provided.

Limitations and Future Research

As mentioned above, this is an exploratory study and the results should be interpreted with caution for a number of reasons. With only 19 dyads participating, the sample size, though larger than in similar previous research, was still small. Additionally, only subsets of seven and nine dyads were available for inclusion in the cortisol and sAA analyses, respectively, reducing statistical power for these analyses. Furthermore, the present study did not use a control group of parents of children with typical development, possibly limiting interpretation of the results. Similarly, results from comparisons with Wust et al.'s (2000) data for the cortisol samples must be viewed with caution, given that these samples were collected and analyzed in a different laboratory and country.

However, the present study, despite being exploratory in nature, has the potential to guide future research in this area. To our knowledge, this is the first study to directly compare cortisol, alpha-amylase, and ambulatory blood pressure and heart rate between mothers and fathers of children with ASD. Indicators of chronic stress, including BP and HR variability, BP dipping, and hypocortisolism, suggest the need for similar larger-scale investigations of physiological markers of stress in parents of children with ASD. Furthermore, the inclusion of a group of parents of children with typical development could provide better understanding of possible specific threats to health associated with chronic parenting challenges. Confirmation of such threats would further underscore the need for relevant support services for all who experience chronic parenting stress, including parents of children with ASD.

Conflict of interest The authors declare that they have no conflict of interest.

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