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The long-term effects of early-life trauma on psychological, physical and physiological health among the elderly: the study of Holocaust survivors

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ABSTRACT

Objectives: To study post-traumatic stress symptoms and post-traumatic growth and heart rate variability among elderly Holocaust survivors and a matched comparison group and the mediational effect of post-traumatic stress symptoms and post-traumatic growth on the association between Holocaust experience and heart rate variability.

Method: 159 Holocaust survivors and 87 matched participants without Holocaust experience answered post-traumatic stress symptoms and post-traumatic growth questionnaires. Heart rate variability time and frequency parameters were measured for a subsample of $N = 133$.

Results: Holocaust survivors reported higher levels of post-traumatic stress symptoms and post-traumatic growth. Most heart rate variability measures were similar in the two groups, except for better heart rate variability measured by the ratio of low frequency/high frequency among Holocaust survivors. Structural equation modeling showed that belonging to the Holocaust survivor group was associated with higher post-traumatic stress symptoms and higher post-traumatic growth, as well as better heart rate variability scores (standard deviation of normal to normal R-R intervals, high frequency and the ratio of low frequency/high frequency) through the mediation of post-traumatic stress symptoms and post-traumatic growth.

Conclusions: The study emphasized the duality of the association between post-traumatic stress symptoms and post-traumatic growth and their integrated effect on heart rate variability.

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Holocaust survivors; early-life trauma; post-traumatic symptoms; post-traumatic growth; heart rate variability

Introduction

Many studies have explored the subject of the psychological effects of coping with trauma. Despite this, knowledge concerning the long-term psychological and physiological effects of childhood trauma during old age is limited, in particular, regarding the case of Holocaust survivors (Fridman, Bakermans-Kranenburg, Sagi-Schwartz, & van Ijzendoorn, 2011; Stessman et al., 2008). To a greater extent, a gap exists in studies that have investigated the co-existence of post-traumatic symptoms with post-traumatic growth among Holocaust survivors (e.g. Wilson, 2014). Therefore, the investigation of physiological measures related to stress is of importance as there is great significance in understanding the effect of mental responses to early trauma on physiological and health measures in older age. The study is based on a combination of the theory of the effects of trauma on post-traumatic symptoms and post-traumatic growth (Tedeschi & Calhoun, 1996), and the psycho-biological approach that link mental processes to physiological measures and their impact on long-term health (Lutgendorf & Costanzo, 2003), with a focus on heart rate variability (HRV).

The study aimed to address three research questions: First, what are the long-term emotional, physical and physiological outcomes of early life trauma in old age among Holocaust survivors in comparison to a matched group with no Holocaust experience. Second, what are the relations between Holocaust experience and HRV. Third, whether post-traumatic stress symptoms and post-traumatic growth have a mediating role between Holocaust exposure and HRV measures.

Holocaust survivors

Holocaust survivors are currently one of the most well-known, severely traumatized groups to have reached old age (Fridman et al., 2011). A Holocaust survivor is any individual, Jewish or non-Jewish, who was dislocated, persecuted or discriminated against by the Nazi regime during the years 1933–1945. There are approximately 500,000 Jewish Holocaust survivors worldwide and 189,000 who live in Israel (Foundation for the Benefit of Holocaust Victims in Israel 2015). Most of the survivors currently alive were children, adolescents or young adults at the time of the Nazi persecution, and are presently in the midst of old age, with the average age being 83 years (Foundation for the Benefit of Holocaust Victims in Israel, 2015).

Post-traumatic stress and post-traumatic growth

Post-traumatic stress disorder or post-traumatic stress symptoms in individuals exposed to a traumatic event are often accompanied by post-traumatic growth, the perception of positive changes as the outcome of an individual's struggle with a traumatic event. Negative outcomes do not necessarily impede consequent psychological development,

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just as psychological growth does not necessarily negate the continuous suffering caused by the trauma (Tedeschi & Calhoun, 1996). Post-traumatic growth following different traumatic events has been found to be associated with well-being (Helgeson, Reynolds, & Tomich, 2006). Different researchers argue, however, that most people manage to cope with trauma and loss, and manage to function at a high level, providing little need or opportunity for post-traumatic growth (Westphal & Bonanno, 2007). Other scholars have argued that statements of positive change may represent defensive or positive illusions, rather than actual growth (Johnson, Hobfoll, Hall, Canetti-Nisim, Galea, & Palmieri, 2007; Westphal & Bonanno, 2007). Furthermore, measurement issues pertaining the validity and reliability of the evaluation of post-traumatic growth reported by individuals and especially their long-term effects on health have been raised (Bussell & Naus, 2010; Park & Lechner, 2006).

Physical health outcomes of stress and trauma

It has been proposed that exposure to negative life events produces neuroendocrinological and immunological dysregulation (McEwen, 1998). Miller, Chen, and Parker (2011) explain that when stress related body dysregulation extends over long periods of time, it contributes to the creation of disease and frailty in late life. Health behaviors, post-traumatic distress, and depressive symptoms may mediate this process (Lapp, Agbokou, & Ferreri, 2011). Studies suggest long-term consequences on physical health among populations who experienced trauma at an early age (Amir & Lev-Wiesel, 2003). This includes higher morbidity, cardiovascular, autoimmune diseases and diabetes (Caspi, Harrington, Moffitt, Milne, & Poulton, 2006; Danese, Moffitt, Pariante, Ambler, Poulton, & Caspi, 2008), and higher rates of disability (Shrira & Litwin, 2014).

The reaction of human physiology to psychological stress is regulated by the vagus nerve, which is part of the autonomic nervous system, and regulates the sympathetic and para-sympathetic nervous systems (Porges, 2007). In chronic stress situations, this balance may be disrupted for long periods; therefore, the regulation of body organs and systems (e.g. the immune system, cardiac activity) can be affected and result in dysregulated function, such as immunological dysregulation (Cohen et al., 2012; Juster, McEwen, & Lupien, 2010), increased inflammation (Cohen et al., 2012). HRV was previously found to be associated with childhood trauma (Jin, Kim, Kim, Hyun, & Lee, 2018), and therefore may be a useful measure of long-term health effects of early trauma in old age, yet has not been assessed among older adults with early trauma exposure.

Heart rate variability (HRV)

HRV is the temporal beat-to-beat variation in successive inter-beat intervals (RR) (Acharya, Joseph, Kannathal, Lim, & Suri, 2006). HRV is regarded as a reflection of the heart's ability to adjust to changing situations by detecting and rapidly responding to varying stimuli (Acharya et al., 2006). Thus, a normal heart rate is characterized by high variability, which is an indication of the ability to adjust to the continuous changes in internal and external conditions. Decreased HRV reflects a change in the cardiac sympatho-vagal balance from the parasympathetic to the sympathetic control of the heart's rhythm; thus, reduced HRV reflects autonomic dysfunction (Porges, 2007). Of importance to this study, is Porges's (2007) suggestion that a chronically depressed vagal tone (activity of the vagus nerve) would indicate poor homeostasis and a neurophysiologic vulnerability to the negative effects of stress. Numerous studies have found an association between decreased HRV and various stressors, including chronic stress (Vrijkotte, van Doornen, & de Geus, 2000), and traumatic life events such as earthquakes (Huang, Chiou, Ting, Chen, & Chen et al., 2001). Worse HRV was found to be related to psychological symptoms such as depression (Ward, Tueth, & Sheps, 2003) post-traumatic stress disorder (Shah, Lampert, Goldberg, Veledar, Bremner, & Vaccarino, 2013), and anxiety (Licht, de Geus, van Dyck, & Pennix, 2009). Although Licht, de Geus, van Dyck, and Penninx (2009) point out that this effect may be related to the use of antidepressants or other psychiatric medications, other studies showed improved HRV when psychological symptoms decrease following medical treatment (Glassman et al., 2002).

Regarding post-traumatic growth, the first and, to the best of our knowledge, only study that examined the relationship between post-traumatic growth and HRV was in response to affective stimulation among individuals involved in the Tianjin explosions in 2015 (Wei, Han, Zhang, Hannak, Dai, & Liu, 2017). The study results indicated that affective stimulation increased HRV in a group with a high post-traumatic growth level compared with a control group, while post-traumatic stress disorder had no effect on HRV measures (Wei et al., 2017).

There is also general evidence showing that HRV declines in old age (Stein, Barzilay, Chaves, Domitrovich, & Gottdiener, 2009; Zulfiqar, Jurivich, Gao, & Singer, 2010). A decrease in HRV has been found to be a strong predictor of morbidity and mortality (de Godoy et al., 2009).

The long-term effects of early life trauma among elderly Holocaust survivors

The long-term effects of severe and prolonged trauma, including physical and mental problems, may continue into old age. These effects may amplify both the physical and mental health problems that arise in later life (Shmotkin, Shrira, & Palgii, 2011), especially when facing stressors related to old age (Kahana, 1992; Kimron & Cohen, 2012). However, contradictory results were found with regard to distress versus adjustment measures among survivors (reviewed in Barel, van IJzendoorn, Sagi-Schwartz, & Bakermans-Kranenburg et al., 2010). Various authors concluded that the majority of elderly Holocaust survivors suffer from post-traumatic stress disorder or various degrees of post-traumatic stress symptoms, in comparison to elderly individuals who do not have a Holocaust background (Lamet, Szuchman, Perkel, & Walsh, 2008; Witztum & Malkinson, 2009). In contrast, other researchers and clinicians have indicated that, in spite of their traumatic pasts, survivors of all ages managed to rebuild their lives in numerous and impressive ways, adapting, after the war, to post-war demands (Barel et al., 2010, Fridman et al., 2011; Kahana, Harel, & Kahana, 1988; Kahana, Harel, & Kahana,

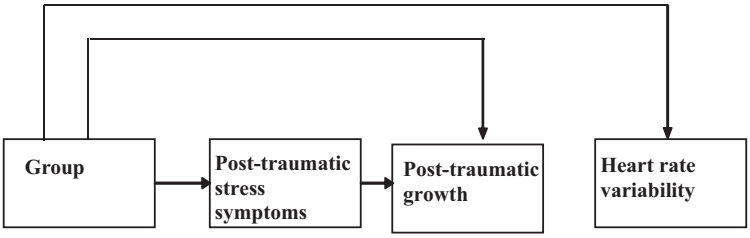

Figure 1. The Proposed Model.

2005; Kahana, Kahana, Harel, & Rosner, 1988). Other studies that have investigated the coping of Holocaust survivors found that elderly survivors displayed more distress than comparison groups when faced with physical stressors in old age, such as acute hospitalization (Kimron & Cohen, 2012) or cancer (Hantman & Solomon, 2007).

Post-traumatic growth has not been widely examined among Holocaust survivors. Lev-Wiesel and Amir (2003) showed low levels of post-traumatic growth, co-existing with post-traumatic stress disorder symptoms, especially arousal. A qualitative study conducted in the United States of America by Wilson (2014) found that the following factors contributed to post-traumatic growth among survivors: a good childhood, self-disclosure, social support, personal characteristics such as optimism and self-confidence, and the ability to build a new life.

Moreover, only a few previous studies examined physical measures among Holocaust survivors. These studies found high levels of physical resilience reported by survivors compared to matched comparison groups of individuals not exposed to the Holocaust (Cassel & Suedfeld, 2006; Fridman et al., 2011). Even fewer studies have examined long-term physiological outcomes of coping among Holocaust survivors. It was found in the existing studies that the offspring of Holocaust survivors with post-traumatic stress disorder had lower levels of twenty-four-hour urinary cortisol secretion compared to those without post-traumatic stress disorder or non-exposed comparisons (Yehuda, Bierer, Schmeidler, Aferiat, Breslau, & Dolan, 2000). Also, a flatter circadian rhythm was found among survivors with post-traumatic stress disorder, compared to non-exposed individuals (Yehuda, Golier, & Kaufman, 2005). Another study failed to find differences in diurnal cortisol levels however found elevated cortisol levels in reaction to stress in survivors' subgroups (van der Hal-van Raalte, Bakermans-Kranenburg, & van Ijzendoorn, 2008). The investigation of physiological measures related to stress is of importance. Studies have shown that the relationship between traumatic events and health outcomes is often mediated by post-traumatic stress disorder (Nillni et al., 2014) and post-traumatic growth (Barskova & Oesterreich, 2009). The mediation possibilities of post-traumatic stress disorder becoming a factor that worsens health problems, while post-traumatic growth acts as a buffer and moderates them, have not been examined in relation to the effects of childhood trauma on health in old age (Aldwin & Park, 2004).

Despite the association found between decreased HRV and psychological outcomes such as depression (Ward et al., 2003) and post-traumatic stress disorder (Shah et al., 2013), the current study is the first to incorporate HRV as a physiological measurement in the investigation of the long-term psychological effects of coping with early life trauma among Holocaust survivors. The first hypothesis proposed that Holocaust survivors would experience higher levels of post-traumatic symptoms and post-traumatic growth than the comparison group, and worse HRV. The second hypothesis proposed that HRV would be negatively associated with post-traumatic stress symptoms and positively associated with post-traumatic growth. The third hypothesis proposed that the group variable would be associated with HRV through the mediation of post-traumatic symptoms and post-traumatic growth (Figure 1).

Research design and methods

Participants and procedure

The study was approved by the Ethical Board of the University of Haifa. The study was conducted between the years 2012–2014. The sample consisted of 246 participants, divided into two groups: 159 were elderly Holocaust survivors (survivor group); 87 individuals had no Holocaust experience (comparison group). Inclusion criteria for participation included being European-born, before or during the period of the Holocaust; and being literate in Hebrew or English. In addition, the survivor group was identified by means of screening questions regarding Holocaust experiences. Participants who confirmed having lived under Nazi occupation during the years 1939–1945 were asked additional questions in order to obtain more details about their Holocaust experience, including their main experience during the Holocaust and whether any of their immediate or extended family members perished in the Holocaust. Holocaust experiences included being sent to concentration camps and/or ghettos, fleeing to hiding places, or experiencing Nazi persecution at home. Participants who appeared to suffer from cognitive decline, assessed by place and time orientation and an inability to respond adequately to questions regarding personal details, were excluded from the study.

A pretest was performed among ten participants in order to evaluate the reliability and clarity of the questionnaire and the feasibility of the HRV measurement. A trained professional for this particular study interviewed participants in person, using an integrated structured questionnaire, and a non-invasive measurement of HRV. In order to decrease any uneasiness resulting from the HRV measurement, participants received a full explanation of the measurement and were given a chance to ask any questions that may have arisen regarding the measurement.

Participants were recruited using a number of techniques. Firstly, a population-based database was utilized, which included year of birth, telephone numbers and home addresses. An official letter, explaining the purpose and goals of the study, as well as what would be required

from the participants, was sent out by mail. A few days later, a research assistant telephoned the potential participant and if the individual agreed to participate in the study, an appointment was set up for a convenient meeting at the participant's home. Four hundred and twenty-seven potential elderly participants were approached out of which 199 (46.6%) refused. An additional 185 (43.3%) participants were excluded from the study due to disease, difficulties in coordinating the interview, telephone numbers that were not updated, the potential participant spoke a foreign language, was born in Israel or had passed away. A total of 38 participants (15.4%) were recruited and interviewed through this method.

Secondly, participants were recruited by referrals from professionals at various service centers for older adults, such as day care centers and independent residential homes. Sixty-five (26.4%) participants were interviewed by this method, out of which two interviews were excluded as too much data was left blank.

A final method of recruiting was a snowball technique initiated by the research assistants. Participants who were interviewed assisted in recruiting other participants by contacting friends who met the study criteria. After obtaining their consent to participate, the researcher contacted the friends. A total of 143 participants (58.1%) were recruited through family and friends.

Materials

Demographic variables included gender, age, marital status, number of children, country of origin, religion, religious level, education, occupation, and socio-economic situation.

Subjective health was measured by self-perceived health. Participants were requested to report how they rated their health compared to other elderly individuals in the same age group, on a five-point scale from 1 = very good, to 5 = bad.

The **Traumatic Events Inventory (**Breslau et al., 1998) is a 17-item questionnaire examining traumatic events (e.g. war and terror-related events, victimization, bereavement, life hardships), which was translated into Hebrew and adapted to experiences related to old age, by Shmotkin and Litwin (2009). Participants in both groups were asked whether they had experienced any "difficult life events" with a yes or no response. A total score was calculated based on the sum of the positively-marked items.

The **Post-Traumatic Stress Disorder Inventory** (Solomon, Benbenishty, Neria, Abramowitz, Ginzburg, & Ohry, 1993) is a 17-item scale shortened from Horowitz, Wilner and Alvarez's (1979) Impact of Event Scale, which has been widely used in Israel (e.g. Lev-Wiesel & Amir, 2001). The scale measures the intensity of intrusion, avoidance, and arousal, rated on a four-point scale, ranging from 1 = not at all to 4 = generally yes. A mean score was calculated. Post-traumatic stress disorder was defined as the person experiencing one or more intrusive symptoms, three or more avoidance symptoms, and two or more arousal symptoms. Internal consistencies in the current study were: intrusion α=.85, avoidance α=.67, arousal α=.72; the total score for post-traumatic stress disorder was α=.84.

The **Post-Traumatic Growth Inventory (PTGI;** Tedeschi & Calhoun, 1996**)** is a 22-item scale that measures the level of reported positive changes experienced in struggles with major life events: personal strength, relationships with others, spiritual change, appreciation of life, and new priorities. The PTGI was translated into Hebrew and validated (Lev-Wiesel & Amir, 2003), and a mean score was computed on a five-point scale ranging from 1 = to a very great degree to 5 = not at all. Internal consistency for the total post-traumatic growth score was α = .91.

Heart Rate Variability (HRV) was measured by the clear waveform of the electrocardiography, using a heart Holter monitor (Norav Holter Device), which is a lightweight ambulatory device that records the electrocardiography changes from six electrodes placed on the participant's chest and back. The measurement was taken from short-term recordings for approximately a 30-minute period, on average, after a few minutes of habituation. A cardiologist (I.M.) analyzed the HRV measures from the electrocardiography. The following time and frequency domains were calculated as indicators of HRV function: Frequency domain analysis is performed by taking a series of numbers along the time axis and computing the Fourier transform, and includes high frequency (HF), low frequency (LF), and the LF/HF ratio. Lower results of HF and a low LF/HF ratio indicate better HRV, while higher LF was used as an indicator for worse HRV (McCraty & Shaffer, 2015). Time domain measures reflect various statistical approaches of measuring and representing the differences in the intervals between adjacent normal R waves, referred to as normal to normal (NN) intervals, over a specified period of time (McCraty & Shaffer, 2015). In this study, time domain variables were assessed: the standard deviation of all normal-to-normal intervals (SDNN), is measured in milliseconds between heartbeats and reflecting all of the cyclic components responsible for variability during the recording period, and the root mean square of the successive differences (RMSSD); higher results indicate higher HRV (McCraty & Shaffer, 2015). A low standard deviation, approximately less than 50 milliseconds, is abnormal and such HRV readings were deleted from the study.

Data analysis

Differences between the survivors and comparison groups, in terms of the background variables and study variables, were analyzed with Kruskal-Willis and Analysis of Variance (ANOVA*)*. Thereafter, in order to test differences between the groups in the study variables while controlling for the background variables of age, gender, education, family status, economic status, life events and subjective health, analysis of covariance (ANCOVA) was used. Although the sample sizes were unequal, the variances of the groups were closely similar (for example, the variances for post-traumatic stress symptoms was 0.306 and 0.390 and for post-traumatic growth 1.073 and 1.194). However, the non-parametric Kruskal-Wallis test was also conducted. Due to the similarity of the results of the Kruskal-Wallis and ANCOVA test, only the ANCOVA results are presented. HRV measures were log transformed for normalization. The research model was tested with structural equation modeling (SEM) using AMOS 23 (Arbuckle, 2012). Model fit was assessed by six measures: Chi square and the Normed Chi square (which is the Chi square divided by the degrees of

Table 1. Demographic characteristics of participants by group.

	Survivors (*N* = 159)		Comparison (*N* = 87)		
	N	%	*N*	%	Difference
Age, years (M, SD)	82.34	5.81	82.69	8.11	$t_{(135.27)} = -0.36$ (1)
Range	71–97		68–100		
Gender (N, %)	61	38.4	28	32.2	χ^2=0.93
Male	98	61.6	59	67.8	
Female					
Education, years (M, SD)	10.85	4.68	13.05	4.40	$t_{(244)} = -3.60$*
Range	0–27		3–30		
Economic Status (N, %)					$\chi^2(2) = 6.46$*
Low	14	8.9	4	4.6	
Medium	118	75.2	58	66.7	
High	25	15.9	25	28.7	
Family Status (N, %)					$\chi^2(2) = 0.15$
Married/Partner	62	39.0	36	41.4	
Widow	81	50.9	43	49.4	
Single, Divorced	16	10.1	8	9.2	
Religiosity (N, %)					$\chi^2(2) = 0.52$
Secular	96	61.1	51	61.4	
Traditional	53	33.8	26	31.3	
Religious	8	5.1	6	7.2	

* $p<.001$; (1)*t* for unequal variances.

Table 2. Means, standard deviations and differences for post-traumatic stress symptoms and post-traumatic growth by group.

	Survivors (*N* = 159)		Comparison (*N* = 87)		
	M	SD	M	SD	F(1, 232) (η^2)
Post-Traumatic Stress Symptoms					
Intrusion	2.17	0.91	1.56	0.59	21.91*** (.087)
Avoidance	1.86	0.72	1.53	0.58	8.94** (.038)
Arousal	2.17	0.77	1.80	0.64	15.05*** (.062)
Total score	2.07	0.62	1.63	0.45	23.73*** (.095)
Post-Traumatic Growth					
Relations with others	2.73	1.26	2.25	1.23	6.29* (.027)
New priorities	2.52	1.46	1.69	1.33	16.96*** (.070)
Personal strength	3.56	1.28	2.86	1.36	12.64*** (.053)
Spiritual change	1.22	1.38	0.79	1.16	5.22* (.023)
Appreciation for life	3.26	1.46	2.06	1.55	31.24*** (.122)
Total score	2.82	1.09	2.11	1.04	19.67*** (.080)

*$p<.05$, **$p<.01$, ***$p<.001$.
Note: The background variables of the study were controlled.

freedom, χ^2/df), are used to assess the model's overall fit and parsimony. Normed Chi square values of $\leq$2.0 indicate good fit; the Comparative Fit Index (CFI), the Tucker–Lewis Index (TLI) and the Normed Fit Index (NFI), which are incremental fit indexes and the root mean-square error of approximation (RMSEA and its confidence interval) measure the discrepancy per degree of freedom and indicates absolute fit of the model. CFI, TLI and NFI scores of >0.95 and RMSEA values of <0.05 indicate a good model fit.

Results

The distribution of background details among the Holocaust survivors and comparison groups is shown in Table 1. The mean age was 82 years and almost half the participants were widowed. Two-thirds of the participants were female. Economic status was slightly higher in the comparison group than among the Holocaust survivor group.

Mean levels and differences between groups in regard to the study variables are shown in Table 2. Total mean scores of post-traumatic stress symptoms and its sub-scales were, in general a medium level, (possible range 1–4, range in the study 1–4), but were higher among the survivors compared to the comparisons. The differences remained significant when controlling for the background variables of age, gender, education, family status, economic status, life events and subjective health, with medium to large effect sizes. In addition, the rate of participants who fulfilled the post-traumatic stress disorder criteria was high in both groups, but was substantially higher among the Holocaust survivors compared to the comparison group: post-traumatic stress disorder was identified in 78.8% ($N = 125$) of the survivors compared to 51.7% ($N = 43$)) of the comparison group participants ($\chi^2(1) = 19.05$, $p<.0001$).

Mean levels for post-traumatic growth (possible range 0–5, range in the study 0–5) were generally a medium level, except for spiritual change, which had a low mean value (Table 2). Mean total scores of post-traumatic growth and means of its sub-scales were significantly higher among the Holocaust survivors (Table 2) and remained higher when controlling for the background variables. Effect sizes of the subscales as well as the total score were mostly medium (small effect sizes were for the subscales of relations with others and spiritual change while large effect size was for appreciation of life).

Mean levels and differences between groups in regard to HRV measures are shown in Table 3. The average heart rate was within the normal range (60–100 beats per

Table 3. Means, standard deviations and differences for heart rate variability measures.

		Survivors ($n = 87$)		Comparison ($n = 46$)		
	Range	M	SD	M	SD	$F(1, 239)$ (η^2)
SDNN	15.78-98.46	52.95	20.59	51.66	17.88	0.100 (.001)
RMSSD	9.64-146.78	54.36	30.37	48.04	23.83	1.18 (.009)
HF	22.63-314.06	166.17	57.74	161.37	59.55	.80 (.001)
LF	11.40-296.06	114.05	46.06	124.37	52.42	1.40 (.009)
LF/HF	0.07-4.84	0.81	0.46	1.08	0.85	3.92* (.022)

*$p<.05$, **$p<.01$, ***$p<.001$.
SDNN = standard deviation of normal-to-normal (NN) intervals, RMSSD = the square root of the mean of the sum of the squares of differences between consecutive normal-to-normal (NN) intervals, LF = low frequency, HF = high frequency, LF/HF = low frequency/high frequency ratio.

Table 4. Correlations among the study variables ($N = 246$).

	2.	3.	4.	5.	6.	7.
1. Post-traumatic stress symptoms	**.24****	.14	**.28****	**.25****	−.10	**−.26****
2. Post- traumatic growth	–	.11	.13	.05	.01	.04
3. SDNN		–	**.83*****	**.32****	.06	−.10
4. RMSSD			–	**.64*****	−.02	**−.30*****
5. HF				–	−.09	
6. LF					–	
7. LF/HF						–

*$p<.05$, **$p<.01$, ***$p<.001$.
Note: the total scores of post-traumatic stress symptoms and post-traumatic growth are presented. SDNN = standard deviation of normal to normal (NN) intervals, RMSSD = the square root of the mean of the sum of the squares of differences between consecutive normal-to-normal (NN) intervals, LF/HF = low frequency high frequency ratio, LF = low frequency, HF = high frequency.

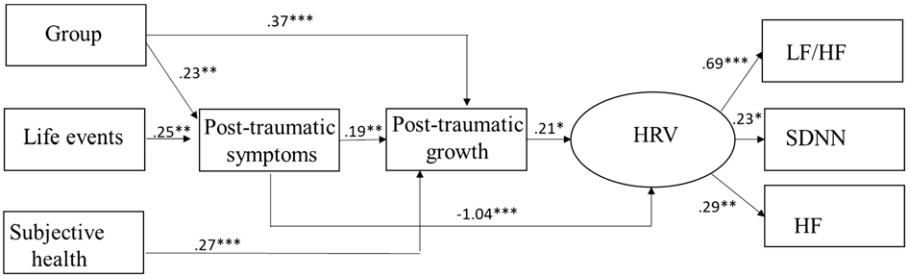

Figure 2. Direct and Mediational Associations among the Study Variables. *$p<.05$, **$p<.01$, ***$p<.001$.
HRV = heart rate variability.
SDNN = standard deviation of normal-to-normal (NN) intervals, HF = high frequency, LF/HF = low frequency/high frequency ratio.

minute); RMSSD measures were within the normal range for individuals aged 60, and above the normal range for SDNN for individuals aged 20–80. Differences between the Holocaust survivors and the comparison group were significant only for the LF/HF ratio, which was lower among Holocaust survivors, indicative of better HRV among Holocaust survivors (small effect size).

The associations between the study variables are presented in Table 4: post-traumatic stress symptoms and post-traumatic growth were positively associated. Both HRV time measures, SDNN and RMSSD, were highly intercorrelated and positively associated with the frequency domain indicator of parasympathetic activity HF, as expected, while LF was not associated with the other HRV measures. The ratio LF/HF (lower number indicative of better HRV) was negatively associated with RMSSD and HF and negatively associated with LF as expected. RMSSD, and HF (all indicative of better HRV) were positively associated with post-traumatic symptoms, with no association with post-traumatic growth.

The study model consisted of the study variables (group, post-traumatic stress symptoms, post-traumatic growth and HRV) and two control variables: life events and subjective health, due to their significant associations with post-traumatic stress symptoms and post-traumatic growth (Figure 2). The examined model was found to have a good fit with the theoretical model: $\chi^2(14) = 14.36$, p=.42, χ^2/df = 1.03; NFI=.94, TLI=.99. CFI=.99, RMSEA=.01 (CI90 .011, .079). HRV is presented as a latent variable consisting of SDNN, HF and LF/HF measures (RMSSD and LF were not included, due to a lack of associations with the study variables). Life events and subjective health were the only background variables significantly associated with HRV and were included in the model. The model shows several direct associations: the group variable is positively associated with post-traumatic stress symptoms and post-traumatic growth; thus, belonging to the Holocaust survivor group is associated with higher post-traumatic stress symptoms and post-traumatic growth. Post-traumatic stress symptoms were directly associated with post-traumatic growth, the higher the post-traumatic stress symptoms, the higher the post-traumatic growth. Post-traumatic stress symptoms and post-traumatic growth were directly associated with HRV; lower post-traumatic stress symptoms and higher post-traumatic growth were related to higher HRV. Several indirect associations were also revealed: post-traumatic stress symptoms partially mediated the association between the group variable and post-traumatic growth. Thus, belonging

to the Holocaust survivor group was related to higher post-traumatic stress symptoms, and post-traumatic stress symptoms were related to higher post-traumatic growth. Post-traumatic growth partially mediated the association between post-traumatic stress symptoms and HRV. Having a higher post-traumatic growth score was associated with higher scores on the HRV latent variable. When the whole model was examined, including post-traumatic growth, post-traumatic symptoms were associated with better HRV (despite the direct correlation as expressed by Pearson correlation coefficients between both variables which were negative). In addition, the group variable was associated with better HRV through the mediation of post-traumatic stress symptoms and post-traumatic growth.

Discussion

The current study is the first to assess the effect of early trauma on HRV in old age among Holocaust survivors compared to a strictly matched comparison group. The findings indicate similar HRV measures among the Holocaust survivors compared to the comparison group, while the LF/HF measure was found to be higher among Holocaust survivors, along with higher levels of post-traumatic symptoms and post-traumatic growth. The study model adds to the finding of differences by showing that that Holocaust survivors with higher post-traumatic stress symptoms had worse HRV (latent variable) than the comparison group, but when accompanied by post-traumatic growth, HRV was found to be better. The effect of posttraumatic growth provides an additional explanation for the differences between groups.

The higher post-traumatic stress disorder rate and the higher post-traumatic stress symptoms levels among the Holocaust survivors compared to the matched controls together with substantial effect sizes (indicative of the strong association between the group variable and post-traumatic stress symptoms), support previous studies, which found that the majority of elderly Holocaust survivors suffer from post-traumatic stress disorder and/or its symptoms (Barel et al., 2010; Lamet et al., 2008; Witztum & Malkinson, 2009). This finding is similar to a large number of investigations on post-traumatic stress disorder that have been conducted on World War II veteran soldiers (e.g. Hyer, Summers, Braswell, & Boyd, 1995).

The findings of the current study also support the few previous studies that reported post-traumatic growth and its co-existence with post-traumatic stress symptoms among Holocaust survivors (Lev-Wiesel & Amir, 2003; Wilson, 2014). In addition, the findings of this study strengthen the previous findings that a certain amount of post-traumatic symptoms are required in order for post-traumatic growth to occur (Tedeschi & Calhoun, 1996). This finding is pursuant to the results of a recent meta-analytic study (Shakespeare-Finch & Lurie-Beck, 2014), and recent studies conducted among burn victims (Baillie, Sellwood, & Wisely et al., 2014) and cancer patients (Gouzman et al., 2015). However, it should be noted that this sample of Holocaust survivors constitutes the hardiest of the survivors, as they have attained a substantial longevity.

Contrasting results have been found in the few studies that have examined the long-term physiological outcomes of coping among Holocaust survivors measured by levels of cortisol (van der Hal-van Raalte et al., 2008; Yehuda et al., 2000; Yehuda et al., 2005).

The examination of the results in terms of HRV opposed our hypothesis. They showed that, in spite of the higher post-traumatic stress symptoms among Holocaust survivors, most HRV measures were not different from those of the comparison groups, and a better HRV measurement of the ratio of low frequency/high frequency (LF/HF) among Holocaust survivors. LF/HF ratio indicates the individual's ability to successfully balance the sympathetic and parasympathetic systems, determining the fine line between stress and a relaxed state of mind, which is extremely important when coping with stressful situations. These findings suggest a higher level of physical health among Holocaust survivors, as reported in previous studies based on self-reports (e.g. Fridman et al., 2011; Shrira, Palgi, Ben-Ezra, & Shmotkin, 2011). It has been argued, however, that although the LF/HF sympatho-vagal balance has been widely used, there is evidence suggesting that LF/HF data does not accurately measure sympatho-vagal balance in health or disease (Billman, 2013). On this note, the possibility that HRV may have been driven by depression or antidepressants (Licht et al., 2009) must be mentioned. However, studies have indicated that post-traumatic stress disorder often co-occurs with depressive symptoms (e.g. Elhai, Grubaugh, Kashdan, & Frueh, 2008); therefore, the two cannot be separated.

The negative relationship between post-traumatic stress symptoms and HRV (measured as a latent variable which consists of the three measures of LF/HF, HF and SDNN) in the present study is in line with our hypothesis as well as numerous studies that reported reduced HRV in various psychological disorders, such as panic disorder and post-traumatic stress-disorder (Shah et al., 2013), depression (Ward et al., 2003) and anxiety (Licht et al., 2009). Previous studies that examined the association between post-traumatic stress-disorder and HRV have indicated, similar to our study, lower LF and HF measures of HRV among post-traumatic stress-disorder sufferers compared with healthy controls and trauma-exposed individuals without post-traumatic stress-disorder (e.g. Hauschildt, Peters, Moritz, & Jelinek, 2011; Wahbeh & Oken, 2013). Furthermore, a lower HRV was found among individuals with post-traumatic stress disorder compared to controls in a meta-analysis of 19 studies, particularly for the parasympathetic measurement of HF (Nagpal, Gleichauf, & Ginsberg, 2013). In addition, the findings that the group variable is associated with both post-traumatic stress symptoms and post-traumatic growth, and that both these variables mediate the association between the group variable and HRV was in line with the study hypothesis. This strengthens previous studies' findings that emphasize the duality of psychological vulnerability together with physical health found among elderly Holocaust survivors (e.g. Shrira et al., 2011). This finding is also in line with the conceptualization of post-traumatic growth, which occurs after the occurrence of a traumatic event(s) and that co-exist with post-traumatic stress disorder or symptoms (Tedeschi & Calhoun, 1996). Of importance, this study provides evidence that this association also exists among elderly survivors of early life trauma. In addition, the current study provided

additional insight regarding the relationship of this association with the objective health measure of HRV.

An additional finding was the partial mediating role post-traumatic growth played between post-traumatic stress symptoms and HRV. This suggests that early childhood trauma is associated with better HRV in older adulthood, but not when coupled with higher post-traumatic stress symptoms. However, when accompanied by post-traumatic growth, HRV was found to be better once again suggesting that post-traumatic growth may be a path to physical health. Of importance, the association found in this study between post-traumatic growth and HRV may support the argument that post-traumatic growth is, in fact, a true positive process of actual growth, as suggested by Tedeschi and Calhoun (2004), rather than a representation of defensive or positive illusions, as described by other authors (e.g. Johnson et al., 2007). Our results were partially in line with a recent study that was the first to investigate post-traumatic growth and HRV. The study indicated that post-traumatic growth was associated with both LF and HF components of HRV, compared with a control group in reaction to affective stimulation (Wei et al., 2017).

The study should be considered in light of its strengths and limitations. It included participants from various cities and communities from most areas throughout Israel; therefore, it may be assumed that the participants accurately represented the Holocaust survivors and comparison group from a large part of Israel. Another major strength of this study was that the comparison group was carefully defined according to age and country of origin, in order to match the comparison group to the Holocaust survivor group as closely as possible. Therefore, it was ensured that all participants were of European origin, so that different cultural perspectives would not influence the results between the two study groups. A further strength of the study was that the number of traumatic events participants experienced during their lives was controlled for throughout the data analysis. Together with this, caution is required in generalizing the results to other groups.

Another major strength of the study is that this is one of the first studies to examine post-traumatic growth, using typical post-traumatic growth scales, among the Holocaust survivor population. In addition, this is the first study to use the HRV measure as a health indicator in a study among Holocaust survivors and it provides insight into the physical association with the effects of childhood trauma among the elderly. This is important, due to a lacuna in the understanding of the effects of severe early trauma on physical health and morbidity in old age (Stessman et al., 2008). This study emphasizes the importance of the HRV measurement some 70+ years later after the trauma, which has abated as a long-term effect mediated by psychological processes in the aftermath of trauma, namely, post-traumatic symptoms and post-traumatic growth. In addition, the study highlights the significance of trauma bodily function, which seems to occur through this psychological pathway via post-traumatic stress and post-traumatic growth.

It must be emphasized that this population is disappearing, and many of them cannot be interviewed due to their physical or mental condition. Therefore, this study may be one of the last opportunities to conduct a study of this nature. Although using HRV measures is a main strength and novelty of the current study, it added to its complexity, especially in regard to the participants' advanced age. As a result, participants with various health conditions were excluded. In addition, many factors may affect these measures such as depression and medication like antidepressants (Licht et al., 2009). A further limitation is the cross-sectional design. Therefore, the associations found may be bi-directional, and any direction of the association or causality may not be inferred. The relatively small and imbalanced sample sizes, may limit the generalizability of the results. A final limitation of the study is that it was conducted before the publication of the DSM-5; therefore, it is uncertain whether these results may or may not be generalized to the DSM-5.

To conclude, the study expands the existing knowledge on the physical and physiological effects of the Holocaust and of early trauma in general. In addition, the current study is unique in its investigation of HRV, as an objective physiological measure of health in old age in relation to long-term coping with early life trauma, particularly among elderly Holocaust survivors.

The knowledge gained from this study may be generalized in a broader context of worldwide populations suffering from trauma today (Fridman et al., 2011). Therefore, knowledge regarding the physical resilience of Holocaust survivors, as well as the co-existence of post-traumatic stress symptoms and post-traumatic growth, should be incorporated and discussed with survivors in the counseling setting of elderly Holocaust or trauma survivors. Further studies are needed to clarify the effects of the Holocaust or other early trauma experience on HRV, as well as to better understand the combined effects of post-traumatic symptoms and post-traumatic growth on objective health indicators. It is suggested that future longitudinal studies should examine inflammation measures, which have also been found to regulate the vagal nerve (Porges, 2007), in order to better understand the balance between physical and emotional health.

Disclosure statement

The authors declare that there is no conflict of interest.

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