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Familial support following childhood sexual abuse is associated with longer telomere length in adult females

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Abstract Robust associations between adverse childhood experiences and shortened telomere length exist, but few studies have examined factors that may moderate this association, particularly with a resilience framework. The present study examined the association between exposure to childhood sexual abuse (and abuse severity) and mean telomere length, and whether social support and optimism moderated this association. The sample included 99 White monozygotic female twins, ranging in age from 35 to 70 (M_{age} = 52.74, SD = 8.55 years), who provided a blood sample for telomere assay, and data on their childhood sexual abuse history, trait optimism, and current social support. Linear mixed effects models were employed to test study hypotheses. There were no effects of exposure to abuse or abuse severity on mean telomere length, nor were there main or moderating effects of optimism, in analyses of the full sample. However, in analyses that only included women exposed to abuse, there was an abuse type × support interaction: among women who experienced abuse in forms other than intercourse, higher levels of social support were associated with longer mean telomere length. Findings from the current study clarify the role of childhood sexual abuse in telomere attrition, and identify one factor that may protect against the negative biological effects of childhood sexual abuse.

Keywords Sexual abuse · Telomere · Protective · Social support · Optimism · Female

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Introduction

Childhood sexual abuse (CSA) is a pervasive issue affecting one in five women and one in 13 men worldwide (WHO, 2016) that has been associated with both short- and long-term physical and psychological consequences (e.g., Fergusson et al., 2013; Irish et al., 2010; Wegman & Stetler, 2009). General physical health problems that have been noted to occur at an increased rate in adults who experienced CSA include (but are not limited to) pain, obesity, gastrointestinal health problems, and adverse cardiovascular health conditions (Irish et al., 2010), with the detrimental outcome being of larger effect in females (Wegman & Stetler, 2009). Given that an association between CSA and long-term physical health outcomes has been established, researchers have begun to explore biological factors through which CSA may lead to long-term

alterations in physical health over long periods of time. Telomeres are one biological marker connected to both adverse childhood experiences (ACEs) and adult physical health (e.g., Haycock et al., 2014; Price et al., 2013). Briefly, telomeres are protein-bound DNA structures located at the ends of chromosomes (in humans, they are comprised of multiple repeats of the sequence: TTAGGG; Blackburn, 2005). Their primary function is to prevent the ends of chromosomes from being recognized as a DNA break(s), thereby allowing for stabilization of the chromosomes (Blackburn et al., 2006). However, during each somatic cell division, telomeres shorten by 30–200 base pairs because DNA polymerase is unable to fully replicate the 3′ end of the lagging DNA strand (Starkweather et al., 2014). This phenomenon is referred to as the "end replication problem" and leads to a decline in telomere length (TL) over time. Telomeres are therefore viewed as a biological marker of aging.

Numerous investigators have examined the association between various ACEs and TL. However, fewer researchers have examined the unique effect of CSA on TL, with the results of such studies yielding mixed findings. For example, in a report by O'Donovan et al. (2011), adults (47% female) who were exposed to childhood trauma (measured via a composite variable that included sexual abuse), and were diagnosed with chronic posttraumatic stress disorder (PTSD), were noted to have significantly shorter mean TL (mTL) compared to controls. However, the authors did not examine the unique association between CSA (or any other trauma) and mTL, and there was insufficient variance to examine this association within the control group, so they were unable to account for PTSD and childhood trauma being confounded in their research cohort. Another study by Tyrka et al. (2011) sampled adults (71% female) who were exposed to any childhood maltreatment (i.e., sexual abuse, and physical and emotional abuse or neglect) and found that these individuals had significantly shorter mTL compared to those individuals not exposed to childhood maltreatment. Specifically, only those individuals who experienced physical or emotional neglect had significant decreases in mTL. The unique effects of sexual abuse on mTL in this sample were not assessed since only two individuals endorsed this type of maltreatment. In younger cohorts, a prospective study by Shalev et al. (2013) found that children (49% female) exposed to physical maltreatment (including sexual abuse) at age 5 had significantly shorter mTL at age 10 compared to children who reported no exposure to maltreatment. However, analyses did not specify which type(s) of physical abuse (i.e., hitting/slapping vs. fondling) shared a unique association with mTL.

In contrast to studies revealing an association between maltreatment (broadly defined) and TL, investigations examining the unique effect of CSA on TL have yielded mixed findings (e.g., Fergusson et al., 2013; Glass et al., 2010; Kiecolt-Glaser et al., 2011; Mason et al., 2015). Across these studies, sample demographics were comparable (i.e., middle age, primarily White women); two studies (Glass et al., 2010; Kiecolt-Glaser et al., 2011) used binary (i.e., yes/no) response options for reporting sexual abuse, while Mason et al. (2015) asked participants to report if abuse occurred via sexual touching only or abrasive sexual activity. The only study to detect a significant effect of CSA on adult health was conducted by Fergusson et al. (2013). In this study, retrospective data were collected on CSA (and other ACEs) from approximately 900 adults, and CSA was categorized into three groups: no contact (e.g., genital exposure by an adult), contact (e.g., fondling), and completed intercourse. Results of this study revealed significant associations between CSA exposure and a variety of mental and physical health problems (e.g., depressive symptoms, self-esteem, doctor/hospital visits), and these effects remained after controlling for potential confounders such as socioeconomic status, sex, and family functioning. Furthermore, the severity of mental and physical health problems increased as duration and severity of CSA increased. Based on these findings, it is possible that a more precise measurement of CSA that includes severity may elucidate the unique effect of CSA on TL. A goal of the present study was to utilize data on CSA severity in an effort to clarify the unique effects of CSA on TL and reconcile conflicting findings within the literature.

Protective factors and telomere length

Although the results of previous research demonstrate a relationship between ACEs and TL throughout the lifespan, risk paradigms dominate this work (for a review, see Oliveira et al., 2016). It is equally important, however, to understand the role of resilience in the context of childhood adversity. In the context of ACEs and TL, similar (or longer) TL among individuals exposed to ACEs, compared with those not exposed to similar adversity, would indicate resilience. Identifying factors that promote resilience would advance our understanding of the complex association between ACEs and TL and identify targets for intervention.

Based on theories of stress and coping, we identified two such factors—social support and optimism—that have been linked to both physical health outcomes (e.g., Holt-Lunstad et al., 2010) and alterations in more proximal biological processes (e.g., Taylor, 2010), that may serve to promote positive biological and behavioral outcomes in response to ACEs. More specifically, as outlined by Lazarus and Folkman (1984), a cognitive-phenomenological approach emphasizes both individual and environ-

mental factors, as well as their interaction, in determining how an individual responds to a stressor. Social support and optimism constitute potential social/environmental and individual factors that may influence how an individual exposed to ACEs appraises (1) the threat associated with adverse experiences, and (2) the ways and extent to which one can respond, adapt, and cope with a stressor.

The first of the hypothesized resilience factors noted above, social support, can alter a person's perception of, and subsequent appraisal and response to, stressful experiences, which can attenuate the biological impact of the stressor and limit the subsequent physical health effects (Cohen & Wills, 1985). To our knowledge, only one investigative team, to date, has examined the protective effects of social support on TL (Asok et al., 2013). Specifically, this research team found that maternal responsiveness—a type of socio-emotional support within families—mitigated the impact of childhood adversity (defined as being in the Child Welfare System) on mTL in young children (45% female). Aside from this work, researchers primarily have examined the direct relation between generalized social support and TL (not specific to ACEs). For example, Carroll et al. (2013) found that social support among older adults (65–84 years old; 52% female) was positively associated with mTL. In addition to this work, Beach et al. (2014) found an inverse relation between unsupportive parenting and mTL in a sample of rural, African American adolescents (64% female). Further, an intervention study using this sample found that adolescents whose parents participated in the intervention and reported increases in levels of warmth and emotional support had significantly longer telomeres 5 years later compared to those adolescents in a control group (Brody et al., 2015). A goal of the current study was to clarify the protective effects of social support among adults in response to a severe childhood trauma (i.e., CSA).

Optimism is the second hypothesized resilience factor in our study, as it can influence an individual's psychological appraisal of stress and coping behaviors (Lazarus & Folkman, 1984). Specifically, if an individual is able to reframe the negative experience in a positive way, this may have a direct influence on an individual's physiological response to stress and subsequent health outcomes (Rasmussen et al., 2009; Smith, 2006). Schutte et al. (2016) examined the association between psychological characteristics and mTL in middle-aged women and found that optimism was significantly associated with TL after controlling for age, biological sex, and psychological traits. Similarly, Zalli et al. (2014) found that older men with shorter telomeres and high telomerase activity—a combination that is hypothesized to indicate a stressed system – reported lower levels of optimism compared to the rest of the sample. These studies provide preliminary evidence that optimism can impact TL; however, this association has yet to be tested as a protective factor in the context of CSA.

The current study

Although there is evidence for a link between ACEs and TL throughout the lifespan, a challenge encountered by researchers in this field has been identifying a sufficient number of individuals who have comprehensive measurements of CSA (e.g., self-report, severity) to examine statistical associations. In the present study we evaluated a cohort of women for whom a more thorough examination of CSA was completed by including information regarding both exposure to abuse and abuse severity. Our sample is restricted to females since they are most likely to experience CSA, and to limit variations in mTL that are associated with biological sex (e.g., Berglund et al., 2016; Carroll et al., 2013), irrespective of exposure to CSA. We hypothesized that (1) exposure to CSA (i.e., yes/no) would be associated with decreases in mTL; (2) increases in CSA severity would be associated with decreases in mTL; (3) social support would mitigate the association between CSA exposure (and CSA severity) and mTL; and (4) optimism would mitigate the association between CSA exposure (and CSA severity) and mTL (see Fig. 1).

Methods

Participant ascertainment and overall study design

The present study group consists of a subset of female–female (FF) monozygotic (MZ) twins ($N = 99$) who participated in the population-based Virginia Adult Twin Study for Psychiatric and Substance Use Disorders (VATSPSUD; for more information on this study and its design, see Kendler & Prescott, 2006). Participants in the current study were drawn from the FF Twin Study, which began data collection in January of 1987. The FF Twin Study consisted of individuals whom were born between 1934 and 1974 and ranged in age from 18 to 54 years ($M_{age} = 29.3$, $SD = 7.7$ years) at baseline (i.e., Wave 1; 1987). All women identified as White, median household income was $35,000–40,000 and an average year of education was 13.5 (i.e., some college) at baseline. The analytic sample was comparable to the larger FF Twin Study, consisting of females who ranged in age from 19 to 48 ($M_{age} = 30.5$, $SD = 7.8$) with an average of 13.9 years ($SD = 2.0$) of education, and median income of $30,000–35,000 at baseline.

A variety of questionnaire and biometric data were collected from the FF Twin Study participants at unequal intervals on 5 different occasions (herein referred to as

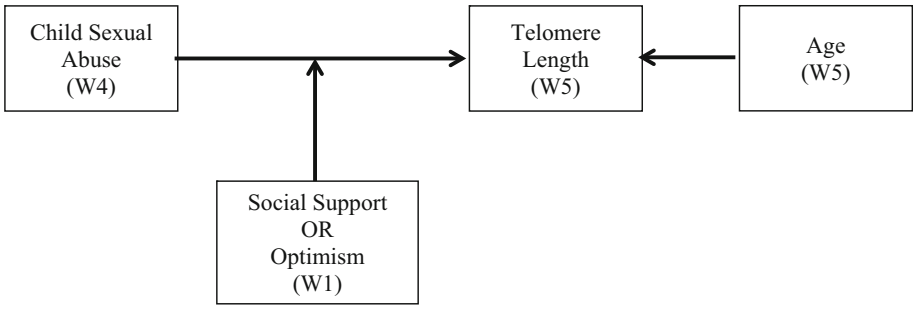

Fig. 1 Hypothesized model for Hypotheses 3 and 4. *Note* Child sexual abuse was assessed retrospectively at Wave 4. Social support and optimism were assessed in separate models

"Waves"). During the 4th Wave of data collection (approximately 8 years after Wave 1), participants responded to questions regarding CSA history. Those women who chose to respond to questions regarding CSA history were then invited to complete an additional health history questionnaire and provide blood samples. After providing their informed consent (Virginia Commonwealth University; IRB #12407), blood specimens were obtained by a health care provider of the participant's choosing (either their own health care provider [with the specimens being shipped via overnight courier to our cytogenetic laboratory] or a health care provider at Virginia Commonwealth University). Mean telomere length data were obtained from these peripheral blood specimens for each participant as described below.

Measures

Childhood sexual abuse

Sexual abuse during childhood was assessed via a self-report questionnaire at Wave 4, which was approximately 8 years after Wave 1. The questionnaire used was an adapted version of a previously developed measure by Mullen et al. (1993). The measure consists of a single item stem asking, "Before you were 16, did any adult, or any other person older than yourself, involve you in any unwanted incidents like…" and participants chose from a list of six different items referring to sexual abuse. Response options ranged on a scale from 0 (never) to 2 (more than once), and items could be collapsed into three categories of abuse: non-genital contact (e.g., unwanted kissing/hugging; 3 items), genital contact without intercourse (e.g., fondling; 2 items), and intercourse (1 item). A binary version of this variable was created where endorsement of any form of CSA was coded as a "1" and no endorsement as "0." Three additional binary variables were created to assess whether or not women were exposed to each type of sexual abuse.

Social support

Social support was assessed at Wave 1 using a subset of self-report items from an original measure created for the VATSPSUD study (cf, Kendler & Prescott, 2006). This subscale consists of 10 items that assess the quality of support obtained from friends (5 items) and relatives (5 items). A sample item from this measure is, "When you are in contact with friends, how often do they make that you feel like they care about you?" Responses ranged from 1 (often) to 4 (never). Items responses were recoded so that higher scores indicated higher levels of support. Reliability for the items regarding social support from friends was low ($\alpha = .59$), while reliability for items regarding social support from family was acceptable ($\alpha = .77$). Scores across support groups (i.e., friends and relatives) were summed to create a total score for social support. Reliability for all 10 items among the analytic sample was adequate ($\alpha = .69$).

Descriptive data also were collected at Wave 4 regarding the type of response and support participants received if they revealed their abuse to another person. Original items were used to obtain this information. The first item assessed the level of support the participant received if they revealed their abuse to someone. The item stem was, "I told someone [about the abuse] and was…" Participants then responded (yes/no) to each of the following options: (a) told no one; (b) blamed or punished; (c) not believed; (d) believed but not supported; or (e) believed and supported. The second item assessed the general response participants received after revealing their abuse to another person. The item stem was, "If you told anyone, how would you rate their response?" Participants then responded (yes/no) to each of the following options: (a) never told anyone; (b) received a negative response; (c) received a mostly negative response; (d) received a neutral response; (e) received a mostly positive response; or (f) received a positive response. Endorsement rates for each of these items can be found in Table 1.

Optimism

Optimism was assessed at Wave 1 using a subset of items from the Life Orientation Test (LOT; Scheier & Carver, 1985). Optimism was assessed via five items that examined a participant's outlook on life (e.g., "I always look on the bright side of things"). Responses ranged from 1 (strongly agree) to 4 (strongly disagree). Item responses were reco-

Table 1 Proportion of responses from individuals exposed to sexual abuse

Support items	
Believed and supported (N = 62)	27.4%
Believed but not supported (N = 61)	11.5%
Not believed (N = 60)	3.3%
Blamed or punished (N = 60)	3.3%
I told no one (N = 62)	67.7%
Response items	
Positive response (N = 69)	17.4%
Mostly positive response (N = 69)	4.3%
Neutral response (N = 69)	5.8%
Mostly negative response (N = 69)	4.3%
Negative response (N = 69)	2.9%
Never told anyone (N = 69)	52.2%

Support items stem was, "I told someone and was…"

ded so that higher scores indicated higher levels of optimism. Scores were summed to create a total score for optimism. Reliability for these items among the analytic sample was adequate (α = .75).

Mean telomere length

Telomere data collection began approximately 10 years after Wave 4, which will be referred to as Wave 5. To obtain the telomere data, genomic DNA was extracted from whole blood using a Puregene DNA Isolation Kit (Qiagen) according to the manufacturer's protocol. After extraction, the DNA was quantified, evaluated to ensure it was not degraded, and stored at − 80 °C until used for telomere assessments. Telomere lengths were quantified using a monochrome multiplex qPCR (MMqPCR) technique, as described by Cawthon (2009) (see Table 2). All specimens were run in triplicate (3 different wells per specimen), with these values being averaged (BioRad CFX Manager Software version 3.0) to obtain the mean T (telomere)/S (albumin single copy gene) variable assessed in the analytic models. For quality control purposes, each plate also contained four "control" specimens (run in triplicate). These quality control standard specimens included: (1) DNA extracted from MCF7 cells [known to have short telomeres]; (2) DNA extracted from HeLa cells [known to have long telomeres]; (3) DNA extracted from a healthy female [known to have moderate telomere lengths]; and (4) blank wells containing no DNA. The T/S ratio values for these control specimens were assessed for each plate to ensure that each control showed small (MCF7), large (HeLa), and moderate (JMS) values, or no amplification product (blank wells) before including the proband values from that batch in the dataset for analysis. Also, to reduce experimental variation (i.e., batch effects), specimens from co-twins were placed on the same multi-well plates.

Statistical analysis

Covariates

Age at time of telomere data collection (i.e., Wave 5), education level, smoking status (yes/no; current and lifetime use), lifetime diagnosis of Major Depressive Disorder (MDD), and lifetime diagnosis of Generalized Anxiety Disorder (GAD) were identified as relevant covariates due to their theoretical and empirical associations with TL (for a review, see Starkweather et al., 2014). Education level was assessed at Wave 4 via a self-report item asking participants to report the number of years of education they had completed prior to the interview. Responses ranged on a scale from 0 (no schooling) to 20+ (doctorate). Smoking status was assessed at Wave 4; lifetime smoking was categorized as having ever smoked regularly for at least a month, while current use referred to regular smoking within the past month. Lastly, lifetime diagnosis of MDD and GAD (i.e., yes/no) was assessed at Wave 4 via an adapted version of the Structured Clinical Interview for DSM-III-R diagnoses (Spitzer et al., 1987). A more detailed description of assessment can be found elsewhere (cf, Kendler & Prescott, 2006), but test–retest reliability for lifetime MDD and GAD diagnoses was acceptable (i.e., $\kappa > .70$). Covariates that had a significant association with mTL (p value $< .05$) were included in downstream analyses. Age was included in all analyses; since telomere length is a biological marker of aging, best practice suggests that it be included in all models.

Table 2 Primers used for MMqPCR for assessment of T/S ratios

Target	Sequence
Telomere	telg: ACACTAAGGTTTGGGTTTGGGTTTGGGTTTGGGTTAGTGT
	telc: TGTTAGGTATCCCTATCCCTATCCCTATCCCTATCCCTAACA
Albumin	albu: CGGCGGCGGGCGGCGCGGGCTGGGCGGaaatgctgcacagaatccttg
	albd: GCCCGGCCCGCCGCGCCCGTCCCGCCGgaaaagcatggtcgcctgtt

Primer sequences used were described by Cawthon (2009)

Study hypotheses

All study hypotheses were tested using linear mixed effects models—allowing for a random effect of twin pair membership—with maximum likelihood estimation being calculated using the "lme4" package (Bates et al., 2015) in R version 3.4.1 (R Core Team, 2017). As noted above, all models controlled for age, and all variables were entered into the models simultaneously for analysis. When assessing CSA severity, two dummy-coded variables were created. The first dummy coded variable compared women exposed to non-genital abuse to women exposed to abuse that included genital contact or intercourse; the second variable compared women who experienced intercourse to women who experienced abuse in the form of genital or non-genital contact. Separate models were tested for each of the dummy-coded variables. If a statistically significant interaction emerged when testing our third hypothesis, mTL was plotted across all values of the moderator for exposed and non-exposed individuals, and a simple slopes analysis was conducted.

Results

Missing data

Although all study participants had full data regarding CSA history (i.e., exposure and type), TL, and age, several participants had missing data regarding social support and optimism. When calculating sum scores for the social support and optimism scales, we applied a missing data threshold of 50%. That is, if at least 50% of the items for each scale had valid responses, the mean of all available items was imputed for those items missing response data. Based on this criterion, only cases missing all response data for the social support ($n = 7$) or optimism ($n = 11$) scales did not receive a total scale score and were thus excluded from their respective analyses. To ensure that analyses were not biased due to missing data, we conducted analyses with linear mixed effects models to determine if participants who were missing data differed significantly on TL or exposure to CSA to those participants with full data. Results for participants missing data on social support revealed no significant differences in mTL ($b = .26$, $p = .12$) or exposure to CSA ($b = .003$, $p = .99$). Results for participants missing data on optimism revealed that participants missing data on optimism tended to have longer mTL compared to participants with data ($b = .44$, $p < .001$), but there were no significant differences in exposure to CSA ($b = .02$, $p = .90$).

Descriptive statistics and correlations between study variables

The present study consisted of 22 twin pairs discordant for CSA (n = 44), 13 pairs concordant for CSA (n = 26), and 29 singletons (i.e., a twin whose co-twin did not participate in the study), 23 of which were exposed to CSA. Average age of first abuse was 10.5 years ($SD = 3.8$; range = 3–16 years). Sixteen women reported being exposed to non-genital forms of abuse (e.g., kissing or hugging in a sexual way), 29 women reported being exposed to abuse involving genital contact (e.g., touching or fondling of private parts), and 24 women reported experiencing abuse that involved intercourse (i.e., attempting or having sexual intercourse).

Table 3 provides descriptive data on demographic and covariate study variables. Data for telomere measurements contained two participants who had unusually high values for their T/S ratio. Raw telomere data for these cases were reviewed and one value was excluded for these cases when telomere measurements were run in triplicate (i.e., only two values were used to create the mean T/S ratio). It was determined that these two extreme scores for mTL were likely a function of error in measurement when using MMqPCR. As a result, it is likely that the remaining two measurements were not accurate either so we removed these two cases from all analyses to avoid biasing the results.

Bivariate correlations between continuous predictors and mTL revealed that there were no significant associations between social support and optimism ($r = -.01$, $p = .93$), social support and mTL ($r = -.03$, $p = .81$), or optimism and mTL ($r = .15$, $p = .16$). When testing bivariate associations between a categorical variable (e.g., CSA exposure) and mTL, social support, and optimism, it was necessary to account for dependent observations in the data (i.e., twins nested within pairs), so linear mixed effects models were employed to test these bivariate associations. Results from these models revealed that mTL was not associated with CSA exposure ($b = .01$, $p = .94$), nor was CSA exposure associated with social support ($b = -.87$, $p = .24$). However, CSA was significantly associated with optimism ($b = -1.31$, $p = .01$), such that women exposed to CSA had lower levels of optimism than those women without a history of CSA. Table 1 presents information on the type of response women received if they told someone about the abuse, as well as the type of support—or lack thereof—that each woman received after revealing their abuse to another person. Sixty-nine women in our sample answered the question about responses to revealing their abuse to someone else, with 21.7% reporting a positive response. In regard to support, 62 women responded to this

Table 3 Descriptive statistics for study variables

Variable	*N*	Mean (*SD*)	Range	Skewness	Kurtosis
Mean T/S ratio	97	1.33 (.40)	.48–2.14	.04	− .96
Age	97	52.74 (8.55)	35–70	.17	− .65
Social support	90	33.33 (3.56)	22–40	− .30	− .01
Optimism	86	15.07 (2.29)	8–20	− .57	.45
Education	97	14.67 (2.14)	12–20	.18	− 1.08
Lifetime MDD[a]	96	43 (44.8%)	–	–	–
Lifetime GAD[a]	97	17 (17.5%)	–	–	–

Mean T/S ratio reflects telomere length measurement. All values reflect data excluding outliers (n = 2) for mean T/S ratio. Range reflects actual range of the data in the study

[a]A binary variable (0/1); values in the "Mean (*SD*)" column reflect the number (and percentage) of participants endorsing that item

question and 27.4% reported being believed and supported by another person.

Covariates

In order to establish covariates to be used in subsequent analyses, bivariate correlations were run between continuous covariates and mTL. There were no statistically significant correlations between mTL and chronological age ($r = -.09$, $p = .39$), or education level ($r = .03$, $p = .74$); however, because telomeres are a biological marker of aging, and to account for the differences in ages between study participants, age was still included as a covariate in subsequent analyses. Linear mixed effects models were employed to examine if there were significant associations between mTL and categorical covariates. Results from these analyses revealed that mTL was not significantly associated with lifetime MDD ($b = .11$, $p = .17$) or lifetime GAD ($b = .10$, $p = .32$) diagnoses. Mean TL also was not associated with current ($b = -.07$, $p = .53$) or lifetime ($b = .06$, $p = .56$) smoking status, nor was CSA exposure associated with current ($b = .09$, $p = .57$) or lifetime ($b = .11$, $p = .28$) smoking status. As such, none of these potential covariates were used in subsequent analyses.

Hypothesis 1

Results from our first hypothesis, which stated that exposure to CSA would be associated with decreases in mTL, revealed that there was no evidence for an association between CSA status ($b = .02$, $p = .42$) or age ($b = -.01$, $p = .18$) and mTL.

Hypothesis 2

Results from our second hypothesis, which stated that increases in CSA severity would be associated with decreases in mTL, revealed that there was no evidence for an association between CSA severity ($b = .01$, $p = .46$) or age ($b = -.01$, $p = .13$) and mTL, when comparing women exposed to abuse in the form of non-genital contact to those women who experienced abuse in the form of genital contact or intercourse. When comparing those women who experienced abuse in the form of intercourse to those who experienced non-genital or genital contact, there was no evidence for an association between CSA severity ($b = .08$, $p = .22$) or age ($b = -.01$, $p = .19$) and mTL.

Hypothesis 3

Results from our third hypothesis, which stated that social support would mitigate the association between CSA exposure and mTL, did not reveal a significant interaction between CSA exposure and social support ($b = .04$, $p = .06$), nor were there any significant main effects of other predictors in the model. Next, models examining the effects of CSA severity on mTL were tested. Results from the model comparing women exposed to non-genital abuse versus women exposed to abuse that included genital contact or intercourse did not reveal a significant interaction between CSA severity and social support ($b = -.05$, $p = .10$), nor were there any significant main effects of other predictors in the model. Results from the model comparing mTL of women who experienced intercourse versus women exposed to abuse in the form of genital or non-genital contact revealed a significant interaction between CSA severity and social support ($b = -.07$, $p = .002$). The fixed effects from the model accounted for 12.66% of the total variance in mTL. Since a significant interaction emerged, the interaction was plotted (see Fig. 2), and a simple slopes analysis was conducted, revealing a significant slope for women exposed to abuse in the forms of non-genital or genital contact ($p = .01$). As can be seen in Fig. 2, for these women, increases in social support were associated with subsequent increases in mTL. For women who experienced intercourse, however, increases in social support trended toward decreases in

mTL, but this slope was not significantly different from zero (p = .08).

Hypothesis 4

Results from our fourth hypothesis, which stated that optimism would mitigate the association between CSA exposure and mTL, did not reveal a significant interaction between CSA exposure and optimism (b = − .004, p = .46), nor were there any significant main effects of other predictors in the model. Next, models examining the effects of CSA severity on mTL were tested. Results from the model comparing women exposed to non-genital abuse versus women exposed to abuse that included genital contact or intercourse did not reveal a significant interaction between CSA severity and optimism (b = − .03, p = .28), nor were there any significant main effects of other predictors in the model. Results from the model comparing mTL of women who experienced intercourse versus women exposed to abuse in the form of genital or non-genital contact did not reveal a significant interaction between CSA severity and optimism (b = .01, p = .45), nor were there any significant main effects of other predictors in the model. In sum, there was no evidence to suggest that optimism moderates the association between CSA exposure or severity and mTL.

Post-hoc analyses

In an effort to clarify the unanticipated findings that social support had a buffering effect on the association between CSA severity and mTL only for those women who experienced abuse in the form of non-genital or genital contact, additional analyses were conducted. Since the reliability for the social support scale was marginal (α = .69) due to the reliability for items assessing friends' social support being low (α = .59), we re-ran analyses for the model that revealed a significant interaction between social support and CSA severity using social support from family and friends separately. The model assessing friends' social support revealed no significant findings, but the model assessing family social support yielded significant findings. Specifically, when comparing women who experienced intercourse to those women exposed to non-genital or genital abuse, there was a significant interaction between CSA severity and family social support (b = − .09, p = .01; see Fig. 3). The fixed effects from this model accounted for 10.2% of the variance in mTL. Results from a simple slopes analysis revealed a significant slope (p = .02) for women exposed to abuse in the form of non-genital or genital contact; for those women exposed to these forms of abuse, increases in family social support was associated with increases in mTL. For women who experienced intercourse, family social support appeared to be associated with decreases in mTL, but the slope was not significantly different from zero (p = .07). These findings suggest that the social support from the family is driving the effect on mTL.

Discussion

Sexual abuse during childhood is a traumatic event that has long-term psychological and physical health implications for its victims (e.g., Browne et al., 1986; Irish et al., 2010; Wegman & Stetler, 2009). It is necessary to understand the biological effects of CSA, but equally important to identify

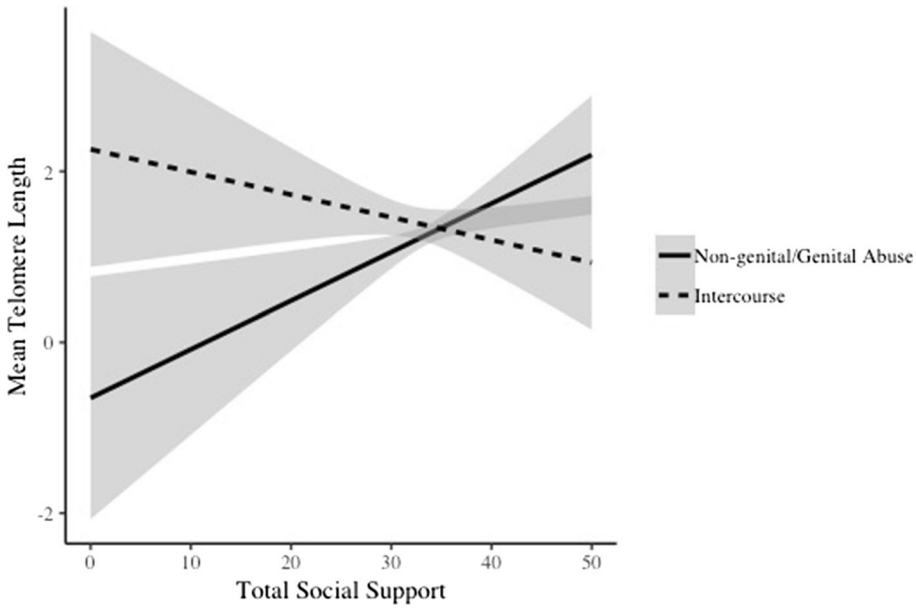

Fig. 2 Interaction between childhood sexual abuse and total social support. *Note* The slope for non-genital/genital forms of abuse was significant (p = .01). Shaded areas indicate confidence intervals. The x-axis represents the total possible range of scores for total social support

protective factors that can serve to promote resilience and subsequent positive outcomes. The goals of the current study were to observe the effects of one severe ACE (sexual abuse) on mTL in adults, and to examine the moderating roles of social support and optimism in order to gain a better understanding of what factors may protect against the negative biological effects of CSA. Although the majority of the study hypotheses were not supported, a significant interaction between social support and CSA was detected. Specifically, as social support increased, mTL increased, but only for those women exposed to less severe forms of sexual abuse (i.e., non-genital or genital contact). Further exploration of this interaction revealed that the effects of support were primarily due to familial (rather than friend) support.

Results from the current study did not reveal evidence of a unique main effect of exposure to CSA on mTL in adult females. Although this was not consistent with some of the literature examining CSA and other forms of maltreatment, these results are not uncommon within the literature (e.g., Glass et al., 2010; Kiecolt-Glaser et al., 2011), and are consistent with the most recent report examining this association among a large sample of middle-aged, White females (Mason et al., 2015). We also failed to find any unique effect of abuse severity on mTL. It is possible that our sample size contributed to our inability to detect an effect of CSA on mTL given limited power. Two other investigative teams, to date, have examined the effects of CSA severity on TL; Mason et al. (2015) found that there was no effect of CSA—regardless of severity—on TL in a sample of middle-aged females. In their study, severity was operationalized as sexual touching only versus physically and verbally abrasive abuse. Alternatively, a study by Fergusson et al. (2013) followed a sample of approximately 900 individuals (80% female) over a 30-year period who had been exposed to CSA, finding that increases in CSA severity (operationalized as non-contact exposure, genital contact, and intercourse) were significantly associated with an increased likelihood of individuals developing various physical and mental health problems in adulthood. Since the effects of severity—operationalized in a similar manner as the current study—appear to have an impact on physical health, it is possible that these effects could be detected among telomeres, but there is currently no evidence to support this hypothesis. Nonetheless, the unique association between CSA severity and TL warrants further examination, particularly among more diverse samples (e.g., men, racial and ethnic minorities). Overall, in the context of previous findings, the present results suggest that the independent effect of CSA on TL remains equivocal among middle-aged White females.

Social support and optimism as moderators

Results from linear mixed effects model analyses revealed several interesting findings. First, results from the model comparing women who experienced intercourse to those women who experienced genital or non-genital forms of abuse revealed a significant interaction between CSA severity and social support. Specifically, for those women exposed to abuse in the forms of non-genital or genital contact without intercourse, increases in social support were associated with increases in mTL. Further, results from post hoc analyses revealed that social support from the family has a protective effect on the association between CSA severity and mTL, but only for women

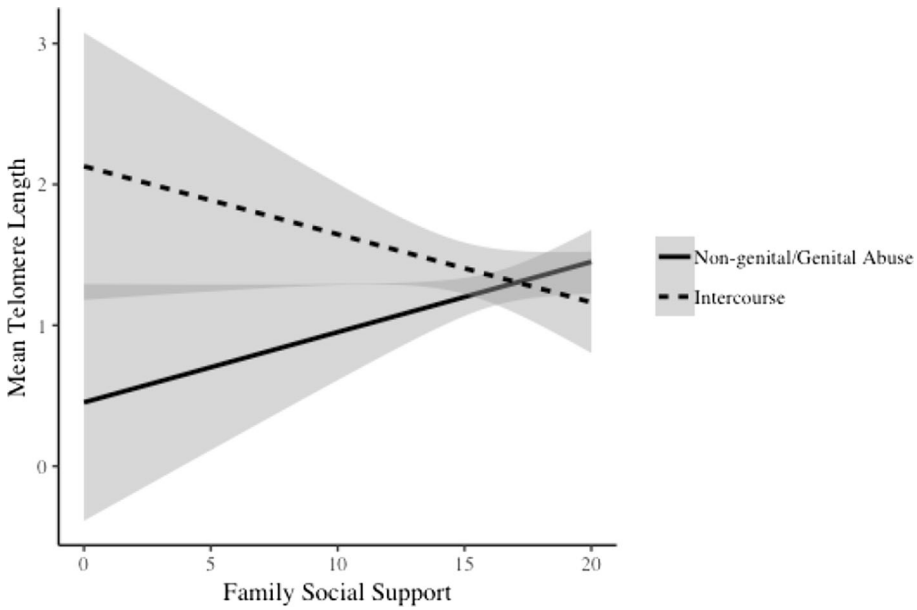

Fig. 3 Interaction between childhood sexual abuse and family social support. *Note* The slope for non-genital/genital forms of abuse was significant (p = .02). Shaded areas indicate confidence intervals. The x-axis represents the total possible range of scores for familial social support

exposed to less severe forms of abuse. The slope for women who experienced intercourse was not statistically significant, but there was a trend in the data (i.e., $p < .10$) such that increases in social support were associated with decreases in mTL. Although the finding was unexpected, there are several explanations for such an association.

One explanation for this unique finding is that the support needs of women who experience intercourse differ from that of women exposed to other forms of abuse. There is evidence to suggest that social support is effective only when the support matches the coping requirement elicited by the stressor (e.g., Cohen & Wills, 1985; Hyman et al., 2003). For example, Hyman et al. (2003) sampled adult females exposed to sexual abuse prior to age 18 and found that social support in the forms of self-esteem and appraisal support had the strongest impact on mitigating the association between CSA and psychological maladjustment in adulthood. It is possible that another measure comprehensively assessing a specific form of support (e.g., self-esteem) would be better suited to capture the effects of social support on mTL among women who experience CSA in the form of intercourse. Alternatively, other sources of social support may be more strongly associated with mTL. For example, Barger and Cribbet (2016) found that, compared to support from friends or availability of finances, spousal support was most strongly associated with mTL among adults.

Another explanation for this finding, particularly the inability to detect a protective effect of social support for females who experienced intercourse, is that more severe forms of abuse impede an individual's ability to form proper social ties, limiting the buffering effects of support throughout the lifespan. Since intercourse is such a severe, invasive form of sexual abuse, the victim's ability to engage in trusting social relationships may be severely inhibited, and even detrimental, particularly when it originates from within the family. For example, a post hoc analysis of the 24 women exposed to intercourse in the current sample revealed that 12 identified the perpetrator as living in the same household during the time of abuse, and 11 of these women identified the perpetrator as a relative. Further, for this subset of women who experienced intercourse *and* revealed their abuse to someone, only four received a positive response, while one received a neutral response, and two received a negative response. It is possible that these women did not receive adequate support around the time of abuse, impeding the development and modeling of proper social relationships. In turn, social support from relatives—even decades after the abuse has taken place—may be ineffective for the victim, especially if they were living with or nearby the perpetrator during childhood.

The analyses examining optimism did not lend support for a moderating role of optimism in the association between CSA and mTL. This was unexpected given the theoretical and empirical support for the association between optimism and TL (e.g., Schutte et al., 2016). However, a significant association between optimism and CSA was detected in preliminary analyses, such that women exposed to any CSA reported lower levels of optimism compared to women with no history of abuse. The average score for optimism among women who experienced CSA in the current sample was 14.66 (out of a possible score of 20). Compared to another study assessing optimism and TL using the LOT (Scheier & Carver, 1985), Zalli et al. (2014) found that individuals with shortened TL had an average optimism score of 14.89. It is possible that the highest levels of optimism among women who experienced CSA in the current sample were not sufficient to serve a protective role in the association between CSA and mTL.

Another unexpected finding regarding optimism was that there was no significant association between social support and optimism in our preliminary analyses. There is evidence that individuals who report higher levels of optimism tend to engage in positive coping strategies, such as reaching out to support networks (e.g., Smith & MacKenzie, 2006), but this did not appear to be the case in the present study. Nevertheless, this is the first study to examine the moderating role of optimism in the association between CSA and TL in adults, and other personality or temperamental characteristics should be explored to clarify their role in buffering against the negative effects of CSA.

Strengths and limitations

The current study has several strengths that advance our understanding of the biological impact of CSA, and the roles that social support and optimism serve in this association. First, the ability to sample MZ twins allowed us to account for many genetic and shared environmental influences that also may be affecting TL. Slagboom et al. (1994) suggest that individual variation in TL is largely heritable ($h^2 = .78$), so our ability to account for these genetic factors clarifies the unique effects of CSA on TL. Second, the inclusion of severity in the measure of CSA provides a much-needed examination of how differing types of sexual abuse impacts female survivors. We suggest that one reason for mixed findings in the literature is the lack of nuanced measurement of CSA; although most of our hypotheses were not supported, the one significant finding suggests that further exploration of CSA severity is warranted. Lastly, the inclusion of protective factors adds valuable information, particularly for intervention and prevention scientists, about factors that can contribute to

positive health outcomes in the face of severe childhood adversity. Exploration of the protective effects of other modifiable factors (e.g., self-regulation) should be a goal for future studies.

Although the current study has several strengths and adds valuable information to the existing literature examining the relation between CSA and TL in adults, there are several limitations to keep in mind when interpreting the findings. First, the uniqueness of the sample limits the generalizability of our findings. Twins are a unique subpopulation that are not representative of the general population and may differ in their development from non-twin siblings. For example, it is possible that the unique closeness shared by twins makes them more likely to discuss certain experiences that in turn affect both twins. Further, our sample was limited in its assessment of only middle-aged White females. Although evidence suggests that the effects of CSA are more detrimental for females, the examination of males and other racial and ethnic groups may reveal unique effects of CSA, social support, and/or optimism on mTL in adulthood. Another limitation of the current study is the small sample size. This presented us with the small, unequal frequencies of CSA severity type, which may explain the unique finding with social support.

The current study also was limited in its assessment of social support and optimism. As mentioned, post hoc analyses revealed marginal reliability for social support items from friends, and the social support measure consisted of five identical items assessing support from family and friends, respectively. It is possible that use of a more nuanced measure assessing specific forms of support (e.g., self-esteem, appraisal) from more sources (e.g., spouses) would clarify our findings. In addition, we were limited in our assessment of how someone responded to participants once they revealed their abuse to another person. Unfortunately, we had too few individuals per response group to test any meaningful associations using these data in our study (see Table 1). Analyses with a larger sample would benefit from understanding how support from these individuals affects the CSA-TL association, as previous research suggests that support responses to sexual abuse have meaningful effects on survivor adjustment (for a review, see Ullman, 1999).

Another limitation of the study was the lack of available data on potential covariates assessed closer to the time of telomere data collection. For example, health behaviors like smoking and exercise affect telomere attrition and it would be helpful to account for these behaviors in future analyses. Lastly, the retrospective nature of the study makes it difficult for us to account for all possible experiences that may have an effect on mTL, and accounting for other significant life events in future studies will help to clarify the unique association between CSA and TL.

Conclusion

The present study adds to our understanding of the unique association between CSA exposure (and severity) and TL among middle-aged, White females, and addresses a gap in the literature by examining the role of protective factors in relation to TL. Although the current findings do not lend support for a direct association between CSA and mTL in female adult twins, familial support does appear to play a mitigating role in this association, albeit only for women exposed to less severe forms of abuse. It will be important for future studies to examine the role of severity and how it is operationalized in order to reveal the true impact of CSA on biological health and overall wellbeing. Given that this literature is still limited, the examination of the role of protective factors in the association between CSA and TL among larger, representative samples will clarify the current findings. Nonetheless, the present findings advance our understanding of the biological effects of CSA and serve to inform prevention and intervention efforts for survivors of sexual abuse.

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Compliance with ethical standards

Conflict of interest David W. Sosnowski, Wendy Kliewer, Timothy P. York, Ananda B. Amstadter, Colleen K. Jackson-Cook, and Marcia A. Winter declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all individual participants included in the study.

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