Journal of
Research in Psychopathology
https://dx.doi.org/10.22098/jrp.2021.1146

2022; Vol. 3, No. 7
Pages: 1 - 9

Original Article

Executive functions, behavioral activation/behavioral inhibition system, and emotion regulation in adolescents with non-suicidal self-injury (NSSI) and normal counterparts

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Abstract

Non-suicidal self-injury (NSSI) is one of the serious public concerns. There are several hypotheses and reasons for NSSI. The aim of this study was to investigate the differences between two groups of adolescents with NSSI and normal counterparts in executive functions, behavioral activation and behavioral inhibition system (BAS/BIS) and emotion regulation. In this cross-sectional causal-comparative study, 50 adolescents (girls and boys) having NSSI and 50 normal adolescents were compared. They performed Bart balloon computer tasks (to measure high-risk decision-making), Wisconsin cards (to measure cognitive flexibility), as well as Carver and White Behavioral Activation/Behavior Inhibition scale and filled Gratz and Roomer's emotion dysregulation scale. Participants who reported NSSI, had higher scores on risky decision making, behavioral inhibition, emotion dysregulation, and lower scores on cognitive flexibility than participants without a history of NSSI. The results support that there is a significant difference between two groups of adolescents with NSSI and normal counterparts in executive functions, emotion regulation and BAS/BIS. The data can also be used to educate, prevent and treat adolescents with NSSI and to promote public health policies.

Keywords

Behavioral activation
behavioral inhibition
Emotion dysregulation
Executive functions
Non-Suicidal self-injury

Received: 2020/10/30
Accepted: 2020/11/15
Available Online: 2022/03/03

Introduction

In the field of pathological psychology, self-injuring behaviors have been known since ancient times as a sign of some mental disorders, especially borderline personality disorder, pervasive growth disorder and impulse control and conduct disorder (Szewczuk-Bogusławska, Kaczmarek-Fojtar, Moustafa, Mahlberg, & Frydecka, 2018). However, in recent years, due to the increasing prevalence of these behaviors and the increasing volume of research devoted to this issue, it has been proposed to create a diagnostic class called self-injury syndrome without suicide (American Psychiatric Association, 2013). Walsh categorizes harmful behaviors into direct and indirect groups. In direct self-injury behaviors, the intent of the behavior is clear and directly damages body tissues, such as self-injury, self-immolation, and suicide attempt. In indirect self-harmful behaviors, the intention and motivation of the behavior are not completely clear and the consequences of the behavior will be determined later, such as risk-taking, overeating, drug abuse, and high-risk and reckless sexual behaviors

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(Walsh, 2012). Bentley, Nock, and Barlow (2009) have proposed that self-injury be considered as a continuum, one end of which is indirect self-injuring behaviors such as smoking and eating disorders, and the other end of which is direct self-injuring behaviors such as self-injury. According to the DSM-5 (2013), NSSI is defined as intentional injury to the body without suicidal intent, which includes a set of behaviors such as cutting, burning, and beating. These behaviors are not socially approved and do not include such things as body piercing, tattooing, part of religious or cultural rituals, and are not limited to peeling wounds or biting nails. Nock and Favazza (2009) consider the diverse types of NSSI including stereotyped self-injury, major self-injury, compulsive self-injury, and impulsive self-injury, which are more common in adolescents. Demographic findings on the types of NSSI indicate an increase in the incidence of these types of behaviors in recent years (Jenkins, Seelbach, Conner, & Alloy, 2013). This has caused public health concerns. Suicide has several negative consequences such as having suicidal ideation and increasing the risk of suicide attempt (Mars, Heron, Klonsky, Moran, & O'Connor, 2019). In a longitudinal study, Muehlenkamp, Xhunga, and Brausch (2019) found that 12% of adolescents who committed suicide at age 16 also attempted suicide at age 21. Although NSSI can occur at any age, its frequency in adolescence is higher than in other developmental periods. Typically, the age of onset of NSSI varies from 12 to 15 years (Kądziela-Olech, Żak, Kalinowska, Wągrocka, Perestret, & Bielawski, 2015). Regarding the prevalence of NSSI among girls and boys, various studies have reported higher rates of NSSI in girls than boys (Siu, 2019). In terms of contextual, economic, and social differences, NSSI occurs in all societies and cultures (De Oliveira Costa, Peixoto, ALRP, Peixoto, Falcão, & da Silva Farias, 2020) and international estimates of the prevalence rate of NSSI according to the definition of NSSI and measurement tools (Simioni, Pan, Gadelha, Manfro, Mari, & Miguel, 2018) reported between 7.5% to 46.6% (Hilt, Nock, Lloyd-Richardson, & Prinstein, 2008). Muehlenkamp (2012) in a review study estimated the prevalence rate of NSSI in 18 studies from 2005 to 2011 to be 18%. This rate in Iran has been reported from 6.2% (Marin, Hajizadeh, Sahebihagh, Nemati, & Ataeias, 2020) to 12.3% (Gholamrezaei, Heath, & Panaghi, 2017).

Executive functions have been described as an umbrella that encompasses a set of interconnected but distinct cognitive abilities, whose function depends on the frontal lobe of the brain and it includes planning, flexibility, fluidity, problem solving, decision making, self-regulation, working memory and inhibition (Friedman, Miyake, Altamirano, Corley, Young, & Rhea, 2016). Some authors have described executive functions in the form of hot and cold executive functions. Cold executive functions are not context-dependent and require logic and critical analysis; in contrast, hot executive functions are context-dependent and personal interpretation dependent, and deal with emotions and motivations (Friedman et al., 2016). Executive function abilities play an important role in shaping adolescents' behaviors and their emotional and social competencies, as they allow him or her flexibility in responding to environmental conditions, risk assessment, and task prioritization. Items that are required to guide more daily tasks and are vital to perform independent, purposeful tasks and successful adaptation (Isquith, Roth, & Gioia, 2013). The role of executive functions in most internalized and externalized disorders in children and adolescents has been investigated (Weyandt, Willis, Swentosky, Wilson, Janusis, & Chung, 2014). Some neuropsychological studies have reported no difference in executive functions of adolescents with NSSI compared to healthy adolescents (Janis & Nock, 2009) and others have reported differences between the two groups (Fikke, Melinder, & Landro, 2011). Fikke et al. (2011) while examining three groups of adolescents with severe NSSI, low NSSI and no NSSI, concluded that people with severe NSSI had impaired working memory, individuals with low NSSI had impaired inhibition, and men and women in the severe NSSI group had problem with working memory tasks; men and women in the low NSSI group were also restrained. In general, the NSSI groups were weaker than the normal group in using effective strategies for completing homework. There was no difference between the groups in performing the transfer tasks (Fikke et al., 2011). In a meta-analysis by Hamza et al. (2015), 27 studies on impulsivity and NSSI showed that there was little evidence of an association between impulsivity computer tests such as the Go/No-Go test and NSSI, while this association was greater for impulsive self-report and self-injury. In general, some studies report a significant relationship between NSSI and performance of tasks and computer tests of executive functions (Schatten, Andover, & Armey, 2015).

According to the theory of sensitivity to reinforcement for personality variability in individuals, three independent emotional systems of behavioral activation, behavioral inhibition and warfare have been proposed (Gray, 1981). Carver and White (1994) considered the behavioral activation system to have three subsets: driver response, reward response, and the pursuit of fun and happiness. In the revised version of the theory, in the war and escape system, the freezing reaction is also present and has been changed to the war, escape and freezing system (Heym & Lawrence, 2010). Biologically, the dopaminergic and limbic pathways play an essential role in the behavioral activation system, and the neuroanatomical foundations of the behavioral inhibition system are located in the orbital frontal cortex, septohypochemical apparatus, and Papez circuit (Hewig, 2005). The blind joint subsystem hypothesis shows that the effects of BAS and BIS on behavior are

interdependent and should not be considered independently (Corr, 2016). In particular, according to his hypothesis, people who score high in BAS and low in BIS are likely to be at the highest risk of engaging in extraterrestrial behaviors. BAS and BIS-related personality structures, including conflict/injury sensitivity and impulsivity, play a role in self-injuring behaviors (Heym & Lawrence, 2010). Some authors also believe that the impulsivity of people with borderline personality disorder who attempt self-injury has a calming role in negative emotions (Linehan, 1993). Accordingly, they also hypothesized that one aspect of impulsivity is urgency, which is defined as the tendency to experience strong impulses, especially when there are negative emotions (Whiteside & Lynam, 2001). According to several studies, the behavioral activation system and behavioral inhibition with high-risk behaviors such as increased suicidal ideation oriented are related (Pessoa, 2008). In a study of 178 students with a history of NSSI, Jenkins et al. (2013) found that both a high BAS score and a low BIS score and its inverse, i.e., a high BIS score and a low BAS score predicts self-injury.

Many aspects of human thinking and reasoning are influenced by emotions. According to studies by cognitive scientists, mental emotional activities occur intertwined with cognitive processes. Thus, emotion and cognition interact with each other and the interaction of the two affects behavior (Pessoa, 2008). Emotion regulation refers to the ability to recognize emotions and modify the experience and expression of emotion, and the internal and external processes responsible for monitoring, evaluating and changing emotional reactions to achieve one's goals (Gross, 2008). Emotional disturbance and disorder due to their inherent importance in daily life, will cause the occurrence and persistence of other problems and disorders. Problems with emotion or emotion regulation characterize more than 75% of the diagnostic categories in the DSM (Werner, Gross, Kring, & Sloan. 2010). Emotion regulation strategies are diverse. In the emotion regulation process model, strategies for position selection, position adjustment, attention allocation, cognitive change, and response modulation are located along the emotion process time (Gross & Thompson, 2007). Emotion regulation also has its own complexities, including the fact that emotion regulation strategies may disproportionately affect the three components of emotional response (experiential, behavioral, and biological) (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Moreover, emotion regulation typically occurs in social contexts and may occur differently in different contexts. Based on the emotion regulation hypothesis, adolescents who attempt self-injury see self-injury as a way to regulate their emotions and reduce negative emotions such as anger, sadness, and anxiety (Glenn & Klonsky, 2013; Svaldi, 2012). The results of meta-analytic studies indicate a significant relationship between NSSI and emotional dysregulation (Wolff, Thompson, Thomas, Nesi, Bettis, & Ranford, 2019). Adolescents with self-injury reported poorer emotion regulation than peers without self-injury (Robinson, Garisch, Kingi, Brocklesby, O'Connell, & Langland, 2019). Chen and Chun (2019) surveyed 438 adolescents aged 13 to 18 years and found that 37% of the adolescents reported a history of self-injury at both moderate and severe levels. Also, adolescents with severe NSSI experienced more negative emotions. They had difficulty in strategies for emotion regulation, emotional control, emotional awareness, and expressing acceptable emotional responses.

Given the above, the hypothesis of the present study was that there is a difference between executive functions, BAS/BIS, and emotion regulation in adolescents with a history of NSSI compared to normal counterparts..

Method

Participants

The present study is a cross-sectional study of causal-comparative type. Participants included adolescents (boys and girls) aged 15 to 17 in Sanandaj (a city located in west of Iran) during 2019-2020. Out of 531 adolescents, 50 adolescents with a history of NSSI were selected as the available sample and were compared with 50 adolescents without a history of NSSI in terms of executive functions, behavioral brain systems, and emotion regulation. A total of five participants (three due to non-completion of some questionnaires and two due to lack of computer tasks) were excluded from the study process.

Instrumentation

Bart Balloon Risk Task

In this task, an image of a balloon appears on the computer screen that the subject can inflate by pressing the button below. There are two temporary and permanent boxes on the screen. Each time the balloon is inflated, 10 points are scored in the box. Instead of inflating the balloon more, the person can press the key to save points. At this time, a new balloon is replaced and the amount saved from inflating the balloon goes to the permanent box. The total number of balloons are 30. Each time the balloon is inflated, the temporary box's scores increase, but if the balloon bursts, all the temporary box points are lost. Here, each time a person inflates a balloon, he or she adds a point to the temporary box, but endangers the entire temporary box balance .Balloons burst at unspecified points, making high-risk decisions possible. White et al. (2008) reported the test reliability through retesting as 0.77.

Wisconsin Card Classification Task

This task assesses the ability to change cognitive strategies in response to changing environmental feedback and requires organized search and the ability to use environmental feedback to change cognitive preparation and is one of the most common tests used to evaluate executive functions. This test has been used to measure flexibility. The computer task version uses 64 dissimilar cards. There are four sample cards at the top of the page which are different from each other in terms of shape (triangle, star, cross and circle), number of shapes (from one to four) and color of shapes (green, blue, red and yellow). There is also a 64-card deck at the bottom of the screen, with only the top card visible. Each card in this category has its own unique features according to the same three rules. In fact, each card represents a state that is not repeated. The participant must place the top card of the card deck in one of the sample cards based on the principle he guesses (by pressing the number written below the sample card on the keyboard) and discover the law of classification according to the right or wrong feedback obtained on the screen. After placing the cards correctly in a category, the law changes and the person must discover a new law based on the feedback. The two main indicators indicate the subject's performance, the number of classes obtained and the number of completion errors (when it is observed that the respondent continues to classify according to the previous principle despite the change of principle by the experimenter or when he classifies the cards on the basis of a false suspicion and insist on a false answer despite receiving false feedback (Rossi et al., 2000).

Emotion Dysregulation Scale

Developed by Gratz and Roemer (2004), this scale contains 36 items that measure the levels of impairment of a person's emotional regulation on a scale of five degrees from 1 (almost never) to 5 (almost always) in six subscales of not accepting negative emotions (6 items), difficulty in performing purposeful behaviors in times of helplessness (5 items), difficulty in controlling impulsive behaviors in times of helplessness (6 items), lack of emotional awareness (8 items), lack of emotional clarity (5 items) and limited access to effective emotion regulation strategies (6 items). The score of 11 on the scale item is calculated inversely. From the total score of the six subscales of the test, the total individual score is calculated for the difficulty of regulating emotion. The developers of the scale obtained its internal consistency with Cronbach's alpha as 0.93 and its reliability with retesting as 0.88 (Gratz & Roemer, 2004).

Behavioral Activation/Behavioral Inhibition Scale (BAS/BIS)

This scale was developed by Carver and White (1994) and has 24 items to measure the components of behavioral activation (13 items) and behavioral inhibition (7 items). Behavioral activation has three subscales of driver (4 items), reward response (5 items) and entertainment search (4 items). The answers to this questionnaire are based on a four-point Likert scale, from strongly agree (4) to strongly disagree (1). The 4 items of the scale have no effect on the scoring and have been added to the scale just to coordinate with the other items. Also, 2 items are scored in reverse. The internal stability of the behavioral inhibition component was 0.74 and the drivers' subscales, reward response, and entertainment search were reported to be 0.73, 0.76, and 0.66, respectively (Carver & White, 1994).

Procedure

After obtaining a written permission from the Department of Education and approval of the Research and Ethics Committee, with the letter number 5200/44061/5801, and after explaining the research and its objectives, the written consent of the candidates for participation was taken in research. Data were collected in two stages. In the first stage, after completing the BAS/BIS scale, the Bart Balloon Risk Assignment task was performed. Then, on the second day, first the Wisconsin cards were completed, then the emotion dysregulation scale was completed. Computer tests were installed on the laptop and performed individually in a separate room, and finally, the obtained data were analyzed using SPSS-22 software. At last, eight 80-minute emotion regulation sessions were taught in groups to thank the participants.

Results

Table 1 shows the Mean±SD age for each group. The results of the independent samples t-test indicate no significant difference between the two groups, in other words, the two groups were matched for this variable.

In order to compare executive function, emotion regulation and BAS/BIS across the two groups, the multivariate analysis of variance (MANOVA) was used. First, the MANOVA assumptions were examined; the results of the Levene's test for homogeneity of and the Kolmogorov-Smirnov test for normality of distributions respectively indicated the internal consistency and normality of distribution for the variables.

Table 1. Comparisons of Demographic Characteristics across Groups

	Self-injury (n = 50)	Control (n = 50)	Statistical Analyses
Age years (S.D)	15.70 (0.61)	15.90 (0.42)	$t_{(98)}$=1.91, P=0.060

Note: Values demonstrate mean scores (SD between brackets)

The results of the Box's M test [F (105, 21895.32) =0.99; P > .05] demonstrate the equality of covariance matrices for independent variables in the groups. Therefore, MANOVA test can be used. Table 2 presents the results of the Hotelling's Trace test. The multivariate Hotelling's Trace test indicated a significant difference between adolescents with NSSI and normal adolescents in dependent variables. In order to determine the differences, MANOVA was performed.

Table 2. Results of Hotelling's Trace test

Hotelling's Trace	F	df1	df Error	P	Eta
2.45	V	14	72	0.001	0.71

Table 3 presents the results of MANOVA for comparing two groups in executive function, emotion regulation and BAS/BIS. The findings presented in Table 3 indicate a significant difference between the two groups in components of executive function: number of categories, Number of errors, Number of balloons exploded, Average of unexploded balloons, Average of exploded balloons. In addition, there was a significant difference between the two groups in all subscales of emotion regulation except No acceptance of negative emotion. Compared to normal adolescents, adolescents with NSSI had a significantly higher mean score on BAS and BIS.

Table 3. Results of MANOVA for Comparison of variables between the two groups

Variable	Group	Mean (SD)	FDf (1-85)	P	Eta
Category WISC	Normal	5.63 (.58)	9.018	.004	.096
	NSSI	5.24 (.64)			
Error WISC	Normal	.78 (1.38)	18.616	.000	.180
	NSSI	1.98 (1.20)			
BART Total	Normal	90.51 (44.79)	107.924	.000	.559
	NSSI	71.13 (114.6)			
Number of Balloons Exploded	Normal	10.12 (1.03)	107.924	.000	.559
	NSSI	12.93 (3.62)			
Average of Unexploded Balloons	Normal	83.73 (6.75)	7.304	.008	.079
	NSSI	87.93 (7.64)			
Average of exploded balloons	Normal	33.05 (8.63)	5.838	.018	.064
	NSSI	37.72 (9.31)			
Emotion dysregulation					
No acceptance of negative emotion	Normal	14.68 (5.32)	.022	.882	.000
	NSSI	14.85 (4.96)			
Difficulties engaging goal-directed behaviors	Normal	15.17 (4.12)	41.515	.000	.328
	NSSI	20.11 (2.93)			
Difficulties controlling impulsive behaviors	Normal	17.00 (4.99)	27.174	.000	.242
	NSSI	22.52 (4.87)			
Lack of emotion awareness	Normal	19.63 (3.72)	16.838	.000	.165
	NSSI	23.07 (4.04)			
Lack of emotion clarity	Normal	12.68 (3.37)	10.324	.002	.108
	NSSI	15.17 (3.81)			
Limited access to effective emotion strategies	Normal	16.17 (3.71)	4.291	.041	.048
	NSSI	17.72 (3.25)			
BAS	Normal	36.44 (5.71)	25.516	.000	.231
	NSSI	42.85 (6.02)			
BIS	Normal	18.02 (4.99)	21.516	.000	.202
	NSSI	22.24 (3.40)			

Discussion

The results of the present study showed that the group of adolescents with NSSI in terms of executive functions, specifically in the executive functions of flexibility and high-risk decision-making are significantly different from the group of non NSSI adolescents and perform weaker than them. The results of this study are consistent with the findings of (Garreto et al., 2017). A key element in defining flexibility is the ability to change cognitive contexts to adapt with the environmental variable stimuli. People who are more cognitively flexible use alternative attention, positively reconstruct their frame of mind, accept challenging situations or stressful events, and are psychologically resilient. They are more tolerant of inflexible people (Burton et al., 2020). Research shows

that people with NSSI score lower on problem solving and flexibility than normal people. Deficiencies in problem-solving capacity may indicate low mental flexibility in people with self-injury. Numerous studies have emphasized the importance of the role of inhibition control in self-injury. Inhibition control is defined as the tendency to act prematurely without foresight (Dalley et al., 2011). The rate of inhibition during adolescence is lower than other periods of development due to the dominance of emotions, and this rate is lower in adolescents with NSSI than in normal adolescents (Allen & Hooley, 2015). Decision-making is one of the basic cognitive processes of human behavior, in which one chooses one of the leading options. This process is both complex and difficult because it has different consequences (Crawford et al., 2003). In high-risk decision-making, one usually chooses an option that has an immediate positive result but a negative long-term one (Appelt et al., 2011). In NSSI, the immediate result of self-injury may be temporary relief from existing tensions, but its long-term consequences are the emergence of suicidal ideation and suicide attempt (Siu, 2019), as well as the persistence of self-injury effects and symptoms on the body. It seems that one of the underpinnings of high-risk behaviors such as self-injury is the inability of a person to postpone rewards and pleasures related to the future. If these behaviors occur frequently, they may be accompanied by a sense of urgency and passion, the resulting pattern of behavior of which is similar to that of addiction (American Psychiatric Association, 2013), and therefore the acquisition of instant gratification may play a role in perpetuating their behavior.

The results of the present study showed that the group of adolescents with NSSI are significantly different from the group of non NSSI adolescents in terms of BAS/BIS. The results of this study are consistent with the findings of (Appelt et al., 2011). Behavioral activation system is associated with positive emotions such as hope and happiness and behavioral inhibition system is associated with negative emotions such as worry and anxiety and passive coping (Guan et al., 2012) and in terms of neuropsychological studies, the behavioral inhibition system in the brain includes the septohypocampus apparatus, and its monoenergetic afferent neurons extend from the brainstem and neocortical projection areas in the frontal lobe, providing motivational bases for behavioral inhibition that may lead to negative consequences, especially in irritating and new tissues (Gary & Naughtan, 2000). According to a study by Ying et al. (2016), adolescents who used self-injury as a way to manage their emotions had higher scores on the BIS, and those who used self-injury as a search engine had higher scores on the BAS. Since in the present study, behavioral inhibition scores were higher than behavioral activation in adolescents with NSSI, it can be explained that they use self-injury as a mechanism to deal with negative emotions such as anxiety and worry and in the face of their problems, they mostly use passive coping styles (Guerreiro, 2015). Regarding the role of behavioral activation and inhibition in self-injury, research results are contradictory, some of them have reported higher levels of behavioral activation (Jenkins et al., 2013) and others have reported higher levels of inhibition (Ying et al., 2016). In sum, BAS and BIS are not predictors of self-injury alone, but their interaction with each other has the ability to predict self-injury (Corr, 2016). The results of the present study showed that the group of adolescents with NSSI are significantly different from the group of non-NSSI adolescents in terms of emotion regulation and perform weaker than them. The results of this study are consistent with the findings of (Robinson et al., 2019). Studies have reported various functions for NSSI, such as relieving or reducing negative emotions, trying to feel anything even if it is painful, and trying to alleviate feelings of emptiness or numbness. NSSI helps adolescents with self-injuring behavior to regulate aroused emotions by converting passive pain into active but controllable pain (Franklin et al., 2010). Emotion regulation is an internal and external process that is goal-oriented and affects human thoughts, physiological system and behavior (Gross, 2008). Adolescents with NSSI are weaker than their peers with non-self-injury in components of emotion regulation such as emotional awareness, acceptance of emotions, expression of emotions, emotion regulation strategies and use more emotion-coping coping style.

Conclusion

NSSI is a heterogeneous behavior that may occur only once or be repeated chronically throughout life. Moreover, several components such as executive functions, behavioral activation and inhibition, emotion regulation, peer influence, media influence, etc. play a role in its occurrence and persistence. Considering the significant difference between adolescents with self-injury and adolescents without self-injury in the variables of brain executive functions, activation and behavioral inhibition and emotion regulation, the results of this study can be useful in prevention, education and treatment of adolescents with self-injuring behaviors and reduce the concerns of adolescents and their families.

Disclosure statement

The authors declare that they have no conflict of interest.

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