

Review Article

Linking Early Adversity, Emotion Dysregulation, and Psychopathology: The Case of Extremely Low Birth Weight Infants

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Received 9 November 2012; Revised 16 February 2013; Accepted 11 March 2013

Academic Editor: Annie Vinter

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The ability to regulate emotion is a crucial process that humans utilize in order to adapt to the demands of environmental constraints. Individuals exposed to early adverse life events such as being born at an extremely low birth weight (ELBW, 501–1000 g) are known to have problems regulating emotion which have been linked to the development of psychopathology in this population. Recent studies have used psychophysiological measures, such as electroencephalogram (EEG) and cardiac vagal tone, to index emotion regulatory processes. The purpose of this paper was three-fold: (1) to investigate the relation between ELBW and emotion regulation issues (pathway 1), (2) to review studies investigating the relation between early emotion regulation and later internalizing problems (pathway 2); and (3) to provide a model in which two psychophysiological measures (i.e., frontal EEG asymmetry and cardiac vagal tone) are suggested to understand the proposed conceptual pathways in the relation between ELBW and psychopathology.

1. General Introduction

Emotions are complex processes that humans use to evaluate the environment, recognize environmental changes, and adjust behaviors according to environmental demands [1]. They are an integral part of human life and have important inter- and intrapersonal functions [2]. Interpersonally, emotions function as signals to others about our internal states and intentions. The intrapersonal functions of emotions give us pertinent information, which we use to make decisions about environmental stressors.

Emotions and their regulation involve cognitive, behavioral, and physiological components. Interactions among these provide one with emotion-specific action tendencies and eventually facilitate explicit action, which can be adaptive or maladaptive [3]. How emotions can be effectively regulated is the topic of significant debate. Of particular interest has been how their dysregulation can lead to problems with adaptive behaviour, and how emotion dysregulatory processes affect the risk for adverse mental and physical health outcomes [3].

Normal development of emotion regulation leads to successful adaptations to the demands of environmental constraints. What is less known is how pervasive problems with emotional regulation, as indexed by psychophysiological measures, can contribute to the development of mental health problems and how early experience shapes these processes.

Early adversity has been defined as early exposure to environmental conditions that negatively impact normative human development [4]. In particular, these adverse exposures are thought to have the capacity to negatively affect the development of emotion regulatory processes. Much research has documented the fact that such adversity affects not only cognitive but also social-emotional development and functioning [1, 4]. Some special types of early adversity that are particularly deleterious to the development of emotion regulation include childhood maltreatment (i.e., physical, emotional, and sexual abuse, and neglect) [1, 5, 6], rearing in poorly staffed orphanages [5, 7], being exposed to recreational and certain prescribed drugs in utero [8], and being born prematurely and/or at low birth weight [9–15].

Some researchers have proposed that these aberrant experiences can affect adult mental health by (1) causing successive damage to the self over time, and/or (2) affecting the individual during sensitive developmental periods [16]. In many cases, these mechanisms may act in concert to affect the risk of the development of psychiatric impairment.

While a multitude of studies have been published on (1) later internalizing problems seen in groups seen exposed to early forms of adversity, (2) early adversity and emotion regulation, and (3) early emotion regulation, and later internalizing problems, relatively few reviews have been conducted on investigating the associations among early adversity, emotion dysregulation and psychopathology. The purpose of this paper was to provide evidence that those exposed to a specific, rare type of early adversity, namely, being born at extremely low birth weight (ELBW, i.e., <1000 grams), represent an adverse circumstance. ELBW individuals have problems with emotion regulation and are at a heightened risk for the development of later internalizing problems.

In this paper, we will (1) discuss how ELBW represents an adverse event, (2) review studies relating ELBW, with emotional regulation issues (pathway 1), (3) review studies relating early emotional regulation with later internalizing problems (pathway 2), (4) propose a model hypothesizing the association between early adversity (ELBW as the adverse circumstance), emotion dysregulation, and psychopathology, and (5) provide some perspectives in which measures of frontal EEG asymmetry and cardiac vagal tone should be considered as means to investigate the conceptual pathways 1 and 2 described in this paper.

2. How Extremely Low Birth Weight (ELBW) Represents an Adverse Circumstance

Infants born preterm are among the most vulnerable groups exposed to early adversity. Not only is their small and underdeveloped size at birth suggestive of exposure to prior physiological stresses, but they are also more vulnerable than normal birth weight infants to postnatal environmental risks. Infants born preterm may experience similar risks to those exposed to other types of early adversity, such as problems with emotion dysregulation and increased risk for developing psychopathology [13, 17].

It is, however, important to make a distinction here between infants born prematurely and those born low birth weight. Those born prematurely are not born full term, meaning that they were born preterm and are subject to underdevelopment. Infants born at low, very low, or extremely low birth weight do not necessarily imply preterm birth. It is possible for those born low birth weight are born full-term but low birth weight and thus subject to similar adversities as preterm infants. These similar early adverse experiences shared by both groups contribute to difficulties in emotional regulation. Thus, it is reasonable to suggest that studies investigating the negative effects of preterm birth on development of emotion regulation can be extrapolated to the

case of early adversities experienced by those born ELBW in the development of emotion regulation [18, 19].

In this section, we will (1) provide an overview of the adverse environmental and biological factors that ELBW infants face in the early stages of development, and (2) demonstrate how these adverse environmental and biological factors have strong implications for negative impact on the early stages of the developing brain, specifically in the development of important processes such as self-regulation.

ELBW infants are especially vulnerable to environmental risk factors. Infants born ELBW are extremely underdeveloped in size and weight (<1000 g) and arrive usually preterm between 23 and 28 gestation weeks. ELBW infants first enter the world subjected to the neonatal intensive care unit (NICU) where neonatal interventions, therapies, and procedures are imposed on the infant in order to increase their chances of survival. Some interventions, therapies, and procedures include surfactant therapy, intravenous fluid therapy, umbilical artery catheter placement to monitor oxygenation, neonatal monitoring of cardiac and respiratory functioning, and phototherapy in the treatment of jaundice [20]. Although the medical procedures are designed to reduce mortality rates of ELBWs, of those who survive, there are a small percentages (~15%) of ELBWs who experience severe developmental outcomes, such as cerebral palsy (CP) [20, 21] and about half develop cognitive and behavioral deficits [21]. Furthermore, ELBW infants receiving intensive care are highly susceptible to neonatal infections—imposing more biological stress on the infant in terms of early developmental growth and increased risk of death [21]. In order to treat neonatal infection, a number of medical procedures are put into place. Some of these include antenatal antibiotics and steroid use, which on their own have significant biological effects on neurodevelopment.

During the early days and weeks of postnatal life in the NICU, neonatal pain exposure due to various medical procedures and susceptibility to neonatal infection (putting ELBW infants at a heightened risk for mortality) are not the only stressful environmental exposures to which ELBW survivors are subjected. ELBW infants are also deprived of immediate primary caregiver attachment. At this sensitive and crucial time where an infant needs to rely on maternal support, there is very little and often none available because of the neonatal interventions imposed on the infant. In the early stages of infant development, the infant relies heavily on caregiver support and feedback in order to self regulate [22–25]. In circumstances of ELBW, the infant is unable to rely on this crucial support for self regulation purposes. Moreover, while intensive care is necessary in order to reduce the risk of morbidity in the ELBW infant, this event not only is stress inducing for the infant, but also becomes a stressful time period for primary caregivers.

There is an extensive literature published demonstrating the importance of the transactional nature/reciprocal relationship between caregiver and infant on the development and acquisition of self-regulation (for a comprehensive review, see Walker et al., 2004). The psychological impact of having an infant born ELBW can be extremely taxing on

parents, and even more so, if there is only one parent support system [23, 25]. The untimely birth of the infant is a stressful event, especially when the infant born ELBW and is subjected to NICU procedures. How caregivers adjust to this distress, behave toward the infant (i.e., maternal touch), and how they go about parenting the infant, all represent important factors in infant regulation. When the caregivers are unable to make positive adjustments to cope with the distressing series of events, the unavailability can result in symptoms of depression and even posttraumatic stress disorder (PTSD).

There are a number of studies published on the negative influence of maternal depression as well as PTSD on the developing infant [24, 26–29]. Depression and PTSD are related to the difficulty in emotion regulation. Consequently, caregiver-infant interaction may be biased by the caregivers' difficulty to regulate emotions and may influence the development of early self regulation.

Neonatal pain exposure via NICU, primary caregiver detachment, and exposure to maternal depression and/or PTSD, all have deleterious effects on the ELBW infant. These environmental factors strongly influence high levels of biological stress. Biological stress in the form of increased glucocorticoids (GCs) exposure, which have damaging effects on the development of brain systems [20, 22, 23]. These brain systems (specifically, the hypothalamic-pituitary-adrenal axis (HPA), amygdala, hippocampus, and prefrontal cortex (PFC)) are highly susceptible to programming in early development [25].

The HPA is part of stress-response activation of which one needs to respond and cope with the demands of the environment. Responses of the HPA axis are programmed by early experiences (e.g., in the ELBW infant, extreme NICU procedures, maternal separation, and maternal psychopathology). The production of high levels of basal cortisol in ELBWs suggests reprogramming of stress physiology [20, 22, 23], where it is thought that the ELBW neonatal reprogramming of stress systems has taken place and has been proposed as the mechanism in altered behavior, cognitive, and emotion processes [23, 25]. In ELBW infants, stress exposure related to unexpected medical procedures, separation from parents, and the impact of primary caregiver psychopathology can have a negative impact on the development of many brain systems involved in regulation of stress.

3. Studies Relating ELBW with Emotional Regulation Issues (Pathway 1)

The emotion regulatory resources one utilizes change across developmental periods and individuals, but individuals become more effective in the ways they regulate emotion across the lifespan. The development of early emotion regulatory processes begins with transactional exchange between caregiver and infant [25]. Feedback and support from the caregiver to infant (i.e., maternal touch, maternal-infant bond) set the fundamental building blocks for important brain systems involved in emotion regulation and dictate behavioral responses from the infant [30]. Successive interaction with primary caregivers, as well as other factors, such

as age-related brain maturation, environmental influences, and the refinement of cognitive and behavioral processes, contribute to the development of emotion regulation [30]. As one moves from the early stages of development, the individual becomes less dependent on others, resulting in a greater dependence on self-regulatory processes by the time children attend school [31]. As individuals progress to adolescence, they develop even more self-sufficient mechanisms of emotion regulation, which become more complex and involve higher cognitive processes. These developmental changes arise with frontal lobe maturation and further augmentation of executive control, allowing more complex cognitive strategies (i.e., self-talk, decision making) and behavioral responses (e.g., such as ability to remove oneself from stress inducing situations) to play a larger role in the regulation of emotion.

Neural processes underlying emotion regulation cannot be defined as independent processes, but rather the regulation of emotion requires synchronization of several brain systems, whereby different systems (i.e., PFC, amygdala, HPA, and hippocampus) work in coordination to regulate each other [32]. In brief, the brainstem mediates arousal and behavioral activation; the limbic system mediates perception, memory, learning, and affective feeling; the cerebral cortex mediates higher order perceptual processes, voluntary control, and executive functioning (i.e., attention, working memory, cognitive control) (for a comprehensive review of the emotional brain, see Dalgleish [33], and Lewis and Stieben [32]). The synchronization of these brain systems underlies emotion and its regulation, including psychological features of "specific action readiness, a restricted attentional focus, a stable cognitive appraisal, and a distinct emotional feeling," [32]. The activation and coordination of these brain systems does not occur in a top-down or bottom-up fashion to produce this psychological series of functions, but rather the systems coevolve at a rapid rate, coordinating with each other [32].

As previously mentioned, infants born preterm are among the most vulnerable groups exposed to early adversity. Not only is their small and underdeveloped size at birth suggestive of exposure to prior physiological stresses, but they are also more vulnerable than normal birth weight infants to postnatal environmental risks. Infants born preterm may experience similar risks to those exposed to other types of early adversity, such as difficulties with emotion regulation [13, 17]. It is well known that early adversities can alter the development of prefrontal brain regions. By altering the development of prefrontal brain regions, which is a foundational component in self-regulatory processes, and specifically emotion regulatory processes, this can potentially affect how one regulates emotion in order to combat environmental stresses.

It is also important to point out that, as mentioned above, not all ELBW infants were born preterm, but most were. Here we review studies involving preterm as well as low birth weight given the limited research on low birth weight infants versus those born prematurely.

Conrad et al. (2010) provided evidence that there are deficits in neuromotor and intellectual functioning in

children born preterm [14]. Consistent with other research published on infants born preterm, Conrad et al. (2010) found that in the childhood and adolescent years, survivors of premature birth demonstrated lower IQ and higher rates of emotional and behavioural problems (e.g., internalizing, externalizing, hyperactivity/inattention problems). Similar findings were reported by Lowe et al. (2005), demonstrating that infant behavioral characteristics had an adverse effect on developmental outcome from 8 to 18–22 months of age in ELBW infants. Lowe et al. (2005) concluded that the majority of children whose cognitive scores significantly decreased from time 1 (8 months) and time 2 (18–22 months) demonstrated low emotional regulation subscale scores on a behavior rating scale. This finding by Lowe et al. (2005) further suggests that the neural mechanisms underlying emotion regulation may also support cognitive processes [34].

Pollak (2008) [1] argued that the earlier the exposure to adversity, the more severe the impact on development. Various studies examining children born at a VLBW and ELBW report that the lower the birth weight and gestational age of these individuals, the more severe the later effects [14]. These findings are supported by other results by Bohnert and Breslau (2008) who reported a greater risk of externalizing and internalizing problems within children of very low birth weight (≤ 1500 g) compared to heavier children (1501–2500 g) [35].

Attentional and processing biases fall under the umbrella of lack of control over emotion regulatory processes. A lack of cognitive control over emotion regulatory processes may lead to poor adaptive functioning [34]. This idea is in line with findings from studies that document high levels of poor adaptive functioning in children born at ELBW [12, 36, 37]. Finally, problems with emotion regulation in infants born prematurely may be due to a natural inclination for this population to engage in emotional over control, either by using avoidance-type behaviors or the use of suppression of emotion [19]. This vulnerable population shows relatively fewer externalizing problems than internalizing problems as they get older, which is evident in studies that demonstrate that personality traits of infants born preterm are shy, inhibited, and/or avoidant into young adulthood [38].

Conversely, there are various studies published reporting no significant problems in cognitive and behavioral functioning in premature and ELBW infants compared to their normal birth weight counterparts [39, 40]. Weisglas-Kuperus et al. (1993) report that VLBW children at high biological risk were able to catch up on their cognitive delay in a highly stimulating home environment, and that VLBW children who were both low and high biological risk in a less stimulating home environment demonstrated a decline in cognitive development. This outcome highlights the influence of environmental factors on the biology of the infant. Despite exposure to the negative impact of adverse circumstance, these studies suggest that there is an avenue to intervene and reverse the damaging effects premature and ELBW can have on cognitive and emotional development [39]. To support this claim, various intervention studies assessing the effects

of different therapy interventions on the cognitive development and the development of attachment patterns (i.e., the nature of the relationship between primary caregiver-infant) in premature and ELBW infants have demonstrated that cognitive level and behavioral levels to be notably higher in the intervention group compared to control [41, 42].

There are a number of other studies that report those born preterm/very low birth weight to have more emotional and behavioral problems and less competence compared to normative children/adolescents as given by parent reports and other various measures [11, 15, 43]. Thus, the increasing reports of attentional problems and emotional overcontrol in children born preterm may be a partial explanation of emotion dysregulation in populations born prematurely and in turn may be a possible explanation to the increasing rates of psychopathology and its stability into childhood, adolescent, and young adult years [13, 17]. This notion is evident in findings by Saigal et al. [10, 44, 45], where data suggest that the nature of the problems ELBWs experience may change over time; however, what does remain stable is that there are an increasing number of problems.

4. Studies Relating Early Emotional Regulation with Later Internalizing Problems (Pathway 2)

Many negative outcomes are associated with the failure to develop successful emotional regulation, ranging from problems with self-esteem to shyness and impairment in interpersonal relationships. On the more severe end of the spectrum is a heightened risk of developing psychopathology. Indeed, Werner and Gross (2010) suggest that 75% of the diagnostic categories of psychopathology in the Diagnostic and Statistical Manual of Mental disorders (DSM-IV) are based on problems associated with emotion and emotion regulation [46].

Throughout this paper, we have discussed and reviewed the development of emotion regulation and both the environmental and biological factors that may play a role in the early stages of its development. Here, we will review studies relating early emotion regulation with later psychopathology, namely, the development of internalizing disorders (i.e., depression and anxiety).

A significant number of studies investigating the role of emotion regulation in psychopathology illustrate that less effective means of emotional regulation strategies/techniques are at the core of internalizing disorders, such as in depression and anxiety disorders (for a review of studies, see, Aldao et al., 2010) [47]. Gross (1998, 1999) has proposed a process model of emotion regulation strategies, where the individual appraises both external and internal events that then necessitate expressive emotion (see Gross, 1998) [48, 49]. Gross' model demonstrates how the individual's capacity to regulate emotion depends on the ability to tolerate and experience emotion, the frequency to which one regulates emotion, and the timing of emotion regulatory strategies, all impact how effective the strategy will be [50]. Emotion regulation strategies include acceptance, avoidance, problem solving, reappraisal, rumination, and suppression. These emotion regulation strategies may be viewed as having adaptive or

maladaptive value. They are responses that can be effective or ineffective depending on their function, context, and timing [51]. When emotion regulation strategies are used in a maladaptive manner, they can be both emotionally and cognitively demanding and can result in adverse mental health outcomes [50].

Emotion regulation strategies help one to cope and manage unwanted feelings of negative emotion. In the face of adversity, to combat the stressful impact of negative emotions, one identifies the emotion and chooses how to respond to that emotion utilizing an emotion regulation strategy. Studies examining emotion regulation and optimal mental health have investigated how psychological resiliency and positive emotions influence the experience of negative emotions in the time of stress. These studies have demonstrated that positive emotion and psychological resiliency serve to moderate stress reactivity and mediate stress recovery, which suggest that adaptive emotion regulation strategies may be at play [52, 53]. Successful adaptation to stress over time has implications for psychological resiliency and successful emotion regulation.

Conversely, when emotion regulation is compromised early in development, there may be difficulties in the ability to regulate emotion adaptively, making one more vulnerable to the development of internalizing disorders. Studies exploring emotion regulation in depression demonstrate that the ability to regulate emotional responses to negative events may help further understand the disabling nature of the disorder [54]. Depression has been associated with difficulties in the disengagement from negative stimuli, memory biases, and deficits in cognitive control which may explain the use of maladaptive emotion regulation strategies, such as excessive use of emotion suppression and rumination [55]. The dominant use of emotion suppression and rumination and less frequent use of other emotion regulation strategies have been related to symptoms of depression [55, 56].

Emotion regulation and anxiety disorders have also been explored, and studies examining this relation have found that anxiety disorders are associated with the inability to regulate emotion effectively where increasing levels of anxiety are highly associated with emotion dysregulation [57, 58]. Orgeta (2011) found that adults experiencing increasing levels of anxiety reported greater difficulty in regulating emotional responses. Experiencing anxiety symptoms affects the ability to regulate emotional experiences [59], which has also been demonstrated in other studies [57, 58].

The relation between cognition and emotion in emotional regulation is highly interconnected, as is evident with the use of various different emotion regulation strategies to assess the way in which one processes emotion and determines how to respond to emotion. Thus, optimal development of brain systems in emotion regulation as well as the acquisition of adaptive emotion regulation strategies is crucial for successful emotion regulation. When these brain systems are disrupted in the early years of development due to adverse circumstances (as given by the case of the ELBW infant), it can affect the way in which one acquires effective emotion regulation strategies, stressing the importance of cognitive, emotional, and behavioral functioning in early development.

5. Model

5.1. Linking Extremely Low Birth Weight, Emotion Dysregulation, and Psychiatric Impairment

5.1.1. A Possible Hypothesis. Using the material reviewed to this point, we next provide a model (see Figure 1) that interfaces these sections particularly as it relates to pathways 1 and 2 discussed earlier. As shown in Figure 1, our model illustrates that being exposed to an adverse circumstance, using the case of being born ELBW, leads to difficulties in the development of emotion regulation (pathway 1). Exposure to adversity early in life impacts the individual both physiologically and psychologically, contributing to poor ability in regulating emotion throughout core developmental periods. Less optimal development of emotion regulation may have a significant impact on human development, such that the individual is unable to regulate emotion effectively. There is an association relating early emotion regulation with later development of psychopathology in adulthood (pathway 2), where unsuccessful means of regulating emotion are evident in internalizing disorders (i.e., anxiety and depression).

Additionally, there are other factors beyond atypical development of emotion regulatory processes that may mediate the link between exposure to early adversity and the development of psychopathology, which has been accounted for in our proposed model (as provided by the growing literature demonstrating a direct relation between exposure to adverse circumstances and later development of psychopathology in adulthood). It is important to highlight the bidirectional relation between atypical development of emotion regulatory processes and the development of psychopathology in adulthood. Here this bidirectional relation represents the growing literature demonstrating emotion dysregulation as a fundamental feature of various psychopathologies. Finally, we provide perspectives that measures of resting frontal EEG asymmetry and cardiac vagal tone should be considered as means to investigate pathways, for examples of pathways 1 and 2. Overall, our theoretical process model illustrates the mediating and moderating roles of atypical development of emotion regulation on understanding the relation between being born at ELBW and the development of psychopathology.

6. Perspectives on Putative Measures in the Model: Frontal EEG Asymmetry and Cardiac Vagal Tone in Pathways 1 and 2

6.1. Frontal EEG Asymmetry: Linking Early Adversity, Emotion Dysregulation, and Psychopathology. Over the past few decades, numerous studies have examined how early adversity affects the developing brain, the development of emotion regulation, and the risk of psychopathology. Here we will provide frontal EEG asymmetry as a means to investigate pathways, for example emotion regulation between early adversity and the risk to developing psychopathology by reviewing studies of infant and child deprivation.

Davidson and colleagues (2003) postulate that high levels of relative left frontal activity are associated with

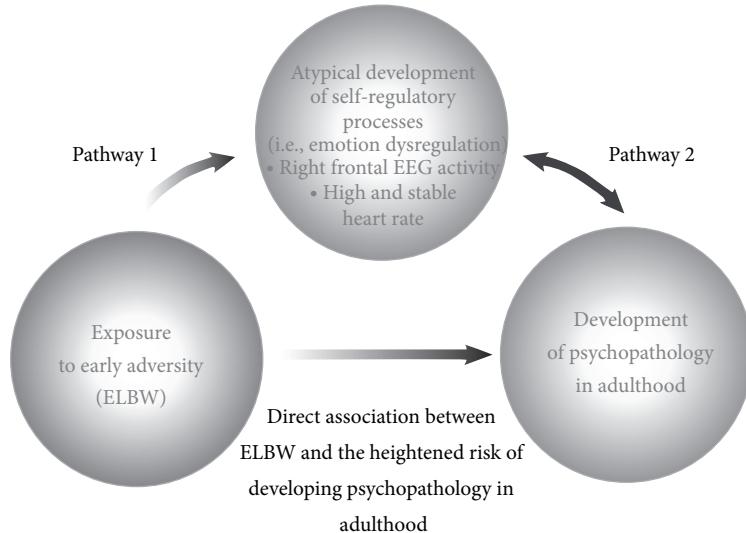


FIGURE 1: Hypothesized associations between early adversity (ELBW representing the adverse circumstance), emotion dysregulation, and later internalizing psychopathology.

the expression and experience of positive, approach-related emotions [60], whereas high levels of relative right frontal activity are associated with the experience and expression of negative, withdrawal-related emotions. Interestingly, this pattern of asymmetry has also been linked to various forms of psychopathology, specifically, anxiety and depression [5, 61–66]. This pattern raises the possibility that right frontal EEG asymmetry provides a means to investigate a pathway, for examples of being born ELBW and the development of psychopathology later in life.

Schmidt et al. (2010) conducted a study examining the development of psychopathology in a group of ELBW survivors in early adulthood. The authors found that ELBWs exhibited greater relative right frontal EEG asymmetry compared to NBW, implicating a tendency for individuals born at ELBW to have difficulties in regulating physical and mental stress [9].

Overall, previous research published on the detrimental effects of premature birth on emotion regulation functioning indicates that problems in neurocognitive functioning persist beyond the postnatal years into young adulthood. Schmidt et al. (2010) demonstrated that frontal EEG asymmetry (as an index of emotion regulation) may mediate the link between ELBW and psychopathology during a young adulthood visit. The authors found that ELBWs exhibited more internalizing behaviour problems than NBW at young adulthood. The authors suggested that greater relative right frontal EEG asymmetry in ELBWs may reflect a predisposition for this population to have difficulties in regulating physical and mental stress. This pattern of right frontal EEG asymmetry observed in survivors of ELBW may be due to early adverse life experiences (such as being born preterm).

6.2. Cardiac Vagal Tone: Linking Early Adversity, Emotion Dysregulation, and Psychopathology. Autonomic nervous system (ANS) measures have been used to specifically index self-regulation of emotion. Basic cardiac function can be

determined by measuring heart rate. Variation in heart rate, also known as heart rate variability (HRV), is generally (or usually/often) measured as the standard deviation of heart rate. An important source of this variation, the parasympathetic component of heart rate variability, is often assessed using a metric known as cardiac vagal tone (CVT) [67]. Cardiac vagal tone at rest is considered a primary index of ANS regulatory capacity. High vagal tone indicates greater variability in heart rate over time (i.e., healthy cardiac control). Another metric, respiratory sinus arrhythmia (RSA), a natural irregularity in the cardiac signal that occurs in conjunction with the respiratory cycle, is also often used to index parasympathetic ANS function.

Hae-Kyung, (2009) used CVT as an indicator of autonomic nervous system functioning (specifically, emotion self-regulatory functioning) in healthy and premature infants. Hae-Kyung discovered that healthy newborns exhibited significantly greater CVT than premature infants [68]. Similar findings were reported by Doussard-Roosevelt et al. (1997) who examined HR and RSA as indexes of developmental outcomes in VLBW infants (<1,500 g). The authors found that high RSA was associated with better social functioning and greater RSA maturation was associated with better cognitive and executive functioning [69]. Lower HR was associated with better behavioral regulation, social skills, and greater maturational decreases associated with better motor skills. Extremely low birth weight infants (birth weight <1000 g) also demonstrated less positive functioning than heavier infants, exposing them to more deleterious developmental effects, meaning that infants born of a lower weight compared to other VLBWs demonstrated poorer outcome (i.e., poorer behavioral regulation, social skills, and motor skills) [68].

HRV has been associated with emotion regulation processes, where high HRV is associated with emotion adaptability and regulation and low HRV associated with emotion maladaptability and dysregulation. The ability to regulate emotion involves a cognitive component, where cognitive

tasks (e.g., such as executive functioning) are predominantly associated with prefrontal cortical activity. As noted previously, the prefrontal cortex functions to tonically inhibit amygdala output. This relation is important because deficits in executive functioning, such as inability to inhibit behavior or inability for the prefrontal cortex to inhibit emotion activation of the amygdala, are present in negative emotional states and dispositions of varying psychopathologies (i.e., depression and anxiety disorders) [70]. It is also important to note that stress can also impair cognitive functioning; the authors suggest that impairment in cognitive functioning may contribute to the cognitive deficits seen in varying mental health disorders. Thus, the authors conclude that when the prefrontal cortex is unable to tonically inhibit control over the amygdala (and sympathetic neural circuits), it may be the explanatory link between psychosomatics and psychopathology.

7. Concluding Remarks

The main objective of this paper was to provide evidence that individuals exposed to a specific, rare type of early adversity, namely, being born at extremely low birth weight (ELBW; i.e., <1000 grams), represent an adverse event. We provided evidence that individuals born ELBW exhibit problems with emotion regulation and are at an increased risk for the development of psychopathology in adulthood (i.e., development of internalizing disorders). In order to demonstrate this connection, we discussed (1) how ELBW represents an adverse event; (2) studies relating ELBW with emotional regulation issues (presented as pathway 1); (3) studies relating early emotional regulation with later internalizing problems (presented as pathway 2); (4) a model in which we hypothesized an association between early adversity (ELBW as the adverse circumstance), emotion dysregulation, and psychopathology; and (5) some perspectives in which measures of frontal EEG asymmetry and cardiac vagal tone might be as putative measures to investigate the conceptual pathways 1 and 2 described in this paper. Given that these psychophysiological measures are open to change, future research might want to consider targeting interventions at this level in order to effectively manage mental health problems in some survivors of ELBW.

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