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The Moderating Role of Integrative Self-Regulation in the Relationship of Impulsivity and Suppression on HRV in CAD Patients

Abstract

The present study aimed to investigate the mediating role of self-regulation processes including integrative self-knowledge, mindfulness, and self-control in the relationship between Impulsivity and Suppression on heart rate variability in coronary artery disease patients. Eighty CAD patients were selected by convenience sampling from two heart clinics in Tehran. They responded to impulsivity, suppression, self-knowledge, mindfulness, and self-control scales. The heart rate variability was measured during responding to a stressor and resting time. The result showed that integrative self-regulation has a mediating role in the relationship between Impulsivity and Suppression and HRV. Higher impulsivity is associated with lower rates of HRV which represents poor heart function. Findings also showed that suppression without considering the mediating effect of the integrative self-regulation process is not associated with HRV values. While Suppression seems to be a more adaptive mechanism when accompanied by higher integrative self-regulation values, associating with higher HRV values indicates better heart function and psychological well-being.

Keywords: *Integrative Self-Regulation, Suppression, Impulsivity, Heart Rate Variability, Coronary Artery Disease.*

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Introduction

Heart rate variability (HRV) is a useful tool for examining the activity and balance of the sympathetic and parasympathetic nervous systems, which together make up the autonomic nervous system (ANS) of the peripheral nervous system (PNS). It measures the variation of time intervals between subsequent beat-to-beat heart rates. (Wang et al. 2022). HRV precisely reflects heart rate fluctuations at the time of physical and mental stress and measures the cardiac autonomic tone (Yilmaz et al., 2018). The close interconnection of the heart and brain was initially expressed by Claude Bernard more than 150 years ago (Thayer et al., 2012). Studies about HRV and cardiovascular diseases have suggested sufficient information about the link between the brain and heart, thus providing the opportunity to investigate the psycho-physiological characteristics of coronary artery disease patients. For instance, Salmoirago-Blother et al. (2019) suggested that psychological traits are associated with heart rate variability and risk of coronary heart disease. Another study suggested that hostility and long-term expression of negative feelings heighten the risk of cardiovascular disease (Bonnano et al, 2004). HRV variables provide valuable information about different medical and health conditions indicate autonomic activity and imbalance and predict the mortality and morbidity of cardiovascular events such as ventricular arrhythmia and sudden cardiac death. Therefore, it has gained great attention as a foreground and biomarker of health conditions in many recent studies (Yilmaz et al., 2018; Reed et al, 2020). In addition to being linked to several medical disorders including cancer, heart disease, and neurological disorders, HRV indexes have been linked to numerous psychopathological disorders like anxiety and depression. (Wang, 2022). Studies have emphasized that HRV analysis has a major potential to throw light on the role of individual differences in self-regulation in regard to their interconnection with HRV as an intersection of heart, brain, and psychological functions (Cattaneo et al, 2021; Heiss et al, 2021). While the relationship between coronary heart disease and psychopathological diagnostics such as depression and anxiety has been indicated by numerous studies, the role of underlying psychological processes and traits has remained poorly explored (Elise et al., 2020). However, a series of studies have explored the association of heart rate variability as a marker of medical conditions with psychological traits such as trait anxiety and trait impulsivity (Beauchaine & Thayer, 2015), trait emotional competencies (Elise et al., 2020), trait hostility and optimism (Salmoirago-Blotcher et al., 2020), further investigation about the association of psychological traits and characteristics with heart rate variability as a biomarker of coronary artery disease is needed. Addressing this gap, the present study explored whether HRV is associated with impulsivity and suppression in coronary artery disease patients. Moreover, we tested the hypothesis that the association between HRV and impulsivity and suppression is moderated by components of integrative self-regulation which are mindfulness, self-knowledge, and self-control (Ghorbani et al., 2010). More specifically, we explored this hypothesis that self-regulatory capacities and HRV values are involved with the suppression of thoughts, emotions, and behavior as well as impulsivity. Impulsivity is considered premature, risky, and not thoughtful behavior. Lack of attention and a poor reflection on consequences are characteristics of dysfunctional impulsivity (Crew et al., 2009). Studies have shown that impulsivity increases the risk of cardiovascular disease and is associated with lower HRV which indicates a less flexible ANS (Holmes et al., 2006). We expected impulsivity to be adversely associated with HRV and self-regulatory capacities (Xing & Wang, 2020), while their correlation with suppression is controversial based on previous studies and there is a need for further studies on the role of suppression in heart disease. Gross and Levenson (1993) described suppression as a form of emotion regulation that consciously inhibits the behavior in response to emotional arousal. Their studies indicated that suppression causes mixed somatic reactions, on the

On one hand, it decreases somatic activity and heart rate which is related to PNS, on the other hand, it activates the sympathetic nervous system. Bonanno et al (2004) suggested that both suppression and expression of emotional and internal experiences are at times beneficial for adaptation as well as harmful on other occasions. Hence, the expressive flexibility theory suggests that this is the flexibility of combining expressive enhancement and suppression abilities that predicts higher adaptive functioning.

Geisler et al. (2010) discussed that emotion regulation has a mediating role in the impact of heart rate variability on overall well-being and heart rate variability is an index of self-regulatory strength. Self-regulatory strength is the ability to control one's thoughts, emotions, and responses (Baumeister & Heatherton, 1996). Emotion regulation is the ability to adjust physiological arousal moment by moment (Gross, 1998). We require a flexible autonomic nervous system (ANS), which is composed of the excitatory sympathetic nervous system (SNS) and the inhibitory parasympathetic nervous system (PNS), to be able to modify stress-driven arousal on a moment-by-moment basis. When they are physiologically aroused, they engage antagonistically. Exposure to physical or psychological stress activates SNS dominantly to provide adaptation to physiological arousal. It leads to a rise in heart rate which is characteristic of the state of arousal. While stability and safety activate PNS dominantly to lower physiological arousal and heart rate. The healthier a person is, the more flexible the ANS reacts, and easily and rapidly transits between high and low arousal states, resulting in rapid variation in heart rate frequency on a time domain (Appelhans et al., 2006). A series of studies have shown higher HRV values represent higher self-regulation abilities (Aritzeta et al., 2022). We can better understand the relationship between values of HRV and self-regulation capacity by referring to the Polyvagal Theory by Porges (2007) which explains the relationship between the emotional experience and the vagus nerve.

The tenth cranial nerve, the vagus nerve, plays the main role in the parasympathetic activity that is involved with self-regulation (Aritzeta, 2022). When we are in a safe and tranquil mode, the ventral vagal activation influences myelinated vagal channels that reduce the frequency of heartbeats, thereby increasing HRV. This stops the sympathetic nervous system and fight-or-flight mechanisms. Hence, It provides the chance for the prefrontal cortex to work better in regard to attention, self-regulation, and impulse control (Grob, 2021). HRV is considered to be a biomarker for psychopathology. Research has suggested that higher HRV levels are associated with lower levels of frustration and better cognitive and emotional performance and adjustment as well as better empathetic responses to other people. Meanwhile, suppressing the vagal brake results in reduced parasympathetic influence thereby increasing cardiovascular pace and reducing HRV and resulting in feelings of anxiety, tension, and malaise in the subject. lower HRV is associated with lower prefrontal activity which is in charge of cognitive function and self-regulation (Aritzeta, 2022). Thus, HRV reflects the activity of the vagus nerve and parasympathetic nervous system (PNS) which is a part of the autonomic nervous system (ANS) and higher HRV values reflect higher dynamic ANS which result in better autonomic self-regulation and overall health (Christodoulou et al. 2020). In exposure to stress and tension, the sympathetic system is activated and the parasympathetic system is responsible to bring back and maintain tranquility (Rostami et al., 2018). Stress is associated with an increase in the release of adrenaline which leads to sympathetic nervous system hyperactivity and a rise in heartbeats and blood pressure (Holmes et al 2006). In a healthy condition, the parasympathetic system restores the balance by self-regulation processes (Vohs, 2004). Researches indicate that there is a correlation between inhibitory and mediating parasympathetic systems with self-regulatory processes. Therefore, HRV reflects self-regulation abilities (Segerstrom, 2007). As far as parasympathetic functioning at the time of experiencing stress and anxiety plays an important role in regulating the psycho-physiological responses, numerous studies have utilized HRV in developing research on self-regulation, emotional coping mechanisms, adaptive functioning, interpersonal processes, and personality studies. HRV variables reflect self-regulatory capacity (Smith, 2020). Many studies demonstrated that high-frequency heart rate variability correlates with many constructive social adaptations such as higher empathy for those who are in discomfort, social capabilities, more satisfying interpersonal relationships, more secure attachment styles complaisant temperament, and higher functionality (Beauchaine & Thayer, 2015). A series of studies have shown higher HRV values represent higher self-regulation abilities (Aritzeta et al., 2022), better cognitive performance, higher adaptive functioning with stress, and better impulse control (Segerstrom, 2007). Inhibiting impulses requires a higher capacity for self-regulation (Segerstrom, 2007). Research shows that Trait impulsivity is the result of disruption in the top-down inhibitory control of the prefrontal cortex (PFC) over subcortical circuits (Beauchaine & Thayer, 2015). The parasympathetic nervous system is involved with prefrontal inhibitory pathways (e.g., Barbas et al., 2003; Ter Horst and Postema, 1997; Wong et al., 2007). The prefrontal cortex has an important role in reducing impulsivity. The prefrontal, insula and cingulate cortices create a neural pathway that shows reciprocal top-down and down-top connections with the amygdala. when this network activates the central nucleus of the amygdala it leads to inhibition of the nucleus solitary tract followed by inhibition of vagal motor neurons in the dorsal motor nucleus and nucleus ambiguus. The parasympathetic nervous system plays a complementary role in the inhibition circuit to the sinoatrial node. This is associated with higher function of PFC and higher heart rate variability (Thayer et al., 2009). Therefore, values of HRV correlate with poor or high executive control (Beauchaine & Thayer, 2015).

Self-regulation is discussed in three dimensions including emotional, cognitive, and behavioral (Hoffmann, 2012). Geisler et al. (2010) discussed that emotion regulation has a mediating role in the impact of heart rate variability on overall well-being and heart rate variability is an index of self-regulatory strength. self-regulatory strength is the ability to control one's thoughts, emotions, and responses (Baumeister & Heatherton, 1996)

Integrative self-regulation consists of mindfulness, self-knowledge, and self-control (Ghorbani, 2010). Mindfulness is the present-oriented state of being and a mode of awareness that derives from intentional attention to current occurring experiences with kindness and openness (Shapiro & Carlson, 2009). Mindfulness increases self-regulatory capacity by diffused attention and consciousness of thoughts and emotions (Christodoulou et al. 2020). Based on experimental studies, mindfulness-based exercises activate the parasympathetic system reduce reactivity to stress, and promote health (Greeson, 2008). Suess et al., (1994) suggested that higher HRV is associated with a higher ability to sustain attention. HRV values are also positively correlated with emotional awareness (Verkuil, 2016). Conversely, studies show a favorable correlation between increased mindfulness and increased levels of self-control, self-management, and self-monitoring abilities. (Osman et al, 2016). For further elaboration, we can refer to Carver and Scheier's (1981) control theory which suggests that attention plays a key role in controlling processes that underlie regulatory capacities. In other words, attention is a key component of reestablishing and regulating a dysregulated system that communicates and connects somatic functions to cognitive and psychological functions (Carver & Scheier, 1981).

Self-determination theory (SDT; Deci & Ryan, 1980) discusses the role of awareness and attention in enhancing well-being. SDT posits that open and conscious awareness provides access to choices that are more congruent with one's self, needs, values, and interests, while autonomic processes and mechanisms are more disconnected from values on a higher level of awareness. Therefore, the process of mindfulness and self-knowledge facilitates a more conscious self-regulatory functioning that supports well-being (Brown & Ryan, 2003). HRV is a physiological marker of inhibitory capacity which is an important factor in self-regulation and indicates self-control ability (Geisler & Kubiak, 2009).

Linear Heart Rate Variability Analysis

HRV parameters indicate linear parameters in time and frequency domains and nonlinear information about symbolic dynamics and compression entropy. Sympathetic and parasympathetic activities can be extracted by these parameters (wang et al. 2022). From almost 70 metrics which are extracted from HRV analysis only a few have been associated with PNS (Christodoulou et al. 2020). The variations in heart rate are analyzed in two methods including Linear methods and non-linear methods. In the present study, we used linear methods to analyze our collected data. Linear methods consist of two methods which are time-domain methods and frequency-domain methods.

1. **Time-domain Method**

Time domains are suitable for analyzing short-term recordings and include some variables such as SDNN (ms), SDANN (ms), RMSSD (ms), and HRV training. index which are used in the present study and are introduced in Table 1.

Table 1. Normal values of common time-domain HRV indexes in 24-h recordings (Yilmaz et al., 2018, and Shaffer & Ginsberg, 2017)

Time	**Explanation**	**Normal**
SDNN (ms)	The parasympathetic portion of autonomic function is shown by the standard deviation of all regular RR intervals throughout a 24-hour ECG recording. A drop in SDNN is linked to a decrease in vagal activity and an increase in sympathetic activity of the sinus node.	141±39
SDANN (ms)	The standard deviation of the average normal-to-normal (NN) intervals for usually 5 minutes as an estimator of the fluctuation in heart rate due to cycles longer than 5 minutes	127±35
RMSSD (ms)	The root mean square of successive differences between normal heartbeats, an important indicator of parasympathetic activity	27±12

Triangular Index (HTI)	A geometric measure calculating the number of total NN intervals/ number of NN intervals in the modal bin	37±15

2. Frequency-Domain Method

Frequency domains analyze heart rate signals based on their frequency and intensity and include calculating four main components which are very low frequency (VLF), ultra-low frequency (ULF), low frequency (LF), and high frequency (HF), described in table 2. (Yilmaz et al 2018). Min RR (ms) and Max RR (ms) are also calculated. HRV can be measured during tonic or resting periods in a 24-hour long-term period (figure 1) or a 2-5-minute short-term period. Data collected in the present study indicate short-term period recordings. While LF and LF/HF parameters are associated with the Sympathetic nervous system as well as the parasympathetic nervous system, RMSSD, HF, and SDNN are associated with PNS (wang et al. 2022). Researchers have emphasized the role of the parasympathetic nervous system in mediating Heart rate variability in its relationship with emotion regulation (Appelhans et al., 2006). In the present study, we analyzed ULF values as an indicator of parasympathetic activities.

Beauchaine and Thayer (2015) also discussed that the high frequency (HF) index could be considered a diagnostic tool, reflecting self-regulation and cognitive control as well as internalizing and externalizing psychopathological symptoms.

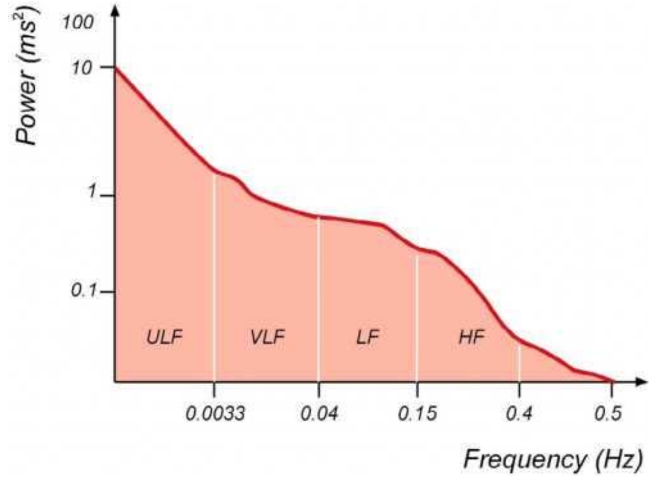

Figure 1. Frequency domains example of a 24-h Holter recording (Yilmaz et al., 2018)

Table 2. Normal values of frequency-domain HRV indexes in short term recordings (Yilmaz et al., 2018, and Shaffer & Ginsberg, 2017

Variable (Unit)	Explanation	Normal Rage
ULF (ms^2)	comprises the frequency components that are below 0.0033 Hz; its nature is still unknown.	
VLF (ms^2)	The average normal-to-normal (NN) intervals' standard deviation for every five minutes. believed to have evolved from vasomotor activity, hormonal regulation, and heat.	627±215
LF (ms^2)	comprises a range of frequencies from 0.04 Hz to 0.15 Hz and is made up of a blend of parasympathetic and sympathetic actions.	1170±416
HF (ms^2)	Includes the frequency range between 0.16 Hz and 0.4 Hz. Reflects the parasympathetic activity of ANS and that is one of the main determinants of respiratory sinus arrhythmia.	975±203
LF/HF ratio (ms^2)	Reflects the sympathovagal balance. Increased LF/HF ratio reflect decreased vagal activation	1.5-2.0

Method

Participants

A quasi-experimental and nonrandomized study was performed. This study used non-probability and convenience sampling. The participants (n = 80) were patients with coronary artery disease who were recruited through referrals from a cardiologist at a heart clinic in Tehran. The inclusion criteria were diagnosis and treatment for cardiovascular disease within the last two years that were consuming beta-blocker medicine for at least the past three months before they participated in the study, with the age range of 40-65 years, and the ability to read and write in Farsi. Exclusion criteria were coronary artery disease patients who were above 65 or under 40 years old, could not read and write, had cardiac arrhythmia, and had not started consuming medicine due to resulting in different ANS activity base-line between patients who are under medication with beta-blocker medicines with those who are not. The clinic ethics committee approved the study and informed consent was obtained from all subjects involved in the study. emotions in participants. This twenty-eight-item questionnaire is based on the Self-Determination Theory and uses a Likert scale to predict how people cope with stress (Kim et al, 2002).

The Integrative Self-Knowledge Scale (ISK), (Ghorbani et al, 2008) is a twelve-item and Likert-scale self-report scale. Cross-cultural investigations among Iranians and Americans have shown the proper validity and reliability of this instrument. This instrument has integrated the Reflective Self-Knowledge Scale to investigate efforts of reflecting on past experiences with the Experiential Self Knowledge Scale that focuses on understanding the present and ongoing experience (Ghorbani et al, 2008).

The Mindful Attention Awareness Scale (MAAS) consists of 15 items with a Likert scale that assesses the mindfulness characteristic of individuals and indicates a receptive state of mind in which attention is focused on and observes the occurring experience in the present moment (Brown & Ryan, 2003). Psychometric research has indicated that this Short version of the MAAS is a reliable instrument for investigating the characteristics of mindfulness among individuals (Osman et al, 2016).

The *self-control scale* used in the study is the short version, thirteen-item, and Likert-scale questionnaire with proper liability and reliability (Tangney et al, 2004). Studies conducted on Iranian society showed a proper measure of Cronbach's alpha for this scale (Sarafraz et al, 2013)

The heart rate variability was measured for about 5 minutes while resting and during responding to a stressor. The Norav Medical HRV Holter, a precise and non-invasive device that detects HRV in real time using seven sensors put on the neck and chest, was utilized in this investigation. The tools and supplies used are discussed in the sections that follow.

Ad hoc recording sheet: Data collected from every patient during the intervention was entered into a special document. Version 4.2.0, Norav Medical software was selected for this study. Using a mathematical algorithm, Version 4.2.0, Norav Medical software transformed the collected data (e.g., RMSSD, SDNN...) to numeric measures which were analyzed by SPSS 22.0.

Results

Statistical analyses were performed using SPSS 22.0 software. The frequencies, percentages, means, and standard deviations of the variants were calculated and regression analysis was performed.

Results of the regression analysis of the variables showed that VLF (Beta=-549/0, p=004/0), HF (Beta=-473/0, p=007/0), and MinRR (Beta=-31/0) predict impulsivity (R2=36/0, p=002/0). None of the HRV variables predict suppression (R2=082/0, p=65/0). While suppression was not associated with HRV, impulsivity was inversely associated with HRV.

Integrative Self-Knowledge (ISK) (Beta=-279/0, p=007/0) and mindfulness (Beta=-404/0, p=001/0) predict impulsivity (R2=48/0, p=001/0), meaning that ISK and mindfulness adversely predict impulsivity.

Self-control (Beta=-395/0, p=025/0) showed a detrimental mediation function in the connection between impulsivity and HRV. ISK (Beta=268/0, p=046/0) showed a detrimental mediation function in the connection between suppression and HRV in the present sample of coronary artery disease patients.

Table3- correlations of HRV indexes with impulsivity, suppression and integrative self regulation variables

Varibales	ULF	VLF	LF	HF	Min RR	Impulsivity	Suppression	ISK	self-control	mindfulness
ULF	1									
VLF	0.463**	1								
LF	-0.331*	-0.082	1							
HF	-0.471**	-0.640**	0.184	1						
Min RR	0.256	0.339**	-0.155	-0.443**	1					
Impulsivity	-0.234	-0.217	0.229	0.140	-0.301*	1				
Suppression	0.064	0.142	-0.138	0.040	-0.70	-0.070	1			
ISK	0.029	0.156	-0.303*	-0.098	0..202	-0.526**	-0.023	1		
Self-control	-0.310*	-0.280*	0.254*	0.104	-0.276*	0.466**	-0.026	-0.415**	1	
Mindfulness	0.122	0.154	61	-0.131	0.183	-0.595**	-0.157	0.414**	-0.390**	1

Results (Table 3) support our primary hypothesis that integrative self-regulation has a mediating role in the relationship between impulsivity and suppression of heart rate variability.

Discussion

This study aimed to investigate the moderating role of integrative self-regulation in the relationship of suppression and impulsivity with the heart rate variability of coronary artery disease patients in exposure to induced stress. The results of the study showed a detrimental mediation function in the connection between impulsivity and HRV. Higher values of self-control are associated with lower impulsivity and higher HRV, therefore higher overall health. It probably shows that sufficient capacity of self-control which reduces impulsivity and increases HRV indicates a more adaptive parasympathetic nervous system activity. Therefore, the result of the present study is aligned with previous studies in reflecting the positive correlation between self regulation and HRV and the negative correlation between impulsivity and HRV in relation to cardiovascular disease (Van den Berk Clark, 2021; Riganello et al, 2023).

While impulsivity is negatively associated with mindfulness and integrative self-knowledge as well as HRV variables, suppression is not associated with HRV unless we include the mediating role of integrative self-regulation variables in its analysis, considering that integrative self-knowledge shows a positive mediating role in the relationship of suppression and HRV values. Findings on suppression are controversial. While suppression could be adaptive at times, it may harm overall health if used chronically (Bonanno et all, 2004) and can be associated with heightened activation of the sympathetic nervous system (Gross, 1998). The expressive flexibility theory is consistent with the results of this investigation suggesting that this is the flexibility of combining expressive enhancement and suppression abilities that predicts higher adaptive functioning (Bonnano et all, 2004). Based on the results of the present study, Suppression alone did not show any correlations with HRV unless analyzed with the inclusion of the mediating role of Integrative self-regulation components. Therefore, suppression seems to be a more adaptive mechanism when accompanied by higher integrative self-regulation values, associated with higher HRV values which indicate better heart function and psychological well-being. Otherwise, based on other studies excessive, long-time, and chronic habits of suppression of thought and emotions may result in chronic activation of the autonomic nervous system (Saeedi et al, 2022). It seems that the association between suppression and HRV is yet to be fully explored by further studies.

Conclusion

In summary, this study illuminates the intricate relationship between impulsivity, suppression, and heart rate variability (HRV) in coronary artery disease patients, with a focus on the mediating role of integrative self-regulation processes. Higher impulsivity is associated with lower HRV, reflecting compromised heart function. Notably, suppression, when coupled with elevated integrative self-regulation, demonstrates a more adaptive mechanism linked to higher HRV and improved psychological well-being. The findings underscore the importance of considering self-regulation factors in understanding the impact of impulsivity and suppression on cardiovascular health. While suppression alone does not exhibit a direct correlation with HRV, its nuanced association necessitates further exploration in future studies. This research contributes to the growing body of evidence highlighting the positive correlation between self-regulation and HRV, emphasizing the interplay between psychological processes and cardiovascular well-being in coronary artery disease patients.

Ethical Statement

Informed consent was obtained from all subjects involved in the study, demonstrating a commitment to ethical research practices. Participants were informed about the study's purpose, procedures, and potential risks, and voluntarily agreed to take part. They were told that they can withdraw from the experiment at any time.

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Conflicts of Interest

The authors declare no conflict of interest.

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