Original research

Overwork and changes in brain structure: a pilot study

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ABSTRACT

Objectives To investigate the effects of overwork on brain structure to better understand its impact on workers' cognitive and emotional health. The goal was to provide evidence for the potential neurological risks associated with prolonged working hours.

Methods A total of 110 healthcare workers were classified into overworked (≥52 hours/week; n=32) and non-overworked groups (n=78). Brain volume differences were assessed using voxel-based morphometry (VBM) and atlas-based analysis. General linear models adjusted for age, sex and total intracranial volume were applied, and correlation analyses explored relationships between weekly working hours and brain volume in regions with significant differences.

Results Overworked individuals exhibited significant changes in brain regions associated with executive function and emotional regulation. Atlas-based analysis revealed a 19% increase in left caudal middle frontal gyrus volume in the overworked group compared with the non-overworked group (p=0.006). VBM showed peak increases in 17 regions, including the middle frontal gyrus, insula and superior temporal gyrus (p<0.05). Correlation analyses indicated a positive association between weekly working hours and brain volume changes in the middle frontal gyrus and insula.

Conclusions This study provides preliminary evidence that overwork is associated with structural brain changes, particularly in regions linked to cognition and emotion. These findings provide novel neurobiological evidence linking prolonged working hours to structural brain changes, emphasising the need for further research to understand the long-term cognitive and emotional implications of overwork.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Prolonged working hours have been linked to various negative health outcomes, including cardiovascular disease, metabolic disorders and mental health issues, such as depression and anxiety. While the behavioural and psychological consequences of overwork have been well documented, little is known about its direct effects on brain structure. Prior research has suggested that chronic stress and insufficient recovery may alter brain morphology, but empirical neuroimaging evidence remains limited.

WHAT THIS STUDY ADDS

⇒ This study provides novel evidence that overwork is associated with structural brain changes, particularly in regions related to executive function and emotional regulation. Overworked individuals exhibited increased brain volume in key regions, such as the middle frontal gyrus, insula and superior temporal gyrus. These findings suggest that long working hours may induce neuroadaptive changes, potentially impacting cognitive and emotional health.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study underscores the need for longitudinal neuroimaging research to establish causal links between overwork and structural brain changes, integrating functional imaging and biomarkers of stress. Future research should explore the long-term implications of these structural brain changes and whether they lead to cognitive decline or mental health disorders. The results underscore the importance of addressing overwork as an occupational health concern and highlight the need for workplace policies that mitigate excessive working hours.

BACKGROUND

Overwork with long working hours has emerged as a critical public health issue in modern societies, with significant implications for both individual well-being and societal productivity. The International Labour Organisation (ILO) estimates that over 800 000 individuals die annually due to long working hours, underscoring its profound impact on global health outcomes.[1] Prolonged working hours are associated with an increased risk of cardiovascular diseases, metabolic disorders and mental health conditions, including depression and anxiety.[2 3] Despite extensive epidemiological evidence linking overwork to adverse health outcomes, the underlying neurobiological mechanisms remain poorly understood.

Recent advances in neuroimaging have provided unprecedented opportunities to investigate how environmental and occupational factors influence brain structure and function. Emerging research suggests that chronic stress and insufficient recovery—key characteristics of overwork—may alter brain morphology and connectivity, potentially predisposing individuals to cognitive and emotional

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dysregulation.[4–6] However, these hypotheses remain speculative, as few studies have directly examined the impact of overwork on brain structure using robust neuroimaging methodologies.

Previous investigations have primarily focused on behavioural and psychological consequences of overwork, such as impaired decision-making, reduced executive function and heightened emotional reactivity.[7 8] While these findings are critical, they fail to elucidate the structural substrates that mediate these effects. Understanding the neuroanatomical changes associated with overwork is essential to developing targeted interventions that mitigate its health consequences and inform occupational health policies.

In this study, we employed voxel-based morphometry (VBM) and atlas-based brain volume analysis to systematically examine the impact of overwork on brain structure. By comparing healthcare workers exposed to long working hours with their counterparts working standard hours, we aimed to identify specific brain regions affected by overwork and explore their potential associations with weekly working hours. This study provides a neurological basis for the adverse health effects of overwork.

MATERIALS AND METHODS

Study population

This study used merged data from the Gachon Regional Occupational Cohort Study (GROCS) and MRI data from a research project on the effect of working conditions on brain structure, supported by the National Research Foundation of Korea. GROCS has been a large-scale longitudinal study of occupational safety and health since 2018.[9] From 2021 to 2023, we invited participants in GROCS to volunteer to undergo additional MRI, and 137 volunteers agreed. Most were healthcare workers, and 110 participants were enrolled in the present study after excluding those with missing data or poor MRI image quality. Studies involving human participants were reviewed and approved by the Institutional Review Board (IRB) of Chung-Ang University (IRB number: 1041078–20231024 HR-287). All the participants provided written informed consent to participate in this study. Baseline characteristics of study participants are described in the online supplemental table.

Overwork and covariables

The baseline characteristics of the participants for which data were analysed included sex, age, type of work and educational level. Participants were asked about their working hours, excluding mealtimes at the workplace. Participants were categorised into overworked (≥52 hours/week) and non-overworked groups based on the Korean Labour Standards Act, which sets 52 hours as the legal upper limit of regular work hours, although it can be extended with the agreement of all parties.[10–12] This threshold has been widely used in occupational health research in Korea due to its strong association with increased health risks, including cardiovascular disease, mental health issues and cognitive impairment.[10 12] Handedness of the participants was also recorded to interpret the brain images. Work-related factors assessed included duration of employment and work type. Participants who were health workers included radiologists, pathologists and other hospital workers.

MR image acquisition

An overview of image analysis approaches is illustrated in figure 1. A three-dimensional T1-weighted magnetisation-prepared rapid gradient echo (T1w MPRAGE) sequence was acquired from 32 and 79 participants in the overwork and non-overwork groups, respectively, with the following parameters: repetition time=1970 ms; echo time=2.84 ms; inversion time=991 ms; field of view=256×256; flip angle=9; in-plane resolution=$0.5\times0.5\times1\ mm^3$; number of slices=192; and scan time=4 min 34 s.

Data processing

Atlas-based volume extraction

The T1w MPRAGE images acquired were processed using the 'recon-all' pipeline in Freesurfer to calculate the volume of brain regions.[13] The recon-all process included three steps. Step 1 involved correcting head motion to reduce artefacts, adjusting intensity variations for uniform brightness, and removing non-brain structures such as the skull. Step 2 involved segmenting brain tissue into white and grey matter and aligning it to a

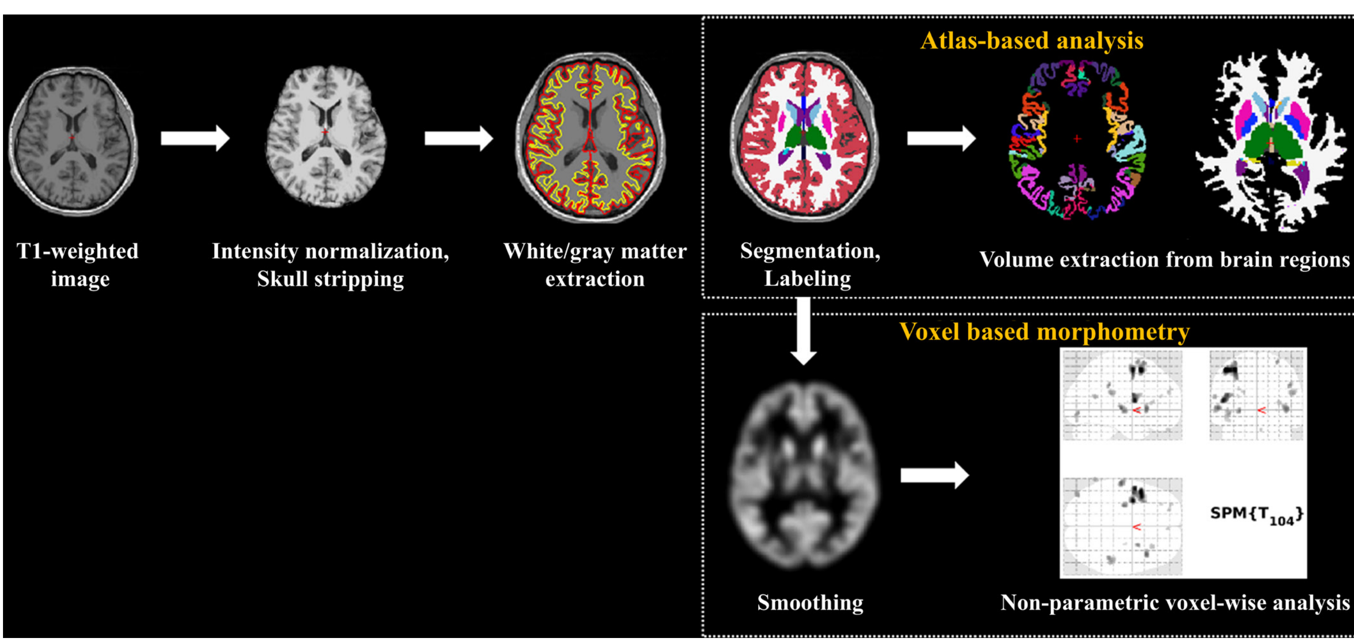

Figure 1 The process pipeline for atlas-based volume extraction and voxel-based morphometry.

standard brain template for accurate volumetric measurement. A brain template provides a standardised reference for spatial normalisation, ensuring that all individual brain images are aligned to a common space. In the next step, an atlas is applied to systematically label specific brain regions based on predefined anatomical boundaries. In the final step, cortical and subcortical regions were labelled using anatomical atlases. The Desikan-Killiany atlas was applied to parcellate the cerebral cortex into 68 distinct regions, while subcortical structures were identified and labelled based on Freesurfer's segmentation process. This step enabled the extraction of volumetric measurements from both cortical and subcortical regions, facilitating in-depth structural analysis.

Voxel-based morphometry

We analysed voxel-wise brain volumes using VBM.[14] The following steps were performed. (1) Segmentation was performed to extract a grey matter mask from the T1w MPRAGE images acquired. (2) The segmented grey matter in the T1w MPRAGE images was registered to a Montreal Neurological Institute 152 template image using nonlinear registration. This method adjusts each individual brain scan to fit a common reference brain while preserving the shape and structure of different brain regions. (3) Gaussian smoothing with an 8-mm full width at half maximum was applied to reduce noise, improve registration, and enhance statistical validity.[14] This process involves applying a mathematical filter that spreads intensity values across neighbouring voxels, effectively softening sharp variations in the image. All processes were performed using the Computation Anatomy toolbox (CAT12) for Statistical Parametric Mapping (SPM12). VBM and atlas-based volume extraction are widely used in neuroscience to quantify brain volume.[13 14] These techniques provide reliable measurements of brain morphology, which are crucial for understanding how external factors can influence brain volume at the voxel and region-of-interest levels.

Statistical analysis

Atlas-based volume analysis

We built a generalised linear model (GLM) with age, sex and total intracranial volume (TIV) as covariates to compare the brain volumes of the overworked group with those of the non-overworked group. Brain volumes and group information were used as dependent and independent variables, respectively. The brain atlas contains 68 cortical and 45 subcortical regions. A false-discovery rate (FDR) correction was applied for multiple comparisons. We conducted Spearman's correlation analysis in the overworked group to investigate the association between weekly working hours and the volumes of brain regions, which showed significant differences between the two groups. All statistical analyses were performed using MATLAB R2023a software (MathWorks, Natick, Massachusetts, USA).

VBM analysis

A GLM was created to compare the voxel-wise brain volumes between the two groups using CAT12. In the GLM, age, sex and TIV were used as covariates, and voxels from the whole brain, excluding the white matter, were evaluated using non-parametric inference with a 5000 times permutation test. For multiple comparison correction, the family-wise error (FWE)-corrected threshold p value was used. The peak VBM value with the smallest p value in a significant cluster was used to elucidate the association with work hours. We assessed the association between weekly working hours and peak VBM values in the overworked group using Spearman's correlation analysis. In addition to Spearman's analysis, we performed GLM analyses to control for potential lifestyle confounding factors such as smoking, drinking and exercise. The GLM analyses were applied to both the significant area or voxel from the atlas-based analysis and VBM analysis.

RESULTS

The baseline characteristics of the study participants stratified according to overwork status are shown in table 1. Among the 110 participants, 32 individuals (28%) belonged to the overworked group. Differences in sex, handedness and work type according to overwork status were not significant. The participants in the overworked group were significantly younger, had lower duration of employment and were more highly educated, compared with those in the non-overworked group. However, the participants were mostly young (younger than 45 years) and, as is typical of healthcare workers, their level of education was very high.

Table 1 Baseline characteristics of study participants according to overwork status

Characteristics	Total (n=110)	Overwork: Yes (n=32)	Overwork: No (n=78)	P value
Sex				
Male	40 (36.4)	12 (37.5)	28 (35.9)	0.8387
Female	70 (63.6)	20 (62.5)	50 (64.1)	
Age (years)	36.11±9.63	35.04±9.89	38.49±9.74	0.0001
Education level				
College or university	39 (35.4)	7 (21.9)	32 (41)	0.0485
Graduate school or Higher	71 (63.6)	25 (78.1)	46 (59)	
Handedness				
Right	107 (97.3)	30 (93.7)	77 (98.7)	0.2561
Left or both	3 (2.7)	2 (6.3)	1 (1.3)	
Duration of employment (years)	8.31 (±8.62)	7.68 (±9.66)	9.82 (±9.43)	0.0002
Work type				
Health worker	46 (41.8)	13 (40.6)	33 (42.3)	0.8868
Nurse	36 (32.7)	11 (34.4)	25 (32.1)	
Physician	28 (25.5)	8 (25)	20 (25.6)	

Data are presented as n (%), or mean (±SD).

Table 2 Group differences according to overwork status and Spearman's correlation analysis of weekly working hours and brain volumes from the atlas-based analysis

	Group differences			Spearman's correlation	
	Overwork (volume, mm^3 (±SD))				
Brain area	Yes	No	P value	Rho	P value
Left caudal middle frontal	6885.88±1011.69	5752.30±714.64	<0.001	0.169	0.356

Group difference was evaluated using a generalised linear model with age, sex and total intracranial volume as covariates. The p value is false discovery rate corrected. Spearman's correlation analysis was performed between the volume of each area and weekly working hours. p value <0.05 indicates statistical significance.

The results of the atlas-based volume analysis are shown in table 2. Among the 68 cortical and 45 subcortical brain regions examined, the left caudal middle frontal gyrus was the only region showing a significant difference between groups. The overworked group exhibited a significantly larger volume in this region (6886±1012 mm^3) compared with the non-overworked group (5793±798 mm^3, p=0.006, FDR corrected). However, Spearman's correlation analysis within the overworked group did not reveal a significant association between weekly working hours and brain volume in this region (p=0.356).

The results of the VBM analysis are displayed in table 3 and figure 2. The overworked group exhibited significantly greater peak VBM in 17 regions compared with the non-overworked group (p<0.05, FWE corrected). These regions included the left middle frontal gyrus, left precentral gyrus, left rolandic operculum, bilateral superior frontal gyrus (dorsolateral), right superior temporal gyrus and left insular cortex. Spearman correlation analysis within the overworked group presented significant positive associations between weekly working hours and peak VBM values in the left middle frontal gyrus, left precentral gyrus, left rolandic operculum, left superior frontal gyrus, right superior temporal gyrus and left insular cortex. These findings suggest a potential relationship between increased workload and volumetric changes in brain regions associated with executive function and emotional regulation.

Sensitivity analyses in online supplemental tables, adjusted for smoking, drinking and exercise, confirmed the robustness of the main findings. The previously demonstrated associations

Table 3 Group differences according to overwork status and Spearman's correlation analysis of weekly working hours and peak value from the VBM non-parametric analysis

		Group differences			Spearman correlation	
		Overwork (peak VBM value (±SD))				
Brain area	x y z	Yes	No	P value	Rho	P value
Left middle frontal gyrus	−46 10 54	0.321±0.039	0.272±0.036	0.001	0.314	0.080
	−33 14 62	0.310±0.042	0.263±0.040	0.011	0.305	0.090
	−33 −2 54	0.422±0.054	0.351±0.051	0.001	0.324	0.070
	−28 54 27	0.428±0.050	0.380±0.040	0.035	0.284	0.115
	−28 40 16	0.130±0.024	0.103±0.024	0.043	0.419	0.017
Left precentral gyrus	−33 −3 40	0.084±0.024	0.065±0.016	0.025	0.411	0.019
Left rolandic operculum	−51 2 10	0.351±0.049	0.300±0.034	0.001	0.374	0.035
	−45 0 18	0.235±0.027	0.206±0.020	0.004	0.450	0.010
	−46 −9 9	0.561±0.063	0.503±0.049	0.049	0.219	0.228
Left superior temporal gyrus	−58 −18 0	0.385±0.065	0.317±0.049	0.006	0.139	0.447
Right insula	40 18 −2	0.610±0.051	0.550±0.048	0.007	0.214	0.240
Left lenticular nucleus—putamen	−27 −14 −3	0.281±0.025	0.251±0.026	0.009	0.121	0.510
Right superior frontal gyrus—dorsolateral	27 6 64	0.381±0.055	0.332±0.039	0.013	0.391	0.027
Right superior temporal gyrus	51 −33 21	0.487±0.086	0.407±0.059	0.015	0.390	0.027
Left inferior occipital gyrus	−44 −82 −8	0.478±0.089	0.400±0.056	0.016	0.326	0.069
Left fusiform gyrus	−42 −82 −16	0.469±0.072	0.404±0.052	0.038	0.264	0.145
Left insula	−45 6 −3	0.526±0.049	0.471±0.045	0.019	0.369	0.038
Left middle temporal gyrus	−63 −56 15	0.460±0.055	0.406±0.043	0.021	−0.123	0.503
Left superior frontal gyrus-dorsolateral	−21 51 22	0.317±0.045	0.277±0.032	0.03	0.581	<0.001
Right insula	30 27 8	0.307±0.049	0.265±0.034	0.032	0.313	0.081
Right gyrus rectus	4 50 −30	0.268±0.032	0.237±0.029	0.035	0.178	0.331
Right inferior parietal area	57 −46 54	0.265±0.033	0.231±0.028	0.042	0.050	0.785
Right lenticular nucleus—pallidum	27 −14 −3	0.252±0.027	0.223±0.027	0.044	0.167	0.361

Group differences were evaluated using a generalised linear model with age, sex and total intracranial volume as covariates. The p-values are family-wise error rate corrected. Spearman's correlation analysis was performed between peak VBM value from each voxel and weekly work hours. p<0.05 indicates statistical significance.
VBM, voxel-based morphometry.

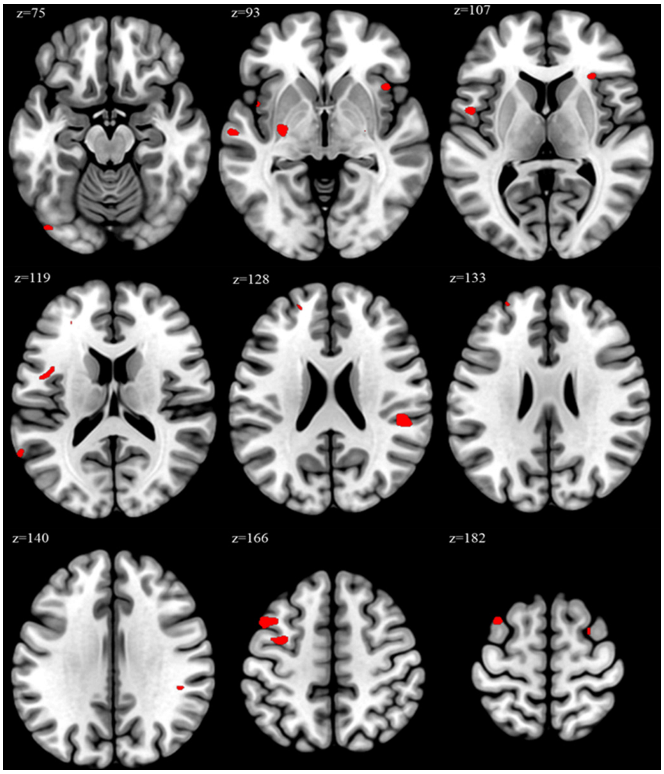

Figure 2 Results of voxel-based morphometry (VBM) analysis showing significant voxels for the contrast between overworked and non-overworked groups. Peak VBM values in the overwork group were significantly higher than those in the non-overwork group in the indicated brain regions (red areas, p<0.05, family-wise error corrected).

between working hours and peak VBM values in the left middle frontal gyrus, left rolandic operculum, left insula, and left superior frontal gyrus remained significant, whereas the association with the left caudal middle frontal region was not significant after adjustment. This suggests that lifestyle factors may partly influence some brain structural changes, but do not fully account for the observed associations.

DISCUSSION

This pilot study provides preliminary evidence of the association between overwork and structural changes in the brain, offering insights into the potential neurobiological consequences of excessive working hours on workers' health. Using atlas-based brain volume and VBM analysis, we demonstrated significant differences in regions such as the middle frontal gyrus, superior frontal gyrus, and insula—areas linked to executive function and emotional regulation. Notably, the increased brain volumes observed in overworked individuals may reflect neuroadaptive responses to chronic occupational stress, although the exact mechanisms remain speculative. While these findings should be interpreted cautiously due to the exploratory nature of the study, they highlight the critical need for further research to confirm these associations. As an attempt to systematically investigate the structural effects of overwork on the brain, this study emphasises the importance of addressing long working hours as a key determinant of workers' cognitive and emotional health.

Our data describe the negative effects of long working hours as a result of altering brain structure. In our study, the overworked group showed higher brain volume in the areas which regulate executive function: the left middle frontal gyrus, left precentral gyrus, bilateral superior frontal gyrus-dorsolateral, and insula.[15 16] Previous studies showed a decline in cognitive ability when working long hours.[17] Several studies have reported that grey matter volume and thickness are related to executive function.[18 19] Based on this information, we assume that our data provide a link between harmful effects of working long hours and brain structure.

Also, our data showed an increased brain volume in the overworked group in the right superior temporal gyrus, left insula, left rolandic operculum, and left middle frontal gyrus, which involve emotional regulation.[20] Working long hours is known to cause mental health problems, such as depression and anxiety.[21 22] Studies have shown that grey matter abnormalities in some areas of the brain change not only in patients with depression,[23] but also in those with subclinical and mild depression.[24 25] Similar findings have been reported in studies on patients with generalised anxiety disorders.[26 27] Consequently, we believe that the alterations in brain volume in overworked individuals may provide a biological explanation for the adverse health effects of working long hours.

Another explanation for our results could be the occupational stress and sleep deprivation induced by long working hours. Occupational stress increases with long working hours,[28 29] and in people with high levels of occupational stress, grey matter volumes correlate with stress level.[30] In addition, people who work long hours complain of sleep disturbances,[8 31] and sleep problems appear to be linked to changes in grey matter volume.[32 33] Further studies are required to determine whether the increase in brain volume is secondary to long-term work.

Recently, MRI studies have revealed evidence of a significant relationship between overwork and structural changes in the brain.[4 34] Ueno *et al* demonstrated a significant positive correlation between domestic work hours and grey matter volume in the superior frontal gyrus in 53 female participants.[34] Matsumoto *et al* also showed a negative correlation between work hours and mean diffusivity values in the anterior limb of the internal capsule and superior fronto-occipital fasciculus in 483 healthy participants, using diffusion tensor imaging. This correlation was especially pronounced for paid employment, suggesting that external motivation may significantly impact white matter structure.[4] Although previous studies have shown changes in different brain regions, they support the notion that working hours can influence executive function in healthy individuals.

However, an increase in the volume, thickness and density of grey matter is commonly interpreted as strengthening of that brain region, as such changes are known to be caused by learning or practice.[35 36] Our data showed an increase in brain volume, which can be interpreted as a positive change. Although research has shown that grey matter is not necessarily positively correlated with brain function, conflicting data have been reported. Some studies have reported a negative association among grey matter volume, cortical thickness and executive function.[18 19] In the case of emotions, individuals with subclinical and mild depression show increased grey matter volumes.[24 25] Because MRI results are not biologically specific, and the exact pathogenesis of grey matter changes is unknown,[37] the presence of significant differences would be meaningful, regardless of whether it is an increase or decrease.

Overwork is a combination of physical and emotional overexertion and a lack of rest. Overuse and lack of rest can negatively affect the brain.[38 39] Our findings reveal significant adverse brain structural differences in the overworked group versus the non-overworked group. The impact of brain structures should be included in discussions on appropriate working hours to protect worker health.

This study has several limitations that should be acknowledged. First, as a pilot study with a relatively small sample size, the findings may lack generalisability to broader populations and should be interpreted with caution. Second, the cross-sectional nature of this study limits the ability to infer causal relationships between overwork and brain structural changes. The observed associations may be influenced by unmeasured confounders or pre-existing differences rather than a direct effect of prolonged working hours. Without longitudinal data, it remains unclear whether these structural changes are a consequence of overwork or a predisposing factor. Future longitudinal studies are essential to track temporal changes and establish a clearer causal link between working conditions and neurobiological alterations. Third, the classification of working hours into a binary distinction (≥52 hours vs <52 hours), while legally and epidemiologically justified in Korea, differs from the more detailed stratifications (eg, <41, 41–48, 49–54, ≥55 hours) used in some prior studies.[1] Although a finer classification could provide additional insights, our approach was chosen to align with Korea's Labour Standards Act and existing occupational health research, which identifies 52 hours as a critical threshold for increased health risks. Additionally, given our sample size (n=110, with 32 in the overworked group), further stratification would have reduced statistical power, potentially compromising the robustness of our neuroimaging analyses. Future studies with larger cohorts should adopt a more granular categorisation of working hours to explore potential dose-dependent effects and provide a more detailed understanding of the neurobiological impact of prolonged work hours. Fourth, potential confounders such as unmeasured lifestyle factors (eg, physical activity, diet or alcohol consumption) and psychological variables (eg, stress or resilience) may influence the observed brain volume changes. While we adjusted for key covariates such as age, sex and total intracranial volume, residual confounding cannot be ruled out. Fifth, the generalisability of our findings may be limited due to the study sample consisting solely of healthcare workers in Korea. Healthcare workers often experience higher physical and psychological workloads compared with the general workforce, and their occupational characteristics may differ significantly.[40] Therefore, it remains unclear whether the observed brain structural changes apply to other occupational groups. Future research should investigate a broader range of populations, including non-healthcare workers from various industries and cultural backgrounds to assess the broader applicability of these findings. Moreover, studies that consider socioeconomic factors and differences in working environments could further enhance our understanding of how prolonged working hours impact brain structure across diverse populations. Finally, while our study discusses potential mechanisms underlying the observed structural changes—such as neuroadaptive responses, chronic stress and sleep deprivation—these remain speculative due to the cross-sectional nature of the study and the lack of direct physiological measurements. Given the limited existing research on the neurobiological impact of overwork, our study serves as an initial exploratory step rather than a definitive causal analysis. Future longitudinal studies incorporating serial neuroimaging, biomarkers of stress and neuroplasticity, and detailed sleep assessments are needed to establish temporal relationships and clarify whether these structural changes represent compensatory adaptations or early signs of neural dysfunction. Additionally, functional MRI and diffusion tensor imaging could provide deeper insights into whether these volumetric differences translate into functional connectivity alterations. Despite these limitations, this study represents a significant first step in exploring the neural correlates of overwork, providing a foundation for further investigations in occupational health and neuroscience.

Conclusion

This study highlights the potential impact of overwork on brain structure, identifying significant differences in brain regions related to executive function and emotional regulation among overworked individuals. By ulising atlas-based brain volume and VBM analyses, we provided preliminary evidence linking prolonged working hours with structural brain changes. While the results should be interpreted cautiously due to the exploratory nature of this pilot study, they represent a meaningful first step in understanding the relationship between overwork and brain health. The observed changes in brain volume may provide a biological basis for the cognitive and emotional challenges often reported in overworked individuals. Future longitudinal and multi-modal neuroimaging studies are warranted to confirm these findings and elucidate the underlying mechanisms. By integrating neuroscience into occupational health policies, this research emphasises the need to develop interventions that protect workers' mental and physical well-being in the face of increasing work demands.

Contributors Conceptualisation: JYC and WL. Data curation: YK, SL and WL. Formal analysis: WJ, SK, YK, SL and JYC. Funding acquisition: WL. Investigation: WJ and SK. Methodology: WJ, SK, JYC, and WL. Project administration: JYC and WL. Resources: YK, SL and WL. Supervision: JYC and WL. Validation: JYC and WL. Writing – original draft: WJ, SK, YK, SL, JYC and WL. Writing – review and editing: JYC and WL. All authors read and approved the final manuscript, and the guarantors of this paper are JYC and WL.

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Competing interests None declared.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval Studies involving human participants were reviewed and approved by the Institutional Review Board (IRB) of Chung-Ang University (IRB number: 1041078-20231024-HR-287). Participants gave informed consent to participate in the study before taking part.

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