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ORIGINAL RESEARCH

The Impact of Executive Dysfunction on Anxiety in Hearing-Impaired College Students: Smartphone Addiction as a Mediator and Academic Procrastination as a Moderator

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Purpose: Hearing-impaired college students often rely on smartphones for information exchange and social interaction due to their hearing limitations, which may increase their risk of smartphone addiction. This study aims to explore the impact of executive dysfunction on anxiety levels in hearing-impaired college students, investigating smartphone addiction as a mediator and academic procrastination as a moderator.

Methods: We conducted a questionnaire survey using the Executive Function Scale, the Anxiety Scale, the Smartphone Addiction Scale, and the Academic Procrastination Scale. The survey included 609 hearing-impaired college students from three universities in Jiangsu, Hunan, and Heilongjiang Provinces, China.

Results: After controlling for age, executive dysfunction was found to significantly predict higher anxiety levels in hearing-impaired college students. Additionally, smartphone addiction partially mediated the relationship between executive dysfunction and anxiety. Academic procrastination further moderated the relationship between smartphone addiction and anxiety.

Conclusion: This study enhances the understanding of the complex interactions between executive dysfunction, smartphone addiction, and academic procrastination in contributing to anxiety among hearing-impaired college students. The findings offer valuable insights for developing strategies to promote the mental health of this population.

Keywords: hearing-impaired, college students, mental health, executive dysfunction

Introduction

With the development of inclusive education, opportunities for hearing-impaired university students to receive higher education in China are gradually increasing. However, these students face many difficulties and challenges due to their hearing impairments. It has been suggested that hearing impairments lead to abnormal neural development and connectivity, adversely affecting executive functions.[1,2] For these students, smartphones are not only tools for communication but also essential for social integration and information acquisition. However, excessive reliance on smartphones can exacerbate cognitive and emotional problems, leading to academic procrastination. Academic procrastination, in turn, is associated with anxiety, and higher levels of procrastination may increase academic stress, thereby triggering anxiety.[3] Therefore, it is necessary to explore the correlation between executive dysfunction and anxiety among hearing-impaired college students. This study aims to enhance understanding of the psychological mechanisms affecting this group and provide theoretical support for the prevention and intervention of anxiety.

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The Impact of Executive Dysfunction on Anxiety in Hearing-Impaired College Students

Executive function is a high-level cognitive ability that includes planning, organizing, controlling, and regulating actions required to complete complex tasks. It consists of three core components: inhibitory control, working memory, and cognitive flexibility.[4,5] Research has shown that college students with hearing impairments often exhibit significant deficits in working memory, including verbal memory span and verbal working memory capacity, which are related to executive function.[6] These students often struggle with understanding verbal instructions, processing information, and mastering social norms when completing tasks and making plans. Similar to their normal-hearing peers, hearing-impaired college students are at a critical stage in their lives, facing various academic, professional, and social challenges. However, due to their special communication and learning needs, they may require additional care and support. Anxiety refers to the subjective unpleasant feelings individuals experience in response to stimuli or events, often accompanied by hyperactivity of the autonomic nervous system.[7] Anxiety is increasingly common among college students, threatening their academic and personal lives.[8] Hearing is crucial for communication and information acquisition.[9] However, individuals with hearing impairments may spend more time and energy understanding and processing information due to executive dysfunction. This can lead to missing important information, ultimately affecting academic performance.[10] Persistent difficulties and frustration can undermine self-confidence, leading to feelings of helplessness, depression, psychological stress, and anxiety.[11] Based on this discussion, this study proposes Hypothesis 1 (H1): Executive dysfunction significantly predicts anxiety in hearing-impaired college students.

The Mediating Effect of Smartphone Addiction Between Executive Dysfunction and Anxiety in Hearing-Impaired College Students

Smartphone addiction is a type of behavioral addiction characterized by uncontrolled smartphone use, leading to physiological, psychological, and social problems, including withdrawal, tolerance and other symptoms.[12] Studies have found that excessive smartphone use negatively affects college students' academic and social functions.[13,14] Moreover, smartphone addiction is susceptible to executive dysfunction.[15] Hearing-impaired college students often face language and communication barriers, causing psychological stress and anxiety. Therefore, it is necessary to further investigate the underlying mechanisms between executive dysfunction, smartphone addiction, and anxiety. Self-regulation theory suggests that ineffective self-regulatory mechanisms may lead individuals to develop undesirable behaviors or habits.[16] Hearing-impaired college students often turn to smartphones for comfort and to escape reality when unable to resolve academic and life difficulties. Smartphone addiction becomes a way to pursue short-term pleasure and relieve anxiety rather than achieving long-term goals. However, excessive smartphone use can distance hearing-impaired students from the real world, forming a vicious cycle. Recent studies suggest that smartphone addiction may be associated with Executive dysfunction and anxiety.[17,18] For hearing-impaired students, communication difficulties may increase their dependence on smartphones, leading to addiction and heightened anxiety. Thus, this study proposes Hypothesis 2 (H2): Executive dysfunction in hearing-impaired college students predicts anxiety significantly through the mediating effect of smartphone addiction.

The Moderating Effect of Academic Procrastination Between Smartphone Addiction and Anxiety in Hearing-Impaired College Students

Academic procrastination is the intentional delay in starting or completing academic tasks.[19,20] It is an avoidant behavior often accompanied by negative emotions such as anxiety. Over time, such behaviors can harm physical and mental health.[21,22] Previous studies have shown that academic procrastination is associated with both smartphone addiction and anxiety.[23–25] For hearing-impaired college students, academic procrastination may moderate the relationship between smartphone addiction and anxiety. Specifically, smartphone addiction may have different effects on anxiety at varying levels of academic procrastination. The correlation between smartphone addiction and anxiety is more pronounced in students with higher academic procrastination. These students might overuse smartphones to escape academic pressures, leading to increased anxiety and negatively[3] impacting academic performance. In contrast, students with lower academic

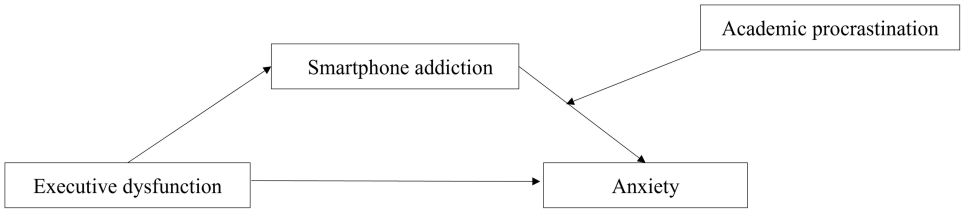

Figure 1 The proposed moderated mediation model.

procrastination tend to plan their smartphone use rationally, improving study efficiency and reducing the risk of addiction and anxiety. Therefore, this study proposes Hypothesis 3 (H3): Smartphone addiction in hearing-impaired college students significantly predicts anxiety through the moderating effect of academic procrastination.

The Present Study

This study aims to investigate the underlying mechanisms between executive dysfunction and anxiety in Chinese hearing-impaired college students. A moderated mediation model was developed to address the following questions: (1) Does smartphone addiction mediate the relationship between executive dysfunction and anxiety? (2) Does academic procrastination moderate the association between smartphone addiction and anxiety? (Figure 1).

Materials and Methods

Participants

A total of 680 questionnaires were distributed across three universities in Jiangsu, Hunan, and Heilongjiang provinces (China). After excluding invalid questionnaires due to missing or regular answers, 609 valid questionnaires were collected, resulting in an effective recovery rate of 89.56%. The sample included 306 male (50.2%) and 303 female (49.8%), aged 18–24 years, with a mean age of 21.19 years (SD = 1.57 years). It is generally accepted that the ratio of subjects to the number of items should be no less than 5:1, with 10:1 being more appropriate.[26–28] Based on these considerations, we decided to recruit 680 participants to ensure an appropriate sample size. Table 1 presents the demographic information.

Table 1 Demographic Information

Variables	Categories	Number	Percentage
Gender	Male	306	50.20%
	Female	303	49.80%
Place of Residence	Urban	150	24.60%
	Rural	459	75.40%
Sibling	Yes	130	21.30%
	No	479	78.70%
Degree of Hearing Loss	Level 1(>90 dB)	486	79.80%
	Level 2(81–90 dB)	86	14.10%
	Level 3(61–80 dB)	28	4.60%
	Level 4(41–60 dB)	9	1.50%
Cause of Disability	Congenital	307	50.40%
	Acquired	302	49.60%

Informed consent was obtained from the university administrators and the students before administering the questionnaire. All participants had a certificate of hearing disability from the China Disabled Persons' Federation (CDPF), ensuring the study focused on the hearing-impaired college student population. Given the special challenges that hearing-impaired college students may have in language comprehension, a pre-test was conducted with about 10 students from each college. Feedback confirmed that the questionnaire was understandable. During the official survey, a class-based group administration method was used, with detailed explanations of the survey's purpose and process provided. Participants were assured of their rights to anonymity and withdrawal at any time. Each student received a gift as a token of appreciation. This study complies with the Declaration of Helsinki and was approved by the Science and Technology Ethics Committee of Nanjing Normal University of Special Education (Ethics approval number: NJTS20240112001).

Research Tools

The Adult Executive Functioning Inventory

The Adult Executive Functioning Inventory (ADEXI), developed by Holst and Thorell in 2018, was used to assess executive dysfunction.[29] It consisted of 14 items and two dimensions: working memory and inhibition. Participants rated their responses on a 5-point Likert scale ranging from 1 = *definitely not true* to 5 = *definitely true*. Higher scores indicated more severe executive dysfunction. This questionnaire is well-suited for vulnerable groups in China.[30] In this study, the Cronbach's α coefficient was 0.93.

Generalized Anxiety Disorder-7

The Generalized Anxiety Disorder-7 (GAD-7) scale, which includes 7 items describing typical symptoms of generalized anxiety, was employed.[31] Participants reported the frequency of these symptoms over the past two weeks on a 4-point Likert scale ranging from 0 = *not at all* to 3 = *almost daily*. Higher scores indicated more severe anxiety symptoms. This scale has been widely used among Chinese college students, demonstrating high reliability.[32] The internal consistency of this scale was 0.94.

Smartphone Addiction Scale

The Smartphone Addiction Scale, developed by Kwon et al in 2013, was used to measure aspects such as excessive smartphone use and daily distractions.[33] It consists of 10 items rated on a 6-point scale ranging from 1 = *strongly disagree* to 6 = *strongly agree*. A higher score represented a stronger tendency towards smartphone dependence. This scale has been validated for use among Chinese college students.[34] The Internal consistency of our sample was 0.92.

Academic Procrastination Scale - Short Form

Academic Procrastination Scale - Short Form (APS-SF) was used to measure the severity of academic procrastination among hearing-impaired college students.[35] It consisted of 5 items rated on a 5-point Likert scale ranging from 1 = *disagree* to 5 = *agree*. Higher scores indicate more serious academic procrastination. The scale is appropriate for Chinese students.[36] The Cronbach's α coefficient of the scale in this study was 0.80.

Statistical Analysis

All statistical analyses were performed using SPSS 26.0 and Process 3.3. SPSS 26.0 was used for data entry, collection, descriptive statistical analysis, and correlation analysis. After calculating bivariate correlations, Hayes' PROCESS macro Model 4 was used to test the mediating role of smartphone addiction between executive dysfunction and anxiety.[37] The moderating effect of academic procrastination on the second path of the mediation process was explored using Hayes' PROCESS macro Model 14.[37] Before applying Models 4 and 14, standardized scores of all variables (except for the dummy variable, gender) were computed, along with interaction terms calculated from the standardized scores. Bootstrapping was used to test confidence intervals, with a 95% confidence interval (CI) calculated through 5000 repeated samples.[37]

Results

Common Method Deviation

Self-reported data may result in common method deviation. To control for this, participants completed the survey anonymously. Harman's single-factor test was also used to check for common method deviation.[38] Principal component factor analysis revealed five factors with eigenvalues greater than 1. The cumulative variance explained by the first factor was less than 40%, indicating no serious common method deviation in this study.

Descriptive Statistics and Related Analysis for Each Variable

Table 2 showed positive correlations between executive dysfunction, anxiety, smartphone addiction, and academic procrastination among hearing-impaired college students. Age, smartphone addiction, and academic procrastination were also significantly correlated and were included as control variables in subsequent model analyses.

Mediating Effect Analyses

To examine the mediating effect of smartphone addiction between executive dysfunction and anxiety, we used Model 4 in PROCESS, controlling for age.[37] The results are presented in Table 3. The first step showed that executive dysfunction significantly predicted smartphone addiction ($\beta = 0.58$, $p < 0.001$). The second step showed that executive dysfunction was significantly associated with anxiety ($\beta = 0.35$, $p < 0.001$). The third step indicated that smartphone addiction significantly predicted anxiety ($\beta = 0.13$, $p < 0.01$). Executive dysfunction remained a significant predictor of anxiety ($\beta = 0.27$, $p < 0.001$). These findings suggest that smartphone addiction partially mediates the relationship between executive

Table 2 Descriptive Statistics and Correlation Coefficients (N = 609)

Variable	*M*	*SD*	1	2	3	4	5
1. Age	21.19	1.57	1				
2. ED	43.43	9.62	0.04	1			
3. Anxiety	13.84	5.45	0.04	0.35**	1		
4. SA	38.70	9.04	0.09*	0.58**	0.29**	1	
5. AP	14.89	3.80	0.08*	0.59**	0.28**	0.42**	1

Notes: *$p < 0.05$; **$p < 0.01$.
Abbreviations: ED, Executive Dysfunction; SA, Smartphone Addiction; AP, Academic Procrastination; *M*, mean value; *SD*, standard deviation.

Table 3 Mediating Effects Analyses (N = 609)

Dependent variable	Independent variable	R^2	*F*	β	*SE*	t
SA	Age	0.35	159.52***	0.04	0.02	1.96
	ED			0.58	0.03	17.67***
Anxiety	Age	0.12	42.63***	0.02	0.02	0.65
	ED			0.35	0.04	9.18***
Anxiety	Age	0.14	31.52***	0.01	0.02	0.43
	ED			0.27	0.05	5.83***
	SA			0.13	0.05	2.87**

Note: ***$p < 0.001$.
Abbreviations: ED, Executive Dysfunction; SA, Smartphone Addiction.

Table 4 Mediation Model Tests with Moderation (N = 609)

Dependent Variable	Independent Variable	R^2	*F*	*β*	*SE*	*t*
Anxiety	Age	0.15	21.04***	0.01	0.02	0.21
	ED			0.20	0.05	3.84***
	SA			0.14	0.05	2.99**
	AP			0.09	0.05	2.00*
	SA×AP			0.06	0.03	2.20*

Notes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
Abbreviations: ED, Executive Dysfunction; SA, Smartphone Addiction; AP, Academic Procrastination.

dysfunction and anxiety. The indirect effect was further tested using the bias-corrected percentile Bootstrap method, yielding a mediated effect value of 0.08, *SE* = 0.03, 95% CI [0.02, 0.14], accounting for 22.38% of the total effect.

Moderated Mediation Model Tests

To examine the moderating effect of academic procrastination on the relationship between smartphone addiction and anxiety, we used Model 14 in PROCESS, controlling for age.[37] The results were shown in Table 4. The interaction term of smartphone addiction and academic procrastination significantly predicted anxiety ($\beta = 0.06$, $p < 0.05$). Thus, the second path of the mediation model was moderated by academic procrastination.

To analyze the moderating effect of academic procrastination on the relationship between smartphone addiction and anxiety, subjects were divided into two groups based on their academic procrastination scores: high academic procrastination (M + 1SD) and low academic procrastination (M - 1SD). The predictive effect of smartphone addiction on anxiety was then examined in each group. As shown in Figure 2, smartphone addiction significantly predicted anxiety among hearing-impaired college students with high academic procrastination (βsimple slope = 0.20, $p < 0.001$), but not among those with low academic procrastination (βsimple slope = 0.08, $p > 0.05$).

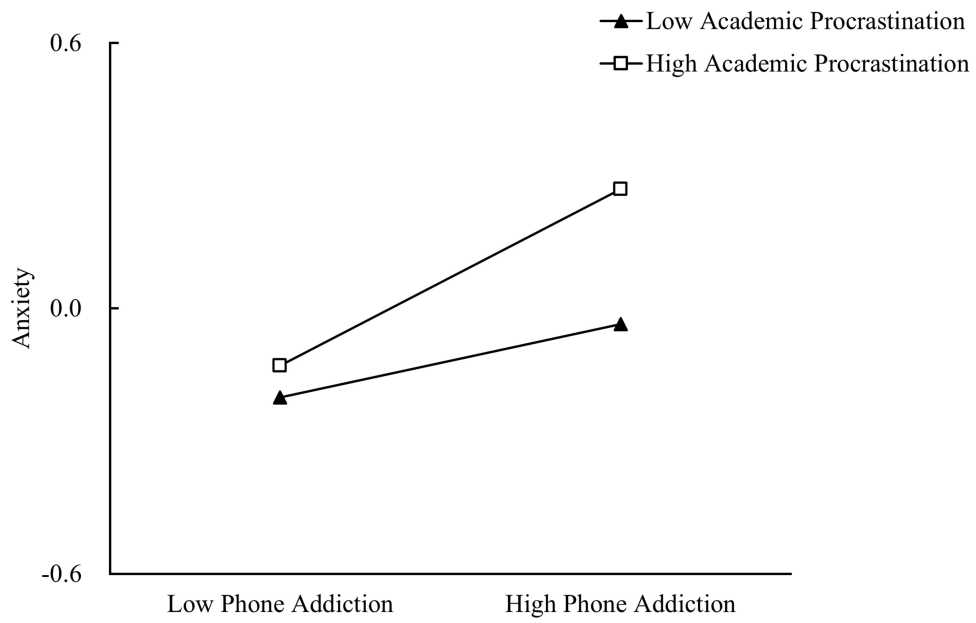

Figure 2 The moderating effect of academic procrastination on smartphone addiction and anxiety in hearing-impaired college students.

Discussion

This study aimed to explore the mediating effect of smartphone addiction between executive dysfunction and anxiety and the moderating effect of academic procrastination in hearing-impaired college students. The findings could provide theoretical support for mental health interventions for this group and promote the development of higher education for hearing-impaired college students.

The Effect of Executive Dysfunction on Anxiety in Hearing-Impaired College Students

The results showed that executive dysfunction significantly predicted anxiety in hearing-impaired college students. The more severe the executive dysfunction, the higher the level of anxiety, supporting Hypothesis 1. This is consistent with several previous studies.[39–41] The findings can also be explained by the theory of mind, which suggests that as typically developing adolescents grow older, they can understand and recognize that others have mental states, emotions, and beliefs different from their own.[42,43] The development of this key skill relies heavily on linguistic communication and social interaction.[44,45] However, hearing-impaired college students' inability to effectively acquire external information through hearing has led them to rely more on vision and other senses to obtain information in their daily studies and life.[46,47] This shift in information acquisition has increased their cognitive load.[6] Additionally, executive functioning, a cognitive domain affected by auditory deprivation, further limits their ability to process complex information and make decisions.[48] When faced with heavy academic pressure, social challenges, or uncertainty about the future, college students with hearing loss may feel overwhelmed, resulting in anxiety. This finding provides a more comprehensive understanding of anxiety in hearing-impaired college students. To help them overcome these problems and maintain good mental health, teachers and classmates can enhance their support and understanding of this population. Encouraging participation in social activities and providing corresponding assistance is also beneficial.[49] Additionally, hearing-impaired college students can relieve anxiety through self-regulation and emotional management.

The Mediating Effect of Smartphone Addiction

This study found that smartphone addiction partially mediated the relationship between executive dysfunction and anxiety in hearing-impaired college students. In other words, executive dysfunction influenced anxiety through the mediator of smartphone addiction, supporting Hypothesis 2. This finding deepens researchers' understanding of the factors influencing the mental health of hearing-impaired college students and extends the study of executive function theories and smartphone addiction, providing new perspectives on this complex psychological phenomenon. Specifically, it reveals how smartphone addiction affects anxiety when hearing-impaired college students face challenges due to executive dysfunction. Although the link between executive dysfunction and mental health problems has been explored in several studies, this study is the first to focus on a specific group of hearing-impaired college students and examine how their executive dysfunction affect anxiety through smartphone addiction.[15,17]

For executive dysfunction and smartphone addiction, the results support the idea that executive dysfunction may be a potential driver of smartphone addiction.[50] One of the major challenges that hearing-impaired college students face is executive dysfunction, which directly affect their self-control.[51,52] Neurophysiological evidence suggests that the prefrontal cortex, responsible for self-control abilities, is deficient in smartphone addicts.[53,54] These findings suggest that hearing-impaired college students may struggle to manage their time effectively when faced with the temptation of instant gratification, such as mobile phones, leading to smartphone addiction. For smartphone addiction and anxiety, the results showed a positive correlation between smartphone addiction and anxiety, consistent with previous studies.[55,56] When hearing-impaired individuals realize they are in a different state from normal-hearing individuals and have difficulty integrating into a social group, they have a greater need for tools such as smartphones to make up for their lack of security.[57] However, excessive smartphone use may distract hearing-impaired college students, negatively affecting their learning and mood.[58] This aligns with the resource conservation model, which suggests that mobile phone addicts who spend too much time and energy in the virtual world have fewer resources to cope with stress and real-world difficulties and are prone to anxiety.[59] Therefore, smartphone addiction may be a significant mental health concern for hearing-impaired college students. Psychological interventions for this group could focus on smartphone

addiction prevention and intervention to improve their executive function and anxiety. Additionally, interventions for smartphone addiction must fully consider the special needs of hearing-impaired students. Providing suitable auditory and visual auxiliary equipment for communication may help hearing-impaired students better adapt to their studies and daily life.

The Moderating Effect of Academic Procrastination

The results showed that academic procrastination moderated the relationship between smartphone addiction and anxiety. Smartphone addiction had a greater effect on anxiety among hearing-impaired college students with high academic procrastination compared to those with low academic procrastination, supporting Hypothesis 3. This result aligns with temporal motivation theory.[60] For people with hearing impairments, they may be more inclined to use smartphones to access information due to communication difficulties.[61] This can take time away from studying and lead to delays in completing academic assignments.[62,63] Schraw et al suggested that academic procrastination is a maladaptive behavior with one of its core characteristics being a deep fear of failure.[19] This fear of failure is viewed as a specific manifestation of anxiety, namely the cognitive symptom of anxiety.[64] In other words, the psychological state of academic procrastinators' fear of failure may be an external manifestation of their internal anxiety. From this perspective, high academic procrastination may be a reinforcing mechanism for the effect of smartphone addiction on anxiety levels in hearing-impaired college students. Hearing-impaired students with high academic procrastination may be more likely to use smartphones as a means of distraction and escapism during academic stress. However, this behaviour instead increases the risk of academic burnout among college students and exacerbated their anxiety.[65] To reduce the negative impact of smartphone addiction and anxiety on hearing-impaired college students, schools and society should provide more support and attention and work together to create a friendly and inclusive educational environment. Such an environment can help hearing-impaired students use smartphones properly and develop a positive and reasonable self-assessment. Additionally, psychological counselors can provide necessary psychological guidance to help them improve learning efficiency and time management skills, promoting the physical and mental health of hearing-impaired college students.

Limitations

The present study demonstrated a significant association between executive dysfunction and anxiety in hearing-impaired college students. It provided new ideas for psychological intervention for smartphone addiction and academic procrastination in this special group. However, the study has limitations. First, the cross-sectional study design did not allow for testing the causal relationships among the variables. Future studies could use longitudinal tracing methods or intervention experiments to test the moderated mediation model in this study. Additionally, this study collected self-reported data from students with hearing loss, where bias between actual levels and subjective perceptions may have influenced the final results. Future research could collect data from multiple sources, such as behavioral observations and interviews.

Conclusion

Executive dysfunction positively predicted anxiety in hearing-impaired college students. Smartphone addiction played a partial mediating role between executive dysfunction and anxiety in hearing-impaired college students. Academic procrastination moderated the second half path of the mediation model. Specifically, smartphone addiction had a greater positive predictive effect on anxiety among hearing-impaired students with higher academic procrastination than among those with lower academic procrastination.

Data Sharing Statement

The data can be obtained by contacting the corresponding author for reasonable requests.

Ethical Approval

This study complies with the Declaration of Helsinki and adhered to ethical norms as approved by the Science and Technology Ethics Committee of Nanjing Normal University of Special Education (Ethics approval number: NJTS20240112001).

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Author Contributions

All authors have made a substantial contribution to the work reported, be it in conception, design, execution, acquisition of data, analysis and interpretation, or all of these; have been involved in drafting, revising, or critically reviewing the article; have given final approval for the version to be published; have agreed on the journal to which the article will be submitted; and agree to accept responsibility for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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