North Korean defectors with PTSD and complex PTSD show alterations in default mode network resting-state functional connectivity

Byung-Hoon Kim, Jiwon Baek, Ocksim Kim, Hokon Kim, Minjeong Ko, Sang Hui Chu* and Young-Chul Jung*

Background

North Korean defectors (NKDs) have often been exposed to traumatic events. However, there have been few studies of neural alterations in NKDs with post-traumatic stress disorder (PTSD) and complex PTSD (cPTSD).

Aims

To investigate neural alterations in NKDs with PTSD and cPTSD, with a specific focus on alterations in resting-state functional connectivity networks, including the default mode network (DMN).

Method

Resting-state functional connectivity was assessed using brain functional magnetic resonance imaging in three groups of NKDs: without PTSD, with PTSD and with cPTSD. Statistical tests were performed, including region of interest (ROI)-to-ROI and ROI-to-voxel analysis, followed by *post hoc* correlation analysis.

Results

In the ROI-to-ROI analysis, differences in functional connectivity were found among the components of the DMN, as well as in the thalamus and the basal ganglia. Right hippocampus–left pallidum and right amygdala–left lingual gyrus connectivity differed between groups in the ROI-to-voxel analysis, as did connectivity involving the basal ganglia. The *post hoc* analysis revealed negative correlations between Coping and Adaptation Processing Scale (CAPS) score and left posterior cingulate cortex–right pallidum connectivity and between CAPS score and right putamen–left angular gyrus connectivity in the control group, which were not observed in other groups.

Conclusions

The results suggest that there are alterations in the functional connectivity of the DMN and the limbic system in NKDs with PTSD and cPTSD, and that these alterations involve the basal ganglia. The lower correlations of CAPS score with right basal ganglia–DMN functional connectivity in patients compared with controls further implies that these connectivities are potential targets for treatment of PTSD and cPTSD.

Keywords

North Korean defectors; PTSD; complex PTSD; functional connectivity; default mode network.

Refugees are displaced from their homelands owing to external factors related to survival. Forced displacement as a result of armed conflict, political persecution or natural disasters causes significant psychological stress. Refugees commonly experience adversities before and during their migration, and living conditions after migration can be harsh and stressful. The high prevalence of post-traumatic stress disorder (PTSD) among refugees is thought to be related to their exposure to traumatic events before, during and after their displacement across national and cultural borders.[1] As the total number of refugees has grown rapidly over the past few decades, reaching over 27.1 million individuals worldwide by the end of 2021,[2] the mental health needs of refugees, who are vulnerable to developing psychiatric symptoms and mental illnesses such as PTSD,[3] have been addressed to ensure timely diagnosis, treatment and rehabilitation.

So far, approximately 30 000 North Korean defectors (NKDs), a subgroup of refugees, have fled North Korea and entered South Korea. South and North Korea have been separated for about 80 years. Although they still have the same ethnicity and language, differences in culture, ideology, government regulations and socio-economic status have grown significantly, making it difficult for NKDs to adapt and settle in South Korea.[4] A recent large-scale analysis that assessed over 22 000 NKDs with propensity score matching against 90 000 people in South Korea indicated that NKDs have higher risk of developing mental disorders than South Koreans, with a hazard ratio of 2.12.[5] Unsurprisingly, PTSD had the highest hazard ratio of 3.10, suggesting harmful effects of the traumatic experiences of displaced individuals, as emphasised in previous studies.[6,7] Difficulties in adapting to a new environment can be worsened by symptoms of PTSD in refugees.[8,9] Currently, reducing mental health problems in NKDs is a socially important issue in South Korea.

Here, it should be noted that the classical definition of trauma for the diagnosis of PTSD is a discretised exposure to actual or threatened death or serious harm.[10] However, NKDs often experience prolonged exposure to non-physical trauma such as political–ideological and family-related trauma.[6] The different role of prolonged and repeated trauma in the development of PTSD symptoms has been acknowledged in psychiatric diagnoses. To address this issue, the ICD-11 was officially updated to define complex PTSD (cPTSD) as a disorder caused by multiple and sustained traumas, distinct from PTSD.[11] Our previous study showed that quality of life (QoL) among NKDs with cPTSD symptoms was lower than that in NKDs with low levels of symptoms or even with PTSD.[12] However, to date, only a few studies have focused on cPTSD in refugees or, more specifically, in NKDs.[13]

With the development of neuroimaging methods, it has been shown that psychological trauma affects the neurobiological system of the human brain.[14,15] The brain regions that are most often associated with PTSD include the amygdala, hippocampus and medial prefrontal cortex.[16] These three regions are hypothesised to form a neurocircuitry that is centred on the amygdala, the limbic system responsible for fear responses.[17] Specifically, the

---

* These authors contributed equally to this work.

amygdala takes inputs to process and learn about fear and sends output signals to other brain regions, such as the hypothalamus, thalamus, and brainstem, to activate the fear response.[16] When the amygdala responds to fear, the medial prefrontal cortex and the hippocampus work together to downregulate the level of reaction to an appropriate range.[18,19] Neuroimaging studies have shown that in patients with PTSD, the amygdala is hyperactivated in response to fear stimuli, and the hippocampus shows reduced volume when compared with that of healthy controls.[20–24]

Another recent perspective extends the neurocircuitry hypothesis to functional network-level disruptions in patients with PTSD.[24] The default mode network (DMN) is one of the most important functional connectivity networks activated at rest and involves the posterior cingulate cortex (PCC), precuneus, medial prefrontal cortex and angular gyrus.[25] The DMN is known to have a role in self-referential thinking and memory recall,[26] and disruption of the DMN has been found in patients with psychiatric disorders including major depressive disorder,[27] schizophrenia[28] and Alzheimer's disease.[29] Evidence from resting-state functional magnetic resonance imaging (fMRI) studies suggests that patients with PTSD exhibit alterations of the DMN. For example, combat veterans with PTSD exhibit reduced functional connectivity between the PCC and the hippocampus.[30] Although some structural neuroimaging studies have focused on the effects of PTSD on structural changes of the brain specific to NKDs,[31,32] not much is known about the changes in the resting-state functional neural network involved in PTSD in NKDs. Furthermore, no previous research has specifically investigated any difference in neural findings between PTSD and cPTSD in traumatised individuals.

Although most people experience at least one traumatic event in their lives, not all develop clinically significant symptoms or disorders such as PTSD. The Roy adaptation model is one of the most widely used models conceptualising the coping process and delineating cognition and regulator subsystems.[33] The Coping and Adaptation Processing Scale (CAPS) is a psychometric scale built upon the Roy adaptation model that can be used to evaluate style and quantify one's capacity for coping.[34] Given that coping and adaptation processing is a crucial part of recovery after traumatic events and could be related to clinical outcomes,[35,36] we used the CAPS to investigate the neural correlates of coping capacity in patients with PTSD and cPTSD.

In this study, we aimed to study the neural underpinnings of PTSD and cPTSD among NKDs. More specifically, we measured functional neural activity using fMRI during rest in a group of NKDs diagnosed with PTSD or cPTSD compared with an asymptomatic group and analysed alterations in resting-state functional connectivity. Here, we tested three hypotheses: (a) that functional connectivity related to the limbic system, especially the amygdala and hippocampus, would be altered in patients with PTSD or cPTSD; (b) that functional connectivity related to the DMN, especially the PCC, would be altered in patients with PTSD or cPTSD; and (b) coping capacity would show different correlation patterns with functional connectivity in both patients with PTSD and those with cPTSD compared with people without PTSD.

Method

Participant recruitment and evaluation

Participants were recruited from the original cohort of 520 NKDs who participated in an online survey in 2021.[12] In the current study, we recruited only women, accounting for 70% of NKDs, to exclude biological variations in the brain by sex or related hormones. Initially, 271 of the 385 eligible cohort participants were contacted for the follow-up study after excluding men ($n = 78$) and those who reported no history of traumatic events ($n = 9$).

Of the 271 patients, 119 refused to participate, and 52 had pre-existing conditions that precluded an MRI scan (e.g. metal implants, claustrophobia, possible pregnancy). Finally, 100 NKD women participated in the current study. Nine participants were excluded because of excessive head motion ($n = 8$) or incomplete MRI scans ($n = 1$), and 18 were additionally excluded from the asymptomatic group who had clinically diagnosed depressive or anxiety disorders ($n = 16$), alcohol addiction ($n = 1$) or arm amputation ($n = 1$). The final sample consisted of 73 NKD women residing in South Korea, all of whom had been diagnosed with PTSD ($n = 21$) or cPTSD ($n = 23$) or were asymptomatic controls ($n = 29$). A flowchart of the participant recruitment process is shown in Fig. 1.

For the final participants, a clinical diagnosis of PTSD or cPTSD was made through a psychiatric interview with a skilled psychiatrist (Y.C.J.). The participants also completed self-report psychometric scales, including the Korean version of the CAPS,[37] which evaluates coping styles in response to stressful events. The CAPS is a four-point Likert scale with 15 items; higher scores reflect better coping skills. Overall QoL was measured by one item from WHOQOL-BREF asking for the participant's overall perception of QoL with a scoring range of 0–4.

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All procedures involving human subjects/patients were approved by the ethical review boards of the Severance Hospital Institutional Review Board (no. 4-2021-1520). Formal written informed consent was obtained from all participants in this study.

Neuroimage data acquisition and pre-processing

A Philips Ingenia CX 3.0T MRI scanner (Philips, Amsterdam, The Netherlands) was used to acquire the neuroimaging data. The participants were instructed to rest with their eyes open during the entire scanning process. T1-weighted structural images were obtained using the SENSE parallel imaging protocol with the following parameters: repetition time, 9.9 ms; echo time, 4.6 ms; flip angle, 8°; number of slices, 170; slice thickness, 1 mm; and matrix size, 512×512. An echo planar image sequence with the following parameters was used to acquire the functional images: repetition time, 2000 ms; echo time, 22 ms; flip angle, 90°; number of slices, 49; slice thickness, 3 mm; and matrix size, 80×80. The acquired images were pre-processed on a Linux workstation using fMRIPrep (v. 21.0.2),[38] which is based on Nipype.[39] Pre-processing of T1-weighted structural images included brain extraction, tissue segmentation, surface extraction and spatial normalisation, whereas pre-processing of resting-state functional images included head-motion correction, slice-timing correction and co-registration. Further details of the pre-processing of neuroimaging data are provided in the Supplementary Material available at https://doi.org/10.1192/bjo.2023.636.

Functional connectivity analysis

The pre-processed structural and functional images for the 73 participants were imported into the Conn toolbox (v. 21.a) in MATLAB (v. 2022a) for analysis of resting-state functional connectivity.[40] Two types of analysis were performed: region of interest (ROI)-to-ROI and ROI-to-voxel. For the ROI-to-ROI analysis, the time series of 116 ROIs defined from the Automated Anatomical Labeling (AAL) Atlas[41] were first extracted by averaging the BOLD signal of voxels within each ROI. Functional connectivity was defined as the Pearson's correlation coefficient between every possible pair of the 116 ROI time series across time, subjected to Fisher's z-transformation. Using this procedure, a 116×116 resting-state functional connectivity matrix was obtained for each
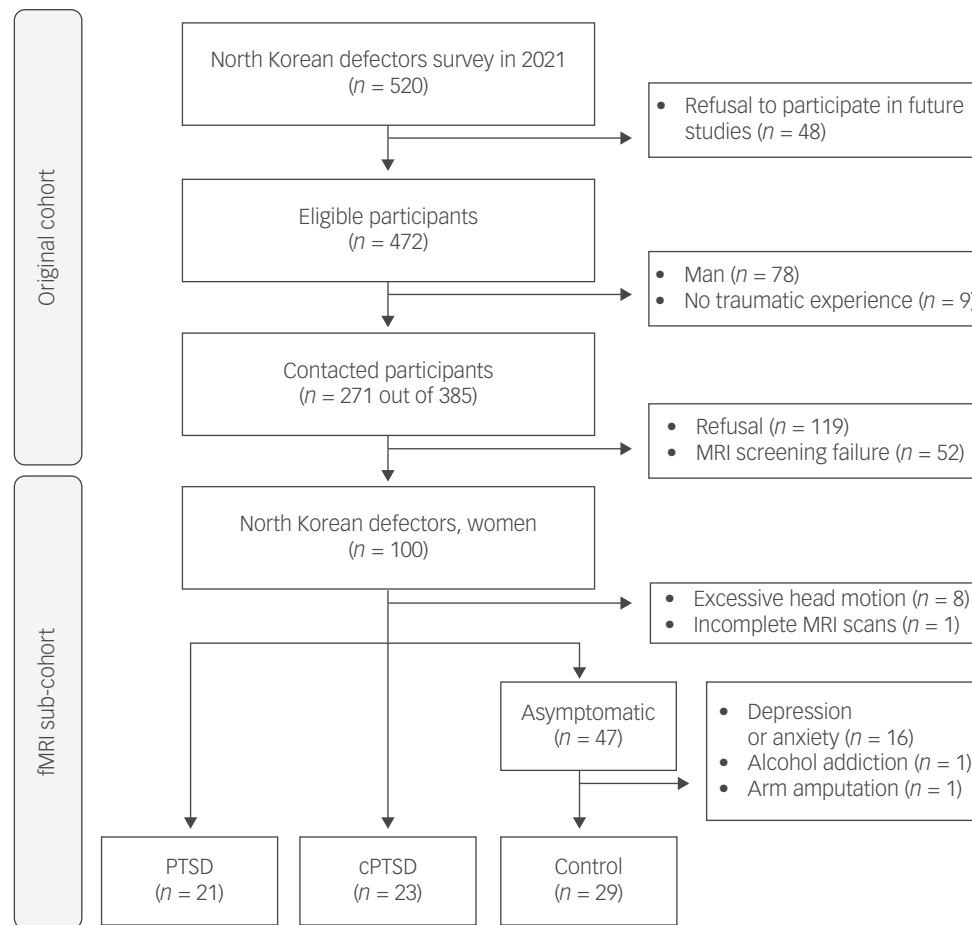
Fig. 1 Flow diagram of participant recruitment and inclusion. MRI, magnetic resonance imaging; fMRI, functional magnetic resonance imaging; PTSD, post-traumatic stress disorder; cPTSD, complex post-traumatic stress disorder.

participant, on which the ROI-to-ROI statistical analysis was conducted. For the ROI-to-voxel analysis, we selected four ROIs from the AAL Atlas, including the amygdala and hippocampus, in both hemispheres. Functional connectivity between the selected ROI and every voxel within the resting-state fMRI data was computed, and this voxel-wise functional connectivity was used for the ROI-to-voxel statistical analysis.

Statistical analysis

For demographic factors, differences between groups were evaluated using one-way analysis of variance (ANOVA). For the ROI-to-ROI analysis, differences in functional connectivity were analysed using ANOVA with cluster-level multivariate pattern analysis omnibus test corrected for multiple comparisons with false discovery rate (FDR) P-FDR < 0.05 and uncorrected connection-level threshold $P < 0.05$ following the standard approach from ref.[42] and the Conn toolbox. For the ROI-to-voxel analysis, differences between the groups were also analysed with ANOVA

with an uncorrected voxel-level threshold of $P < 0.001$ and cluster-level threshold of $k \geq 10$. For the functional connectivities that showed significant results in the ANOVA, a *post hoc* Tukey test was performed to further identify the differences between each pair in the three groups. To test the relationship between functional connectivity and trauma-related characteristics, the *post hoc* Pearson's correlation between functional connectivity strength and CAPS was evaluated per group. All statistical analyses were conducted with Python 3.8.5 using the 'pandas' and 'pingouin' packages, except for the group difference test for functional connectivity, which was performed with the Conn toolbox.

Results

Demographics and psychometric scales

Demographic characteristics and psychometric scale scores for each group are summarised in Table 1. No between-group differences

Table 1 Demographic characteristics and psychometric scale scores of study participants; mean values for each group are reported, with the standard deviation denoted in parentheses

	Control ($n = 29$)	PTSD ($n = 21$)	cPTSD ($n = 23$)	F	P
Age, years	44.21 (10.26)	46.29 (9.28)	47.52 (11.62)	0.672	0.514
Years of residence in South Korea	11.86 (4.89)	13.10 (3.89)	11.65 (4.87)	0.630	0.536
Overall QoL	3.48 (0.95)	3.24 (0.70)	3.13 (0.81)	1.205	0.306
CAPS score	43.13 (3.91)	39.71 (5.37)	37.35 (7.73)	6.658	0.002

PTSD, post-traumatic stress disorder; cPTSD, complex post-traumatic stress disorder; QoL, quality of life; CAPS, Coping and Adaptation Processing Scale.

were found for age, years of residency in South Korea or education level. No significant differences were found in QoL scores among the control, PTSD and cPTSD groups; however, CAPS scores showed significant differences among groups (F = 6.658, P = 0.002).

Functional connectivity analysis

ROI-to-ROI functional connectivity analysis revealed nine pairs of functional connectivity across the bilateral PCC, bilateral middle cingulate cortex (MCC), bilateral thalamus, right putamen, right pallidum and left angular gyrus; the nine pairs of ROIs differed significantly among groups (Fig. 2). Among the results, all functional connectivity, except that between the right putamen and left angular gyrus, was related to the PCC (Table 2). Functional connectivity between the PCC and MCC showed the highest F-statistic among all connections. From the ROI-to-voxel analysis, significant group differences in functional connectivity were found between the right hippocampus and a region within the left pallidum ($P < 0.001$, $k = 10$) and between the right amygdala and the left lingual gyrus ($P < 0.001$, $k = 12$; Fig. 3). No significant results were found for functional connectivity with the left hippocampus and left amygdala as seed ROIs.

Post hoc statistical analysis

The *post hoc* Tukey test for the ROI-to-ROI analysis results demonstrated significantly decreased functional connectivity in patients with cPTSD between the left PCC and right putamen compared with the control group (t = 2.641, P = 0.027) and between the right PCC and bilateral MCC compared with the PTSD group

(left: t = 2.664, P = 0.026; right: t = 2.770, P = 0.019). No other significant group difference was found by *post hoc* Tukey test for the ROI-to-ROI analysis. Correlation analysis revealed significant negative correlations of CAPS scores with functional connectivity between the left PCC and right pallidum ($r = -0.446$, P = 0.015) and between the right putamen and left angular gyrus in the control group ($r = -0.433$, P = 0.0019; Fig. 4). No significant differences were found in the *post hoc* statistical analysis of the ROI-to-voxel results.

Discussion

In this study, we investigated resting-state functional connectivity in traumatised NKDs. Disruption of the functional connectivity network grounded in the bilateral PCC was found in the ROI-to-ROI analysis, suggesting abnormal changes in the DMN in NKDs with cPTSD. ROI-to-voxel analysis showed altered functional connectivity between the right hippocampus and left pallidum, and between the right amygdala and left lingual gyrus. *Post hoc* Tukey test revealed significantly decreased functional connectivity in the cPTSD group for the left PCC and the right putamen, and for the right PCC and bilateral MCC when compared with both the control group and the PTSD group, respectively. Correlation analysis revealed a significant negative correlation between CAPS score and functional connectivity of the left PCC and the right pallidum, and of the right putamen and left angular gyrus, in the control group.

Statistical analysis of the psychometric scales showed that QoL scores did not differ among the control, PTSD, and cPTSD groups. Although it may be expected that control participants who did not
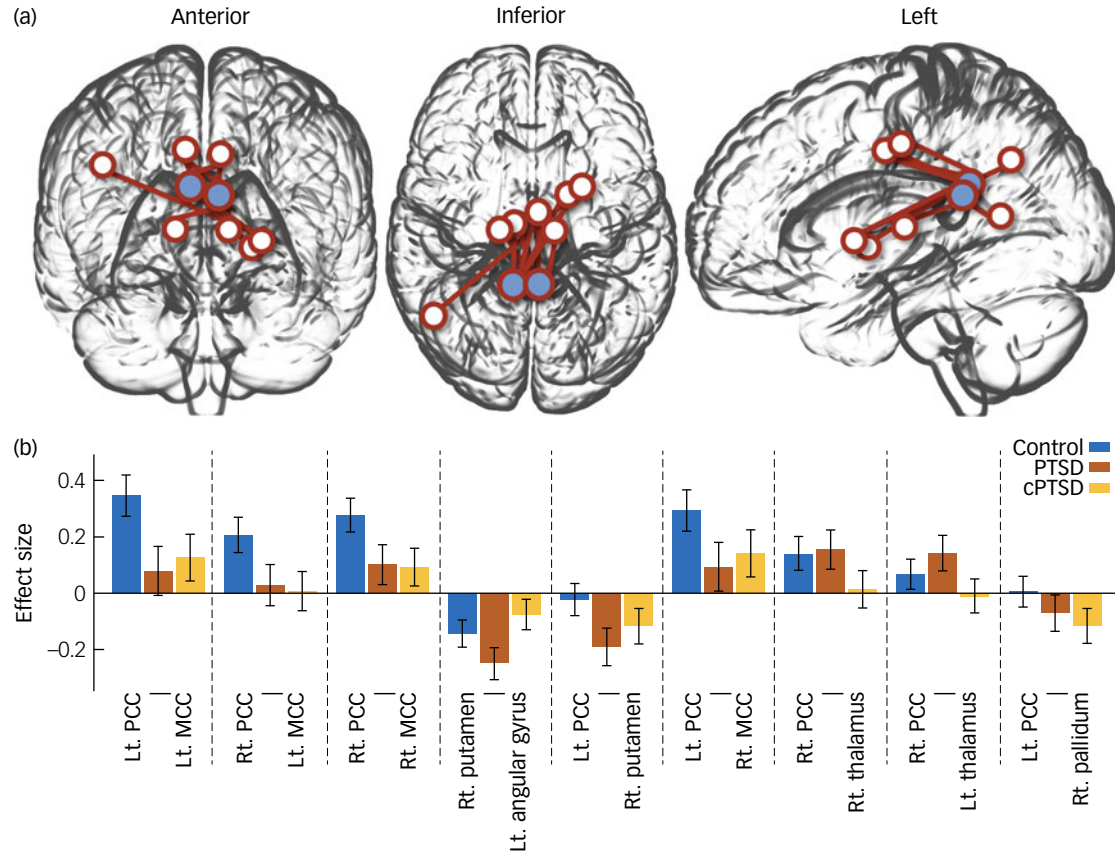

Fig. 2 (a) Glass brain plot of region of interest (ROI)-to-ROI analysis results showing significant group differences. Blue circles indicate bilateral posterior cingulate cortices. (b) Bar plot of ROI-to-ROI analysis of variance results. PTSD, post-traumatic stress disorder; cPTSD, complex post-traumatic stress disorder; Lt, left; Rt, right; PCC, posterior cingulate cortex; MCC, middle cingulate cortex.

Table 2 Statistics from analysis of variance of functional connectivity between groups

Functional connectivity	F	P
Lt. PCC–Lt. MCC	9.45	<0.001
Rt. PCC–Lt. MCC	7.96	0.001
Rt. PCC–Rt. MCC	7.58	0.001
Rt. putamen–Lt. angular gyrus	7.23	0.001
Lt. PCC–Rt. putamen	5.29	0.007
Lt. PCC–Rt. MCC	4.91	0.010
Rt. PCC–Rt. thalamus	3.88	0.025
Rt. PCC–Lt. thalamus	4.33	0.017
Lt. PCC–Rt. pallidum	3.17	0.048

Lt, left; Rt, right; PCC, posterior cingulate cortex; MCC, middle cingulate cortex.

develop PTSD or cPTSD would have better subjective QoL, we interpret this insignificant difference as reflecting the specific selection of participants. In particular, the controls were also NKDs, who were likely to have experienced traumatic events and to have low socioeconomic status, even without a clinical diagnosis of PTSD or CPTSD.[43] The CAPS score, which reflects an individual's capacity for coping, showed significant differences between the groups. It is plausible that people who develop PTSD or cPTSD may have a lower capacity for coping than those who do not, even if they have a similar subjective feeling about their QoL. As our aim was to delineate the neural correlates that underlie PTSD and cPTSD, along with their relationships with coping capacity, it can be said that our participant groups well represented our study goal and hypothesis.

ROI-to-ROI analysis revealed functional network-level disruption of the DMN, which supports our hypothesis. More specifically, the results suggested differences in PCC-grounded functional connectivity among the three groups, with these differences involving the left angular gyrus, bilateral MCC, bilateral thalamus and basal ganglia. However, the PCC and angular gyrus constitute the DMN; significant results in the MCC, thalamus and basal ganglia require further interpretation. Unsurprisingly, a previous meta-analysis of fMRI activation in patients with PTSD indicated that abnormality of the MCC is a general finding, irrespective of the type of trauma experienced, and is involved in processing specific motor

components of noxious stimuli.[44] Another finding related to fMRI activity in PTSD was in the ROI-to-voxel analysis, which indicated a difference in functional connectivity between the right amygdala and left lingual gyrus. The lingual gyrus plays an important part in visual processing, especially visual memory,[45] and its role in the amygdala extends to emotional visual memory processing.[46] As expected, given the symptoms of re-experiencing PTSD, the amygdala and lingual gyrus are among the regions that show changes in resting-state activity in patients with PTSD.[47] However, it should be noted that the ROI-to-voxel analysis results were statistically corrected with less conservative thresholds and require careful interpretation.

Whereas the above results can be thought to replicate findings for PTSD in general, aberrant functional connectivity reaching the thalamus and basal ganglia components is rather specific to our study sample, that is, NKDs. Significant results for the basal ganglia were found in both the ROI-to-ROI and ROI-to-voxel analyses, demonstrating the potential role of the basal ganglia in mediating the interplay between the subcortical-level fear circuit and functional network-level DMN. Although the basal ganglia are best known for coordinating motor functions,[48] a more recent viewpoint is that they have a general role as coordinators of various functions, such as in the cognitive[49] and emotional[50] domains. Our results suggest that NKDs show unique involvement of the basal ganglia in coordinating the interaction of subcortical and functional network-level circuitry in PTSD and cPTSD.

The neural implications of PTSD and cPTSD in NKDs were further delineated using a *post hoc* Tukey test. Significant decreases in the strength of functional connectivity were found between the right PCC and bilateral MCC and between the left PCC and right putamen in the cPTSD group, compared with the PTSD and control groups. These findings suggest that prolonged and repeated exposure to traumatic events blunts the strength of the functional connectivity between the MCC and right PCC and between the left PCC and right putamen significantly more than single or no discrete trauma events. A recent study using electroencephalogram reported weaker thalamic functional connectivity in patients with child abuse cPTSD compared with PTSD and control during the inhibitory Go/NoGo task.[51] This is in contrast to our results, where according to the ROI-to-ROI analysis, the relationship of
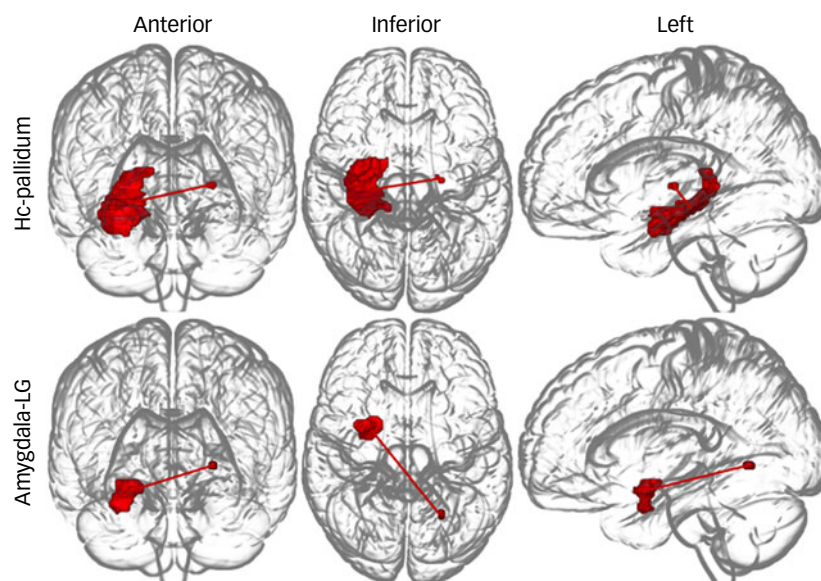

Fig. 3 Glass brain plot of ROI-to-voxel analysis results showing significant group differences. ROI, region of interest; Hc, hippocampus; LG, lingual gyrus.
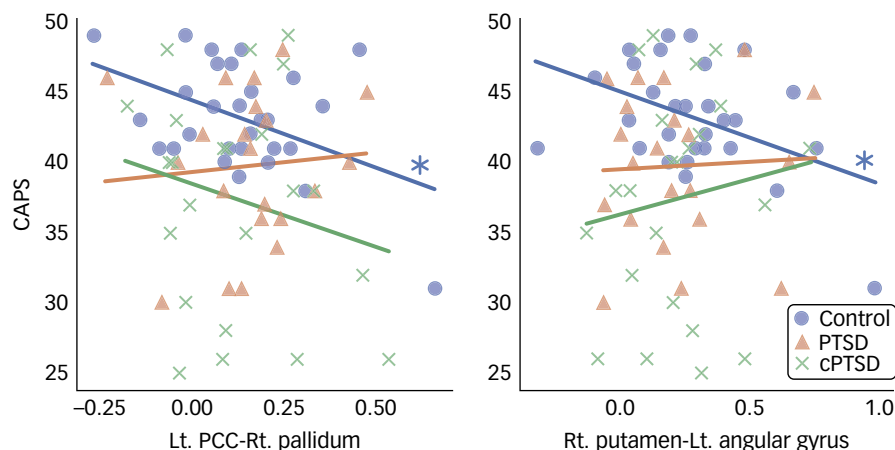
Fig. 4 Scatter plot of significant *post hoc* correlation analysis results. CAPS, Coping and Adaptation Processing Scale; PTSD, post-traumatic stress disorder; cPTSD, complex post-traumatic stress disorder; Lt, left; Rt, right; PCC, posterior cingulate cortex.

thalamic involvement and involvement of the DMN was not specific to the cPTSD group. This discrepancy may be related to a difference in the fMRI experiment (resting state versus task) or, more interestingly, to the type of trauma (forced displacement versus child abuse). Future studies to investigate the neural effects of cPTSD based on the type of trauma could focus on the functional connectivity of the thalamus.

In the *post hoc* correlation analysis, the negative correlations of CAPS score with the functional connectivity of the left PCC–right pallidum and of the right putamen–left angular gyrus were not significant in the PTSD and cPTSD groups. These results suggest that NKDs with better coping capacity show lower connectivity strength between the DMN (left PCC and left angular gyrus) and the right basal ganglia (pallidum and putamen), whereas this relationship is blunted in NKDs who develop PTSD or cPTSD. Given that several studies have suggested that the putamen and pallidum are related to resilience and coping in response to stressful conditions,[52,53] the interactions of the right putamen and pallidum with the DMN can be considered to have an important role in resilience and coping in NKDs, as found in the control group. However, the insignificant correlations in the PTSD and cPTSD group indicate that these disorders affect the functional connectivity between the DMN and the right basal ganglia and blunt its role in coping to stressful events. Although this interpretation might require careful observation with more relevant data, we expect that it may be clinically relevant and that functional connectivity between the DMN and the right basal ganglia could be a potential future target for neuromodulation in the treatment of PTSD and cPTSD.

One of the limitations of our study is that medication, which could have affected functional connectivity, was not considered in the analysis. Another possible limitation is that the ROI-to-voxel analysis was not statistically thresholded at the cluster level, which may have led to an overestimation of false-positive findings. Last, only female participants were included in this study to minimise the possibility of group differences in the gender ratio, which limits the generalisability of our results.

In conclusion, the results confirmed our three hypotheses regarding functional connectivity changes in traumatised NKDs. Specifically, alterations in functional connectivity related to the limbic system and the DMN were found, along with involvement of the basal ganglia. Coping and adaptation showed different correlation patterns with functional connectivity in both patients with PTSD and those with cPTSD when compared with people without PTSD. Among the strengths of our study, it is the first to

investigate resting-state functional connectivity in NKDs, focusing on both PTSD and cPTSD, with a large number of prospectively recruited participants. The results provide new insight into the neurological underpinnings of PTSD and cPTSD, which is expected to help deepen our biological understanding of trauma-related disorders and improve their treatment.

Byung-Hoon Kim (ID), Department of Psychiatry, Yonsei University College of Medicine, Seoul, Republic of Korea; and Institute of Behavioral Sciences in Medicine, Yonsei University College of Medicine, Seoul, Republic of Korea; **Jiwon Baek**, Mo-Im Kim Nursing Research Institute, Yonsei University College of Nursing, Seoul, South Korea; **Ocksim Kim**, Department of Nursing, Yonsei University College of Nursing and Brain Korea 21 FOUR Project, Seoul, South Korea; **Hokon Kim**, Department of Nursing, Yonsei University College of Nursing, Seoul, South Korea; and Brain Korea 21 FOUR Project, Seoul, South Korea; **Minjeong Ko**, Department of Nursing, Yonsei University College of Nursing, Seoul, South Korea; **Sang Hui Chu**, Mo-Im Kim Nursing Research Institute, Yonsei University College of Nursing, Seoul, South Korea; and Department of Nursing, Yonsei University College of Nursing, Seoul, South Korea; **Young-Chul Jung** (ID), Department of Psychiatry, Yonsei University College of Medicine, Seoul, Republic of Korea; and Institute of Behavioral Sciences in Medicine, Yonsei University College of Medicine, Seoul, Republic of Korea

Correspondence: Young-Chul Jung. Email: eugenejung@yuhs.ac

First received 7 Aug 2023, final revision 10 Nov 2023, accepted 28 Nov 2023

Declaration of interest

None.

References

1 Steel Z, Chey T, Silove D, Marnane C, Bryant RA, Van Ommeren M. Association of torture and other potentially traumatic events with mental health outcomes among populations exposed to mass conflict and displacement: a systematic review and meta-analysis. *JAMA* 2009; **302**(5): 537–49.

2 UNHCR. *Global Trends: Forced Displacement in 2021*. UNHCR, 2022 (https://www.unhcr.org/62a9d1494/global-trends-report-2021).

3 Fazel M, Wheeler J, Danesh J. Prevalence of serious mental disorder in 7000 refugees resettled in Western countries: a systematic review. *Lancet* 2005; **365**(9467): 1309–14.

4 Jeon BH, Kim MD, Hong SC, Kim NR, Lee CI, Kwak YS, et al. Prevalence and correlates of depressive symptoms among North Korean defectors living in South Korea for more than one year. *Psychiatry Invest* 2009; **6**(3): 122.

5 Lee R, Lee SM, Hong M, Oh IH. Assessing mental illness risk among North Korean refugees and immigrants resettled in South Korea. *JAMA Netw Open* 2022; **5**(10): e2236751.

6 Jeon W, Hong C, Lee C, Kim DK, Han M, Min S. Correlation between traumatic events and posttraumatic stress disorder among North Korean defectors in South Korea. *J Trauma Stress* 2005; **18**(2): 147–54.

7 Jeon WT, Eom JS, Min SK. A 7-year follow-up study on the mental health of North Korean defectors in South Korea. *J Trauma Stress* 2013; **26**(1): 158–64.

8 Shin JE, Choi JS, Choi SH, Yoo SY. The effect of postmigration factors on quality of life among North Korean refugees living in South Korea. *Int J Environ Res Public Health* 2021; **18**(21): 11036.

9 Lee MK, Kim O, Kim KA, Chu SH. Factors associated with posttraumatic growth among North Korean defectors in South Korea. *Sci Rep* 2022; **12**(1): 3989.

10 American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders: DSM-5 (Vol. 5, No. 5)*. APA, 2013.

11 Brewin CR, Cloitre M, Hyland P, Shevlin M, Maercker A, Bryant RA, et al. A review of current evidence regarding the ICD-11 proposals for diagnosing PTSD and complex PTSD. *Clin Psychol Rev* 2017; **58**: 1–15.

12 Baek J, Kim KA, Kim H, Kim O, Ko M, Kim SH, et al. The validity of ICD-11 PTSD and complex PTSD in North Korean defectors using the International Trauma Questionnaire. *Eur J Psychotraumatol* 2022; **13**(2): 2119012.

13 McGinty G, Fox R, Roberts B, Makhashvili N, Javakhishvili JD, Hyland P. Post-traumatic stress disorder, complex post-traumatic stress disorder, and coping styles among internally displaced Ukrainians. *J Loss Trauma* 2023; **28**(7): 571–87.

14 De Kloet ER, Joëls M, Holsboer F. Stress and the brain: from adaptation to disease. *Nat Rev Neurosci* 2005; **6**(6): 463–75.

15 Herringa RJ. Trauma, PTSD, and the developing brain. *Curr Psychiatry Rep* 2017; **19**: 69.

16 Ressler KJ, Berretta S, Bolshakov VY, Rosso IM, Meloni EG, Rauch SL, et al. Post-traumatic stress disorder: clinical and translational neuroscience from cells to circuits. *Nat Rev Neurol* 2022; **18**(5): 273–88.

17 Fenster RJ, Lebois LA, Ressler KJ, Suh J. Brain circuit dysfunction in post-traumatic stress disorder: from mouse to man. *Nat Rev Neurosci* 2018; **19**(9): 535–51.

18 Shin LM, Wright CI, Cannistraro PA, Wedig MM, McMullin K, Martis B, et al. A functional magnetic resonance imaging study of amygdala and medial prefrontal cortex responses to overtly presented fearful faces in posttraumatic stress disorder. *Arch Gen Psychiatry* 2005; **62**(3): 273–81.

19 Kredlow AM, Fenster RJ, Laurent ES, Ressler KJ, Phelps EA. Prefrontal cortex, amygdala, and threat processing: implications for PTSD. *Neuropsychopharmacology* 2022; **47**(1): 247–59.

20 Karl A, Schaefer M, Malta LS, Dörfel D, Rohleder N, Werner A. A meta-analysis of structural brain abnormalities in PTSD. *Neurosci Biobehav Rev* 2006; **30**(7): 1004–31.

21 Logue MW, van Rooij SJ, Dennis EL, Davis SL, Hayes JP, Stevens JS, et al. Smaller hippocampal volume in posttraumatic stress disorder: a multisite ENIGMA-PGC study: subcortical volumetry results from posttraumatic stress disorder consortia. *Biol Psychiatry* 2018; **83**(3): 244–53.

22 Hayes JP, Hayes SM, Mikedis AM. Quantitative meta-analysis of neural activity in posttraumatic stress disorder. *Biol Mood Anxiety Disord* 2012; **2**(1): 1–13.

23 Patel R, Spreng RN, Shin LM, Girard TA. Neurocircuitry models of posttraumatic stress disorder and beyond: a meta-analysis of functional neuroimaging studies. *Neurosci Biobehav Rev* 2012; **36**(9): 2130–42.

24 Rauch SL, Shin LM, Phelps EA. Neurocircuitry models of posttraumatic stress disorder and extinction: human neuroimaging research – past, present, and future. *Biol Psychiatry* 2006; **60**(4): 376–82.

25 Raichle ME. The brain's default mode network. *Annu Rev Neurosci* 2015; **38**: 433–47.

26 Mak LE, Minuzzi L, MacQueen G, Hall G, Kennedy SH, Milev R. The default mode network in healthy individuals: a systematic review and meta-analysis. *Brain Connect* 2017; **7**(1): 25–33.

27 Yan CG, Chen X, Li L, Castellanos FX, Bai TJ, Bo QJ, et al. Reduced default mode network functional connectivity in patients with recurrent major depressive disorder. *Proc Natl Acad Sci USA* 2019; **116**(18): 9078–83.

28 Garrity AG, Pearlson GD, McKiernan K, Lloyd D, Kiehl KA, Calhoun VD. Aberrant 'default mode' functional connectivity in schizophrenia. *Am J Psychiatry* 2007; **164**(3): 450–7.

29 Greicius MD, Srivastava G, Reiss AL, Menon V. Default-mode network activity distinguishes Alzheimer's disease from healthy aging: evidence from functional MRI. *Proc Natl Acad Sci USA* 2004; **101**(13): 4637–42.

30 Miller DR, Hayes SM, Hayes JP, Spielberg JM, Lafleche G, Verfaellie M. Default mode network subsystems are differentially disrupted in posttraumatic stress disorder. *Biol Psychiatry* 2017; **2**(4): 363–71.

31 Jeong H, Lee YJ, Kim N, Jeon S, Jun JY, Yoo SY, et al. Increased medial prefrontal cortical thickness and resilience to traumatic experiences in North Korean refugees. *Sci Rep* 2021; **11**(1): 14910.

32 Kang W, Kang Y, Kim A, Tae WS, Kim KJ, Kim SG, et al. Shape analysis of the subcortical structures in North Korean refugees with post-traumatic stress disorder and major depressive disorder. *Psychiatry Res* 2022; **326**: 111527.

33 Roy C. Research based on the Roy adaptation model: last 25 years. *Nurs Sci Q* 2011; **24**(4): 312–20.

34 Roy C, Bakan G, Li Z, Nguyen TH. Coping measurement: creating short form of coping and adaptation processing scale using item response theory and patients dealing with chronic and acute health conditions. *Appl Nurs Res* 2016; **32**: 73–9.

35 Agaibi CE, Wilson JP. Trauma, PTSD, and resilience: a review of the literature. *Trauma Violence Abuse* 2005; **6**(3): 195–216.

36 Park S, Lee Y, Jun JY. Trauma and depression among North Korean refugees: the mediating effect of negative cognition. *Int J Envir Res Public Health* 2018; **15**(4): 591.

37 Song CE, Kim HY, So HS, Kim HK. Reliability and validity of the Korean version of the Coping and Adaptation Processing Scale–Short-Form in cancer patients. *J Korean Acad Nurs* 2018; **48**(3): 375–88.

38 Esteban O, Markiewicz CJ, Blair RW, Moodie CA, Isik AI, Erramuzpe A, et al. fMRIPrep: a robust preprocessing pipeline for functional MRI. *Nat Methods* 2019; **16**(1): 111–6.

39 Gorgolewski K, Burns CD, Madison C, Clark D, Halchenko YO, Waskom ML, et al. Nipype: a flexible, lightweight and extensible neuroimaging data processing framework in Python. *Front Neuroinform* 2011; **5**: 13.

40 Whitfield-Gabrieli S, Nieto-Castanon A. Conn: a functional connectivity toolbox for correlated and anticorrelated brain networks. *Brain Connect* 2012; **2**(3): 125–41.

41 Tzourio-Mazoyer N, Landeau B, Papathanassiou D, Crivello F, Etard O, Delcroix N, et al. Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. *Neuroimage* 2002; **15**(1): 273–89.

42 Jafri MJ, Pearlson GD, Stevens M, Calhoun VD. A method for functional network connectivity among spatially independent resting-state components in schizophrenia. *Neuroimage* 2008; **39**(4): 1666–81.

43 Choi SK, Min SJ, Cho MS, Joung H, Park SM. Anxiety and depression among North Korean young defectors in South Korea and their association with health-related quality of life. *Yonsei Med J* 2011; **52**(3): 502–9.

44 Boccia M, D'Amico S, Bianchini F, Marano A, Giannini AM, Piccardi L. Different neural modifications underpin PTSD after different traumatic events: an fMRI meta-analytic study. *Brain Imag Behav* 2016; **10**: 226–37.

45 Palejwala AH, Dadario NB, Young IM, O'Connor K, Briggs RG, Conner AK, et al. Anatomy and white matter connections of the lingual gyrus and cuneus. *World Neurosurg* 2021; **151**: e426–37.

46 Taylor SF, Liberzon I, Fig LM, Decker LR, Minoshima S, Koeppe RA. The effect of emotional content on visual recognition memory: a PET activation study. *Neuroimage* 1998; **8**(2): 188–97.

47 Disner SG, Marquardt CA, Mueller BA, Burton PC, Sponheim SR. Spontaneous neural activity differences in posttraumatic stress disorder: a quantitative resting-state meta-analysis and fMRI validation. *Hum Brain Mapp* 2018; **39**(2): 837–50.

48 Graybiel AM, Aosaki T, Flaherty AW, Kimura M. The basal ganglia and adaptive motor control. *Science* 1994; **265**(5180): 1826–31.

49 Middleton FA, Strick PL. Basal ganglia output and cognition: evidence from anatomical, behavioral, and clinical studies. *Brain Cogn* 2000; **42**(2): 183–200.

7

50 Pierce JE, Péron J. The basal ganglia and the cerebellum in human emotion. *Soc Cogn Affect Neurosci* 2020; **15**(5): 599–613.

51 Bryant RA, Tran J, Williamson T, Korgaonkar MS. Neural processes during response inhibition in complex posttraumatic stress disorder. *Depress Anxiety* 2022; **39**(4): 307–14.

52 Dillon DG, Holmes AJ, Birk JL, Brooks N, Lyons-Ruth K, Pizzagalli DA. Childhood adversity is associated with left basal ganglia dysfunction during reward anticipation in adulthood. *Biol Psychiatry* 2009; **66**(3): 206–13.

53 Holz NE, Tost H, Meyer-Lindenberg A. Resilience and the brain: a key role for regulatory circuits linked to social stress and support. *Mol Psychiatry* 2020; **25**(2): 379–96.