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ORIGINAL RESEARCH

The effect of future time perspective on procrastination: the role of parahippocampal gyrus and ventromedial prefrontal cortex

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Abstract

Procrastination is an almost universal affliction, which occurs across culture and brings serious consequences across multiple fields, such as finance, health and education. Previous research has showed procrastination can be influenced by future time perspective (FTP). However, little is known about the neural basis underlying the impact of FTP on procrastination. To address this question, we used voxel-based morphometry (VBM) based on brain structure. In line with previous findings, the behavioral result indicated that FTP inventory scores were significantly negatively correlated with procrastination inventory scores ($r = -0.63$, $n = 160$). The whole-brain VBM results showed that FTP scores were significantly negatively correlated with the grey matter (GM) volumes of the parahippocampal gyrus (paraPHC) and ventromedial prefrontal cortex (vmPFC) after the multiple comparisons correction. Furthermore, mediation analyses revealed that the effect of GM volumes of the paraPHC and vmPFC on procrastination was mediated by FTP. These results suggested that paraPHC and vmPFC, the critical brain regions about episodic future thinking, could be the neural basis responsible for the impact of FTP on procrastination. The present study extends our knowledge on procrastination, and provides a novel perspective to understand the relationship between FTP and procrastination.

Keywords Procrastination · Future time perspective · Voxel-based morphometry

Introduction

A majority of people admits to procrastinating at least sometimes, and this dilatory behavior brings serious consequences, more specifically, poor academic performance (Skowronski and Mirowska 2013), financial difficulties (Ferrari et al. 1995), low level of health (Steel and Ferrari 2013) and well-being (Steel and Klingsieck 2016). As Steel (2007) reviewed, procrastination was the phenomenon that individuals were "to voluntarily delay an intended course of action despite expecting to be worse off for the delay". Previous researchers have explored different possible correlates with procrastination, including construal level (Mccrea et al. 2008), individual differences and demographics (Steel 2007). Given that procrastination concerned a person's ability to meet deadlines (Díaz-Morales and Ferrari 2015; Ferrari and Díaz-Morales 2007), the temporal component was clearly important to understand this behavior. Many behavioral studies have demonstrated that procrastinators usually had a low level of future time perspective (FTP) (Díaz-Morales and Ferrari 2015; Ferrari and Díaz-Morales 2007; Jackson et al. 2003; Sirois 2014; Specter and Ferrari 2000). However, little is known about the neural substrates underlying the effect of FTP on procrastination.

Previous studies attempted to investigate the possible causes about the effect of FTP on procrastination. Time perspective represented an individual's way of relating to the psychological concepts of past, present, and future (Zimbardo and Boyd 1999). Future time perspective (FTP), in particular, reflected non-conscious processes involving the use of future frames in encoding, storing, and recalling experienced past events or in forming expectations, goals, and imaginative views towards future (Boyd and Zimbardo 2005). Future-oriented people tended to carefully plan and organize their future work activities for the attainment of long-range goals (Rose 2007; Zimbardo and Boyd 1999).

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Nevertheless, procrastinators lacked this engagement in planned behaviors (Díaz-Morales and Ferrari 2015; Ferrari 2001). Developing, remembering and executing a plan needed a basic ability of episodic future thinking (EFT; Fox et al. 2008). This ability of projecting self into the future and mental simulation of future events facilitated the link between goals and actions (Atance and O'Neill 2001; Karniol and Ross 1996; Raffard et al. 2013). Many studies indicated that procrastinators often chose to pursuit short-term benefits regardless of long-term goals (Steel 2007; Steel and Klingsieck 2016; Tice and Baumeister 1997). It seems that lacking this ability of envisioning the future goals may increase more procrastinating behaviors. Conversely, FTP was a predisposition toward envisaging future goals and striving to them (Zimbardo and Boyd 1999), which might indicate that FTP-oriented people had the higher level of EFT abilities (Atance and O'Neill 2001). Taken together, EFT abilities may play a vital role in the effect of FTP on procrastination.

It has been demonstrated that the EFT ability relied on a core network of brain regions comprising the medial temporal lobe (MTL, namely the hippocampus and the parahippocampal gyrus), medial prefrontal cortex, medial parietal cortex or other neocortical regions (Addis et al. 2007; Irish et al. 2012; Pannacciulli et al. 2006). Many fMRI studies showed that parahippocampal areas (Bjork et al. 2009) and the right hippocampus (Addis et al. 2007; Patton et al. 1995) had a greater activity when individuals were thinking about the future. Some lesion studies demonstrated that future-thinking impairment was present when hippocampus lesions (Hassabis et al. 2007; Nichols et al. 2005; Race et al. 2011; Wang et al. 2014). Future-oriented individuals normally looked into the future and had forward-thinking patterns of behaviors (Padawer et al. 2007). Nevertheless, procrastinators had a poor ability of planning for future (Ferrari and Díaz-Morales 2007). It seemed that the EFT was important in the relation between procrastination and FTP (Tice and Baumeister 1997; Zimbardo and Boyd 1999). As a result, these brain regions of MTL may account for the impact of FTP on procrastination.

In the present study, we employed voxel-based morphometry (VBM) to explore the neural substrates responsible for the impact of FTP on procrastination. The VBM was an effective method to assess the local structure of brain and was often used to predict individual's personal characteristics. Future time perspective and procrastination can be regarded as a kind of personality (Lay 1991; Schouwenburg and Lay 1995; Zimbardo and Boyd 1999). Thus, we used the VBM in the current study. At first, we used General procrastination scale and Zimbardo Time Perspective Inventory (only FTP dimension was measured) to assess individual's level of procrastination and FTP respectively. Then, we performed the whole-brain VBM analysis to explore the regional grey matter (GM) volumes correlated with FTP. Finally, mediation analyses were performed to test whether these brain regions related to FTP plausibly contributed to the effect of FTP on procrastination.

Methods

Participants

One hundred and sixty healthy college students (104 women, M = 19.74 years, SD = 1.56 years; 56 men, M = 20.10 years, SD = 1.58 years) were recruited from Southwest University (China). All of the participants were right-handed and had normal or corrected-to-normal vision. None had a history of neurological or psychiatric disorder. All participants volunteered to participate in this study and were gave informed consent prior to the participation. The study was approved by the Institutional Review Board of the Southwest University. After the experiment, all participants were compensated with some payments.

Measures

Procrastination

Levels of procrastination were assessed with General procrastination scale (GPS; Lay 1986), which was used most often to measure procrastination (Dewitte and Lens 2000; Gustavson et al. 2014; Spada et al. 2006). The scale included 20 items, and had 5-point Likert-type response format ranging from 1 (strongly disagree) to 5 (strongly agree). This scale was unidimensional and its total scores were used as the indicator of participants' level of procrastination (Howell et al. 2006; Pychyl et al. 2000). Higher scores indicated the higher tendency of procrastination. It has been reported that Cronbach's alpha coefficient was 0.82 (Lay 1986). In this study, reliability were adequate (Cronbach's alpha coefficient = 0.87).

Future time perspective

The Zimbardo Time Perspective Inventory (ZTPI; Zimbardo and Boyd 1999) was a 56-item self-report questionnaire designed to assess individuals' time perspective. The scale consisted of five dimensions, but we only used the future time perspective (FTP) dimension in this study. In this part, all items were answered using a 5-point Likert-type response format ranging from 1(strongly disagree) to 5(strongly agree). Scoring yielded a total score and higher total scores signified higher levels of FTP (Zimbardo and Boyd 1999). In this study, Cronbach's alpha coefficient in FTP was 0.74.

MRI data-acquisition and pre-processing

Structural images were acquired on a 3.0-T Siemens Trio MRI scanner (Siemens Medical, Erlangen, Germany). A 16-channel circularly polarized head coil was used, with foam padding to restrict head motion. High-resolution T1-weighted anatomical images were acquired using a magnetization-prepared rapid gradient echo (MPRAGE) sequence, with a total of 128 slices at a thickness of 1.33 mm and in-plane resolution of 0.98×0.98 mm^2 (TR = 2530 ms; TE = 3.39 ms; flip angle = 7°; FoV = 256×256 mm^2).

The acquired structural MRI images were processed using SPM12 software (http://www.fil.ion.ucl.ac.uk/spm/software/spm12/) implemented in Matlab R2009a (MathWorks Inc., Natick, MA, USA). First, for better image registration, all T1-weighted anatomic images displayed in SPM12 were manually reoriented to place the anterior commissure at the origin of the 3-dimensional Montreal Neurological Institute (MNI) space. Then, the images were segmented into grey matter, white matter and cerebral spinal fluid in SPM12 (Ashburner and Friston 2005). Next, the DARTEL algorithm was used to generate a group-specific template based on the participants. For each participant, a flow field storing the deformation information for warping the participants' scans onto the template was created. These were used to spatially normalize grey matter images to MNI space using affine spatial normalization as implemented in the normalization algorithm included in the DARTEL toolbox. In order to preserve the GM volumes within a voxel, the images were modulated using the Jacobean determinants derived from the spatial normalization by DARTEL. Finally, data were spatially smoothed with an 8-mm full-width at half-maximum (FWHM) Gaussian kernel to increase the signal to noise ratio.

VBM analysis

Statistical analysis of grey matter (GM) volumes data were performed using SPM12 software. In the whole-brain VBM analysis, we performed a multiple linear regression to identify regions where GM volumes were correlated with individual differences in FTP. The FTP scores were used as the variable of interest in these analyses. Previous studies have suggested that some aspects of brain asymmetries interacted with gender (Kulynych et al. 1994), and age had a significant effect on brain morphology as well (Good et al. 2001). Thus, to rule out the possible confounding variables, age and gender were entered as covariates into the regression model. The global GM volumes were added as a global measure for proportional global scaling (Peelle et al. 2012). The global or regional GM volumes were calculated by the MATLAB script "get_totals" provided by Ridgway (http://www.cs.ucl.ac.uk/staff/g.ridgway/vbm/get_totals.m). We applied explicit masking using the population-specific masking toolbox in SPM12 in order to restrict the search volumes within gray matter and white matter (http://www.cs.ucl.ac.uk/staff/g.ridgway/masking/). This approach was used instead of absolute or relative threshold masking in order to decrease the risk of false negatives caused by overly restrictive masking, and potentially interesting voxels were excluded from the statistical analysis (Ridgway et al. 2009). Additionally, in order to correct for multiple comparisons in interpreting these results, a small volume correction (SVC) with a sphere of 10 mm radius was used according to previous studies (Calvo-Merino et al. 2005; Modinos et al. 2010; Overeem et al. 2003; Yue et al. 2013). We used Addis and Schacter (2008) for parahippocampal gyrus and Okuda et al. (2003) for ventromedial prefrontal cortex. The map of the correlation between GM volumes and FTP scores was superimposed on a template provided by BrainNet Viewer (http://www.nitrc.org/projects/bnv) for display.

Finally, for sake of investigating whether these brain regions related to FTP plausibly contributed to the effect of FTP on procrastination, we extracted mean GM volumes from these brain regions. Sequentially, mediation analyses were performed by the INDIRECT procedure (Preacher and Hayes 2008) with 5000 bootstrap samples.

Results

Behavioral result

Behavioral results showed that FTP inventory scores were significantly negatively correlated with procrastination inventory scores ($r = -0.63$, $p < 0.001$; see Fig. 1).

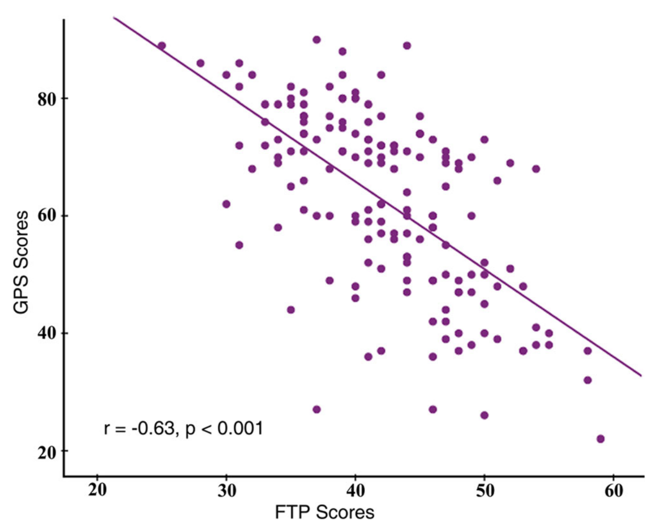

Fig. 1 Behavioral correlation results. Significantly negative correlation between FTP scores and GPS scores (the inventory of FTP and procrastination respectively)

VBM result

First, in order to explore the brain regions correlated with FTP, we conducted a multiple regression analysis, while age, gender and global GM volumes were entered as covariates. Figure 2 and Table 1 demonstrated all the brain regions correlated with the FTP scores ($p < 0.01$, uncorrected; cluster size >50). And after the multiple comparisons correction, the GM volumes of the right paraPHC (parahippocampal gyrus; x = 18, y = −12, z = −28; $p < 0.05$, corrected) and the left vmPFC (medial prefrontal cortex; x = −14, y = 46, z = −26; $p < 0.05$, corrected) were still negatively correlated with the FTP scores.

The mediation analysis

Finally, to investigate how paraPHC and vmPFC plausibly contributed to the effect of FTP on procrastination, we performed the mediation analyses by using INDIRECT procedure (Preacher and Hayes 2008) with 5000 bootstrap samples. It was shown that the impact of the GM volumes of paraPHC and vmPFC on procrastination was mediated by the FTP (95% percentile CI = 0.05 to 0.25 and 0.14 to 0.32, respectively; see Fig. 3). This result indicated that the brain regions in the paraPHC and vmPFC could be the neural basis underlying the effect of FTP on procrastination.

Discussion

In this current study, we investigated the neural basis underlying the effect of FTP on procrastination. In line with previous studies, FTP inventory scores were inversely correlated with procrastination inventory scores. Neuroimaging results showed that FTP scores were negatively correlated with the GM volumes of paraPHC and vmPFC respectively after the multiple comparisons correction. Furthermore, the mediation analyses demonstrated that the effect of GM volumes of the paraPHC and vmPFC on procrastination was mediated by FTP respectively. Our findings provide a novel insight into the paraPHC and vmPFC accounting for the impact of FTP on procrastination, and extends our understanding on procrastination.

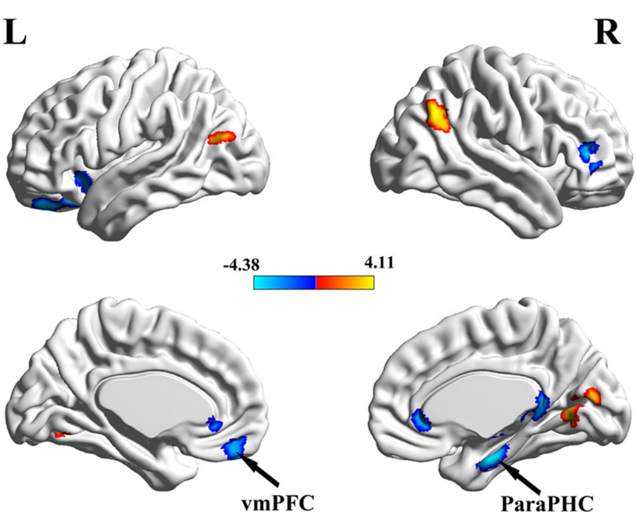

Fig. 2 Significant brain regions correlated with FTP were observed ($p < 0.01$, uncorrected; cluster size >50). Arrows indicate predicted areas with activations significant at $P < 0.05$ after small volume correction using a 10 mm sphere

In line with previous research, FTP inventory scores were significantly negatively correlated with procrastination inventory scores. Future-oriented individuals guided their actions by future expectations, enjoyment, pleasure and excitement, and believed in making sacrifices in the present for rewards that may be earned in the future (Gupta et al. 2012; Zimbardo and Boyd 1999). These individuals constructed their view of the future as positive and had a high level of EFT ability (Atance and O'Neill 2001). However, procrastinators had a low level of EFT ability because of their less possibility to consider the potential future outcomes of their current behavior (Rebetez et al. 2016). Thus, it was no surprise that the behavioral result in our study was consistent with those previous studies, showing the negative correlation between FTP and procrastination (Ferrari and Díaz-Morales 2007; Jackson et al. 2003; Sirois 2014).

The whole-brain VBM analysis demonstrated that FTP inventory scores were negatively correlated with the GM volumes of the paraPHC and vmPFC. Some pathological studies found that future thinking deficit was associated with atrophy of frontal cortex, hippocampus, lateral temporal in dementia (Ashburner and Friston 2005; Ridgway et al. 2009; Viard et al. 2014; Irish et al. 2013). Many functional neuroimaging studies have highlighted the engagement of the neural network consisting of the ventromedial prefrontal cortex (vmPFC) and medial temporal lobe (hippocampus and parahippocampal gyrus) when participants are engaged in imagining future events (Addis et al. 2007; Hassabis et al. 2007; Okuda et al. 2003; Szpunar et al. 2007; Race et al. 2011). Thus, paraPHC and vmPFC made a critical contribution to episodic future thinking (EFT). Furthermore, some research found that future-oriented people were prone to imaging their future experiences and anticipate their consequences (Díaz-Morales et al. 2008; Richard et al. 1996; Seijts 1998). As a result, paraPHC and vmPFC which played a key role in EFT may have a close association with FTP. In addition, it was worthy to mention that there was a complex and controversial issue on the relationship between the function of one brain region and its morphological characteristics (Craik and Bialystok 2006). Effective cognitive functioning depended on the density and richness of synaptic connections and on the specificity of synaptic pruning from grey matter perspective (Craik and Bialystok 2006; Giedd et al. 1999). In general, the GM volumes in the cortex increased until

Table 1 Correlations between the GM volume of the whole brain and FTP: voxel-wise analysis

Brain region	MNI	t	Cluster size
Only -			
Right parahippocampal Gyrus	18, −12, −28	−4.01	246
Left medial prefrontal cortex	−14, 46, −26	−4.09	377
Left insula	−32, 14, −14	−3.15	135
Right inferior Frontal Gyrus	50, 44, 8	−4.38	140
Right anterior cingulate cortex	8, 36, 0	−3.09	79
Right posterior cingulate cortex	6, −44, 10	−3.35	75
Only +			
Left lingual gyrus	−20, −64, −8	3.54	87
Right lingual gyrus	8, −64, 2	3.43	157
Left middle temporal gyrus	−48, −74, 22	3.08	91
Right angular gyrus	54, −62, 36	4.11	286

Only +: the brain regions positively correlated with FTP ($p < 0.01$, uncorrected); only -: the brain regions negatively correlated with FTP ($p < 0.01$, uncorrected)

adolescence, reflecting the growth of synapses but then decreased after adolescence reflecting synaptic pruning (Craik and Bialystok 2006). Specifically, the peak age of GM volumes varied across brain regions– about age 12 for frontal and parietal lobes, age 16 for the temporal lobe, and age 20 for the occipital lobe (Giedd et al. 1999). The participants in our study were around twenty years old at which they may be experiencing the process of synaptic pruning (Craik and Bialystok 2006; Sowell et al. 2003), which indicated the smaller of the GM volumes of paraPHC and vmPFC individuals were, the stronger abilities of EFT they would be in our study. Given that, it is understandable to find that the GM volumes of paraPHC and vmPFC were negatively correlated with FTP inventory scores in our study.

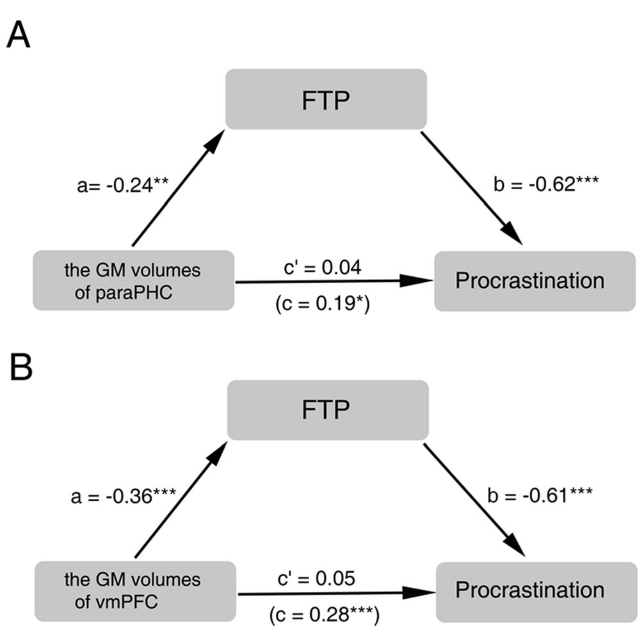

Fig. 3 Mediation analyses results. It showed that FTP mediated the impact of the GM volumes of the paraPHC (**a**) and vmPFC (**b**) on procrastination. *: $p < .05$; **: $p < .01$; ***: $p < .001$

Furthermore, our mediation results suggested that the impact of GM volumes of paraPHC and vmPFC on procrastination was mediated by FTP respectively. ParaPHC and vmPFC normally played a crucial role in the EFT ability (Race et al. 2011). Consistent with this view, a great number of fMRI research showed the evidence of greater activity during descriptions of future events in a set of regions, including the ventromedial prefrontal cortex (vmPFC) and the medial temporal lobe (hippocampus and parahippocampal gyrus) (Addis et al. 2007; D'Argembeau et al. 2008; Okuda et al. 2003; Szpunar et al. 2007). This EFT underlay the ability to project events that involved the self into the future for better planning and understanding of the consequences of current behaviors (Tulving 1999). It seemed that the individual who had a high level of this ability may be more likely to be the future-oriented person (Atance and O'Neill 2001). Unfortunately, procrastinators were less future-oriented (Gupta et al. 2012). They usually had poor mental representations of imagined events and found it hard to simulate future events, which may led to less devotion to goal-oriented behaviors, ending with procrastination (Sirois 2004). That is, the inability of EFT resulting from the abnormality of the brain regions in paraPHC and vmPFC may impact one's level of FTP. These individuals were less likely to consider the potential future outcomes of their current behavior and then tended to procrastinate (Rebetez et al. 2016). Previous structural MRI studies (Hu et al. 2018) and rest-fMRI studies (Zhang et al. 2017, 2016) support the finding on the close relationship between procrastination and paraPHC and vmPFC. Besides, many studies also showed that FTP had a negative connection with impulsivity (Lennings and Burns 1998; Moreira et al. 2016). It indicated that the impulsive individuals were impaired in their abilities to think about the future (Cosenza and Nigro 2015).

This shorter extension of future time perspective may result in one's procrastination (Sirois 2004). A behavioral genetic study supported this viewpoint, which displayed a 100% of genetic variation between procrastination and impulsivity (Gustavson et al. 2014). As a result, it was showed that the impulsivity may play an important role in the effect of future time perspective on procrastination. However, some research found that the level of ones' impulsivity could be reduced when they were required to engage in anticipating the future consequences of present behaviors (Bromberg et al. 2015; Daniel et al. 2013). Thus, it seemed that EFT ability may be a more essential and important impacting factor underlying the effect of future time perspective on procrastination. Taken together, paraPHC and vmPFC—the crucial brain region of EFT—may be the neural substrates responsible for the impact of FTP on procrastination.

In this study, we explored the neural substrates underlying the effect of FTP on procrastination by using the method of VBM. However, our study had several limitations. First of all, some research indicated that the age of study groups was a crucial factor needed to consider for a clear understanding of the brain function-structure friendship (Craik and Bialystok 2006). Thus, in the future, we should recruit participants at more ages to understand the problem thoroughly. Besides, we were not able to draw the causal conclusion in this study. In this study, we only used VBM by which personality trait can be predicted by local structure of grey matter assessed (Kanai and Rees 2011). In the future, some causal study methods, such as the longitudinal study and functional magnetic resonance imaging (fMRI) should be conducted to help us have further understanding about this problem.

In summary, we employed the VBM method to explore the effect of FTP on procrastination based on brain structure. It was found that FTP inventory scores were negatively correlated with the GM volumes of paraPHC and vmPFC. Moreover, the mediation analyses demonstrated that the effect of GM volumes of the paraPHC and vmPFC on procrastination was mediated by FTP respectively. Therefore, the paraPHC and vmPFC could be responsible for the impact of FTP on procrastination. Furthermore, the present study provides a novel insight into the brain regions accounting for the effect of FTP on procrastination, and extends our understanding on procrastination.

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Compliance with ethical standards

Conflict of interest All authors (including Miss. Peiwei Liu and Dr. Tingyong Feng) declare they have no conflict of interest.

Informed consent statement All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, and the applicable revisions at the time of the investigation. Informed consent was obtained from all participants for being included in the study.

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