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Hippocampal Subfields Volume Reduction in High Schoolers with Previous Verbal Abuse Experiences

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Objective: Reduced hippocampal volume and alterations in white matter tracts have been frequently reported in adults having the history of emotional maltreatment. We investigated whether these structural change occur in adolescents with previous verbal abuse (VA) experiences.

Methods: Hippocampal subfield volume and white matter structural connectivity measures were assessed in 31 first year male high school students with various degrees of exposure to parental and peer VA.

Results: The high VA group showed significant volume reduction in the left cornu ammonis (CA) 1 and left subiculum compared to the low VA group ($p < 0.05$). Volumes of left hippocampal subfields CA1 and subiculum were negatively correlated with previous VA experiences ($p < 0.05$). Increased mean diffusivity (MD) of the splenium of the corpus callosum was related to high VA score across all subjects ($p < 0.05$). There was an inverse relationship between volume of the CA1 and subiculum and MD of the splenium ($p < 0.05$).

Conclusion: Exposure to parental and peer VA may affect development of the left hippocampal subfields and the splenium of corpus callosum. These structural alterations can be discernible during adolescence.

KEY WORDS: Hippocampus; Diffusion tensor imaging; Parenting; Adolescent.

INTRODUCTION

Childhood maltreatment is a major risk factor for behavioral problems and psychiatric disorders.^{1,2} Previous studies make efforts to find structural changes of brain in the victims of childhood maltreatment. Among various structural changes, diminished hippocampal volume has been frequently reported in studies of adults with childhood maltreatment history.³⁻⁸ Psychopathology related to childhood maltreatment, such as post-traumatic stress disorder, can inhibit the development of hippocampus.^{9,10} However, while some studies have reported hippocampal

volume reductions in maltreated children and adolescents,¹¹⁻¹³ many studies have not.¹⁴⁻¹⁹

One reason why maltreatment-associated alterations in hippocampal volume have been reported more consistently in adults than children, is that early stress may have a delayed effect on hippocampal development.^{20,21} Based on animal studies it is likely that robust effects of early life stress on hippocampal volume emerge between onset of puberty and early adulthood.²⁰ However, this needs to be determined in humans. Furthermore, most studies have not assessed volume of specific hippocampal subfields because methods for automated segmentation have recently been developed.^{22,23} A recent study with young adults with verbal abuse (VA) experiences revealed that the specific hippocampal subfields, such as the left cornu ammonis (CA) 3, dentate gyrus (DG), and subiculum can be more vulnerable than the others.²⁴

In addition to hippocampal structure differences, sev-

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eral studies have reported abnormalities in white matter structural connectivity. In particular, diffusion tensor imaging (DTI) studies of maltreated individuals report diminished integrity in several white matter tracts including: uncinate fasciculus,^{25,26} cingulum bundle,²⁵⁻²⁷ corpus callosum,^{28,29} fornix,^{25,27} superior longitudinal fasciculus^{26,27,30} and inferior longitudinal fasciculus.³¹ Although several major fibers, such as cingulum bundle and fornix, connect hippocampus with other brain structures,³² the lack of studies explores the relationship of hippocampal alteration with the change in the integrity of the fiber tract. Furthermore, while major white matter tracts are matured during adolescence,^{33,34} most of those studies focused on children^{25,29} or adult subjects.^{22-24,27} Therefore, alteration in white matter structural connectivity and its relationship with the development of hippocampus are needed to be verified in adolescents with childhood maltreatment experiences.

One of the major aims of the current study was to determine whether exposure to parental and peer VA were associated with diminished hippocampal subfield volume measures in adolescents. We evaluated effects of parent and peer verbal aggression on hippocampal subfields volume in first year high school students as they are likely at a stage of maturity when maltreatment related volume differences may become apparent. Further, they have recently passed through a developmentally sensitive period (11-13 years) when the hippocampus may be particularly susceptible.³⁵ Additionally, white matter structural connectivities were measured so as to determine if maltreatment related differences in subfield volume correlated with alteration in the integrity of specific fiber pathways. We expected that volume reduction in the specific hippocampal subfields and alterations in white matter tracts that may connect hippocampus with other brain regions become clear in adolescents.

METHODS

Subjects

To recruit preclinical subjects, we advertised our study as an investigation of language use in Korean adolescents to high school students (1st year). We explained detailed information about our study to the students who want to attend this study. Forty-three high school (1st year) male subjects agreed to participate in this study. Two psycholo-

gists interviewed with participants using the Kiddie-Schedule for Affective Disorders and Schizophrenia-Present and Lifetime version-Korean version (KSADS-PL-K) and Wechsler Intelligence Scale for Children-Revised to evaluate the subjects' psychiatric history and intelligence quotient (IQ), respectively. Three authors in this study (one child psychiatrist and two psychiatrists) reviewed the results of KSADS-PL-K of participants to exclude participants with psychiatric disorders. Also, subjects who reported overt sexual or physical abuse experiences were excluded in our study. We thought considering all types of abuse can be confounding factors in a small sample study since effects of abuse experiences varies depending on the types of abuse.³²

Exposure to parent or peer VA was assessed using the Korean version of the Verbal Abuse Questionnaire (VAQ).³⁶ A score of 40 or above on the VAQ was defined as substantial exposure for peer VA²⁸ and high-level exposure for parental VA²⁷ in previous studies. This cutoff point was verified in our previous validation study of the Korean version of the VAQ with 5,814 young adults.³⁶ Symptoms of anxiety and depression were evaluated using the State-Trait Anxiety Inventory (STAI)³⁷ and Beck Depression Inventory (BDI).³⁸

Exclusion criteria of the study were previous/current psychiatric history or sexual/physical abuse history, full-scale IQ less than 70, significant head trauma or brain disease history, or any contraindication for functional magnetic resonance imaging (fMRI). Of the 43 subjects, twelve subjects were excluded based on the pre-established criteria: seven subjects with low IQs (<70), two subjects with a history of a major depressive disorder, one subject who reported a previous traffic accident, one sub-

Table 1. Characteristics of the subjects

Characteristic	Data
Age (yr)	16.12±0.48
Intelligence quotient	101.42±17.41
Total VAQ	65.94±25.27
Peer VAQ	37.77±18.07
Parental VAQ	28.16±10.92
Beck Depression Inventory	5.06±4.32
State-Trait Anxiety Inventory-State	40.35±7.67
State-Trait Anxiety Inventory-Trait	46.55±6.61

Values are presented as mean±standard deviation.
VAQ, Verbal Abuse Questionnaire score.

ject with a craniopharyngioma (suspicious) in the nasal cavity, and one subject who reported severe VA history (VAQ score >3 standard deviation [SD]). Finally, 31 subjects (mean age, 16.12; SD, 0.48) were used for statistical analysis. All of the 31 subjects represented no previous/current psychiatric history including depressive disorder, anxiety disorder, psychotic disorder and substance abuse in KSADS-PL-K. Characteristics of the subjects were described in Table 1.

For group comparisons, subjects were divided into low VA ($n=15$) and high VA ($n=16$) groups, based on the scores of peer and parental VAQ using k-means clustering analysis. This data-driven classification method created a low VA group in which no subject had substantial exposure to either peer or parental VA (Fig. 1). As expected, mean scores in the low VA group (peer VAQ, 22.4; parental VAQ, 21.5) were significantly lower than in the high VA group (peer VAQ, 52.2; parental VAQ, 34.4) (all $p < 0.01$).

All subjects and their parents voluntarily joined this study with written consent. The study was approved by the Ethics Committee of Korea Advanced Institute of Technology (KAIST; KH2012-27).

Image Acquisition

All MRI images were acquired at 3.0 Tesla (MAGNETOM[®] Verio; Siemens, Erlangen, Germany). A high resolution structural image was obtained with a T1 weighed sequence (TI=900 ms, TR=1800 ms, TE=2.52 ms, flip angle=9°, FOV=256×256 mm, slice thickness=1 mm, voxel

size=1×1×1 mm). A DTI was also acquired with 64 encoding directions and the following parameters: $b=1,000$ s/mm², TR=9,700 ms, TE=93 ms, FOV= 230×230 mm, slice thickness=2.5 mm, voxel size=1.8×1.8×2.5 mm. In addition, our subjects also finished task-based fMRI scan, and the results of fMRI are recently published.³⁹⁾

The Analyses of Hippocampal Subfields

Both automated cortical parcellation and volumetric segmentation were performed using Freesurfer software version 5.3.0 (<http://freesurfer.net>), while the hippocampus was analyzed using recently improved segmentation procedures now included in version 6.²³⁾

Overall, the segmentation process consisted of two steps; extraction of the cortical surface and modeling of the cortical surface.⁴⁰⁻⁴⁴⁾ In the cortical extraction step, motion correction, automated Talairach transformation, skull stripping, segmentation of the subcortical structures and intensity normalization were included. In the cortical modeling step, tessellation of the gray-white matter boundary using segmented white matter, automated topology correction, and surface deformation for placing the surface within the optimal boundary. After the cortical models were made, cortical thickness using Euclidean distance between vertices and cortical volume was measured. The volumes of thirteen hippocampus subfields including the CA1, CA3, CA4, DG, and subiculum were automatically segmented using Bayesian inference based on the computation atlas that combines *in vivo* and ultra-high resolution *ex vivo* MRIs images.²³⁾ An estimated total intracranial volume (eTIV) was also acquired to control the effects of variation of head sizes.

Partial correlation analysis was used to evaluate the relationships between the volumes and VA experiences using the scores of total VAQ, peer VAQ, and parental VAQ. In addition, analysis of covariance (ANCOVA) was used to determine if there were group differences in thickness and hippocampal subfield volumes. Age, total IQ, and eTIV were included as covariates, and p value less than 0.05 represented statistical significance in these analyses.

The Analyses of White Matter Connectivity Using Tract-based Spatial Statistics (TBSS)

One subject who was in the low VA group was excluded in the DTI analysis due to poor cooperation. The DTI was processed using FMRIB's Diffusion Toolbox in

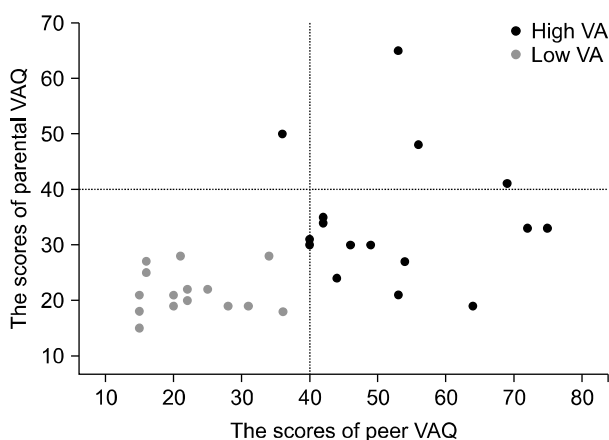


Fig. 1. Scatterplot of the Verbal Abuse Questionnaire (VAQ) scores in the subjects. The dashed line represents the cutoff point 40 of the VAQ.

FMRI Software Library v5.0. After correcting for eddy current distortions and head motion, fractional anisotropy

Table 2. The results of partial correlation analysis between VAQ score and hippocampal subfields

Measure	PeVAQ	PaVAQ	ToVAQ
Right CA1	-0.192	-0.084	-0.171
Right CA3	-0.141	-0.242	-0.201
Right CA4	-0.087	-0.127	-0.115
Right DG	-0.115	-0.140	-0.140
Right subiculum	-0.120	0.005	-0.083
Right total	-0.242	-0.175	-0.245
Left CA1	-0.445 [†]	-0.341	-0.458 [†]
Left CA3	-0.326*	-0.214	-0.321*
Left CA4	-0.342*	-0.207	-0.329*
Left DG	-0.355*	-0.189	-0.331*
Left subiculum	-0.385 [†]	-0.271	-0.386 [†]
Left total	-0.467 [†]	-0.306	-0.459 [†]

VAQ, Verbal Abuse Questionnaire; CA, cornu ammonis; DG, dentate gyrus; PeVAQ, peer VAQ score; PaVAQ, parental VAQ score; ToVAQ, sum of peer and parental VAQ scores.

* $p < 0.1$, [†] $p < 0.05$.

(FA), radial diffusivity (RD), axial diffusivity (AD) and mean diffusivity (MD) of each voxel was measured using a diffusion tensor model. A mode of anisotropy (MO) was used to provide complimentary information related to tract anisotropy, such as crossing or kissing fiber.⁴⁵⁾ Using TBSS pipeline,⁴⁶⁾ FA maps in each subject space were projected into the $1 \times 1 \times 1 \text{ mm}^3$ MNI152 space. A skeletonized FA image was created with a mean FA image in each subject. All FA images were projected onto the mean FA skeleton and were thresholded using an FA value of 0.2 to reduce inter-subject variability. Other diffusion metrics images were projected onto the skeleton using a transformation matrix for FA map. The skeletonized maps consisting of FA, MD, AD, MD, and MO were used to assess the group differences and correlation with the VAQs (peer VAQ, parental VAQ, and total VAQ). In the group analyses, non-parametric multiple comparison correction was performed with 10,000 random permutations and a two-dimensional threshold-free cluster enhancement option were used. The threshold for statistical significance

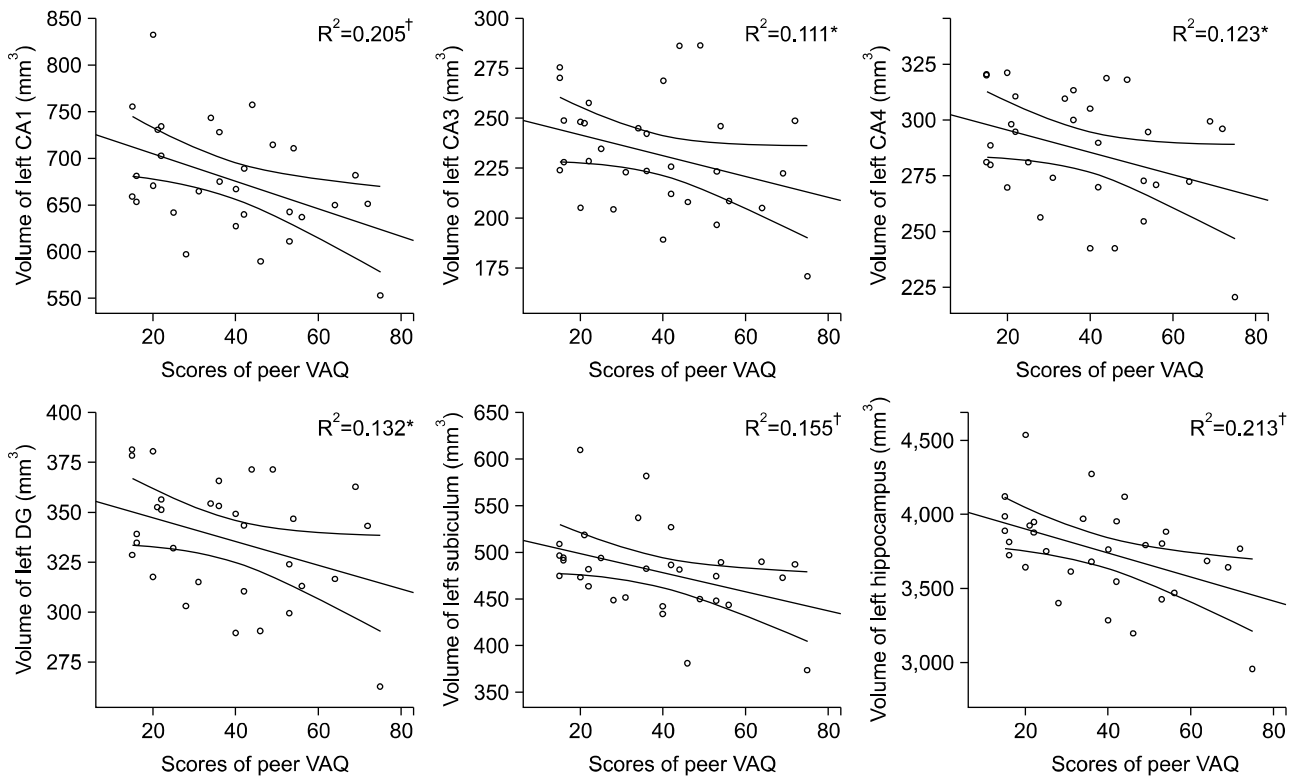


Fig. 2. Regression graph showed relationships between the volumes of left hippocampal subfields and peer Verbal Abuse Questionnaire (VAQ) scores.

CA, cornu ammonis; DG, dentate gyrus.

* $p < 0.1$, [†] $p < 0.05$ (in partial correlation analysis).

was a corrected $p < 0.05$. Age and total IQ were used as covariates. TrackVis (version 0.6.0.1), which is available at <http://www.trackvis.org>, was used for streamline tractography.

RESULTS

Relationships between the Volumes of Hippocampal Subfields and Previous Verbal Abuse Experiences

In partial correlation analysis, previous VA experiences were significantly correlated with the volumes of the left CA1 ($r = -0.458$, $p = 0.014$ for total VAQ; $r = -0.445$, $p =$

Table 3. Group differences of hippocampal subfields

Measure (mm ³)	Low VA (n=15)	High VA (n=16)	Analysis, $F(1,26)$	Effect size, PES
Right CA1	756.8±89.5	728.4±79.3	0.59	0.02
Right CA3	250.2±33.5	241.5±42.0	0.03	0.01
Right CA4	301.6±31.2	294.2±36.5	0.14	0.01
Right DG	354.6±35.4	344.6±39.9	0.25	0.01
Right fimbria	106.2±10.4	105.9±19.2	<0.01	<0.01
Right subiculum	494.7±43.3	482.8±47.5	0.13	0.01
Right presubiculum	335.1±38.8	327.4±43.3	0.04	<0.01
Right total	4,011.0±346.2	3,846.8±364.7	1.12	0.04
Left CA1	703.3±59.1	656.0±50.2	4.27*	0.14
Left CA3	238.8±20.7	226.3±33.3	0.92	0.03
Left CA4	294.5±20.7	279.2±28.6	1.81	0.07
Left DG	346.0±24.5	327.9±32.2	2.06	0.07
Left fimbria	113.9±17.3	109.8±20.4	0.02	<0.01
Left subiculum	501.7±45.4	460.1±40.3	5.45*	0.17
Left presubiculum	339.1±29.0	320.8±34.9	1.79	0.06
Left total	3,899.2±275.6	3,624.4±299.1	5.30*	0.17

Values are presented as mean±standard deviation.

VA, verbal abuse; PES, partial eta squared; CA, cornu ammonis; DG, dentate gyrus.

* $p < 0.05$.

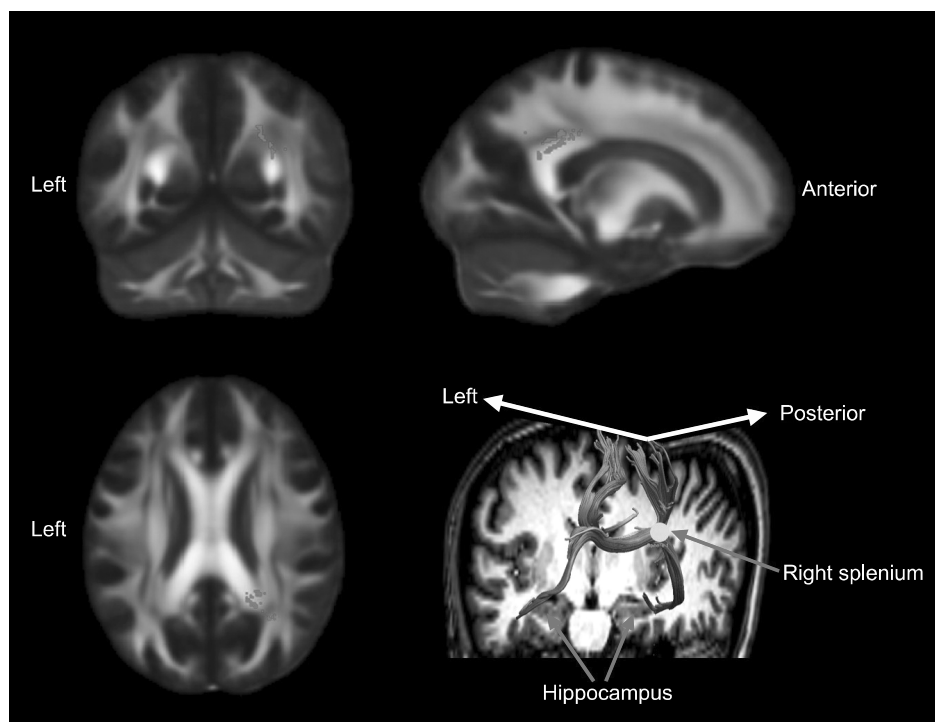


Fig. 3. The white matter region that showed a positive correlation with total Verbal Abuse Questionnaire (VAQ) scores. The mean diffusivity of splenium of corpus callosum and right posterior corona radiata showed a significant positive relationship with total VAQ scores (corrected $p < 0.05$). Montreal Neurological Institute (MNI) coordinates were X=28, Y=-55, Z=23. The background images are MNI152 templates.

0.018 for peer VAQ) and subiculum ($r = -0.386$, $p = 0.043$ for total VAQ; $r = -0.385$, $p = 0.043$ for peer VAQ) (Table 2). Also, other left hippocampal subfields (CA1, CA3, CA4, and DG) showed marginally significant relationship with previous VA experiences (total VAQ and peer VAQ) (all $p < 0.1$) (Table 2, Fig. 2). The scores of behavioral measurements including BDI and STAI scores did not show any significant correlation result with the volumes of hippocampal subfields.

In two group comparison analysis using ANCOVA, the high VA group showed significant volume reduction in the left CA1 and left subiculum compared to the low VA group (Table 3).

Relationships between the White Matter Connectivity and Previous Verbal Abuse Experiences

There was a significant positive correlation between MD in the splenium of the corpus callosum overlying the right corona radiata with total VAQ scores (corrected $p < 0.05$; Fig. 3). There were no other significant correlations with other measures of diffusivity and no significant group difference was found in FA, RD, AD, MD, and MO values between the high and low VA groups. Also, the scores of behavioral measurements including BDI and STAI scores did not show any significant correlation result with the measurements of white matter connectivity.

Relationship between Volume of Hippocampal Subfields and MD in the Region of the Splenium of the Corpus Callosum

MD values were extracted from the region of interest (ROI) within the splenium of the corpus callosum (voxel size=11, corrected $p < 0.04$) and showed high degree of significance in the correlation analysis with the volume of hippocampal subfields. Across all subjects, MD values in the ROI showed significant negative relationships with volumes of the left CA1 ($r = -0.481$, $p = 0.011$), left CA4 ($r = -0.424$, $p = 0.027$), left DG ($r = -0.387$, $p = 0.046$), and left subiculum ($r = -0.420$, $p = 0.029$). Streamline tracts generated from the ROI within the splenium reached bilateral hippocampus (Fig. 3).

DISCUSSION

In our results, first year high school students who reported high levels of exposure to VA had smaller volumes

of the left CA1 and subiculum compared to students who reported low levels of exposure to VA. Furthermore, white matter changes involving the splenium of the corpus callosum revealed significant relationships with VA experiences and with hippocampal subfield reduction.

The volume of human hippocampus increases through adolescence.⁴⁷ The hippocampus has a high density of corticosteroid and corticotropin-releasing hormone (CRH) receptors, and exposure to early life chronic stress, which induces the release of CRH and corticosteroid, is associated with the structural atrophy of hippocampus.⁴⁸⁻⁵⁰ In line with previous studies,^{3,4,24,51} only left hippocampal subfields volume showed significant negative correlations with VA experiences in our study. Left hippocampus is particularly involved in autobiographical event memory processing.⁵² Childhood maltreatment experiences can influence more on left than right hippocampus. Also, the deleterious effects of stress hormones, such as corticosteroid, on hippocampus occurs through excitatory pathway mediated by *N*-methyl-D-aspartate (NMDA) receptors.⁵³ Differential distribution of NMDA receptor subunits between the left and right sides hippocampus is reported,⁵⁴ and lateralization of stress-susceptibility can be aroused by asymmetrical distributions of NMDA receptors between the left and right hippocampus.⁵⁵ Furthermore, it is unclear why the left CA1 and subiculum appeared to be more significantly associated with degree of exposure to VA than other subfields, but some previous studies lend credence to this observation. First, previous studies have reported that the CA1 subfield is more vulnerable to corticosterone administration,⁵⁶ metabolic insult,⁵⁷ and ischemic injury^{58,59} than other hippocampal subfields. Second, chronic early life stress induces dendrite atrophy in the CA1 pyramidal neuron.^{50,60} Third, the density of glutamatergic receptor (NMDA) is higher in the CA1 than in the CA3 and DG.⁶¹ Chronic stress can increase glutamatergic transmission that can be associated with a metabolic vulnerability.⁶² In addition, the subiculum subfield seems to be closely connected to the stress system and involved in glucocorticoid negative feedback.^{63,64} The subiculum has abundant glucocorticoid receptors;^{65,66} several studies reported higher density of glucocorticoid receptor in subiculum than in other hippocampal subfields, such as the CA3, CA4,⁶⁷ and DG.⁶⁸ Therefore, the changes in the CA1 and subiculum could be sensitive markers in the victims of VA.

Other left hippocampal subfields including the CA3 and DG also showed marginally significant relationships with previous VA experiences in this study. There are many studies that suggested susceptibility to chronic stress in other hippocampal subfields including the CA3.⁶⁹⁾ In animal studies, single or repeated stress reduces brain-derived neurotrophic factor gene expression in the CA3 and DG⁷⁰⁾; chronic stress suppress neurogenesis in the DG and remodeling of CA3 pyramidal cells.^{48,71,72)} In sum, volume reductions in left hippocampal subfields can be generally affected and both the CA1 and subiculum may be more susceptible to VA experiences in a dose-dependent pattern.

In a study of adults with maltreatment, the strongest associations with number of types of abuse and severity of abuse were found in the left CA2-3, CA4-DG, and subiculum.²⁴⁾ Recently developed method for hippocampal subfields analysis provide a more accurate measure of the CA1 volume,⁷³⁾ and reassign a significant portion of the CA2-CA3 to CA1. Therefore, our results on the left CA1 and subiculum volume reductions may be similar to the results of previous studies in adult^{8,24)} and pediatric participants.¹²⁾ One reason why we may have observed maltreatment associated differences in hippocampal volume in relatively young adolescents is that all of our participants were males. Prior reports suggest that the hippocampus appears to be much more vulnerable to effects of maltreatment in males than in females.^{74,75)}

Multiple factors including genetic predisposition and environmental stressors affect the development of psychopathology.⁷⁶⁾ Among multiple factors, small hippocampus can be a vulnerability factor for future psychiatric illnesses. In a recent large-scale study, small hippocampus volume is significantly related to major depressive disorder⁷⁷⁾ as well as schizophrenia.⁷⁸⁾ Also, subjects with small hippocampus volume are vulnerable to psychological trauma.⁷⁹⁾ It is still unclear whether small volume of hippocampus results from the neurotoxic effects of psychiatric illnesses or represents a vulnerable factor for future psychiatric illnesses. In our study with healthy subjects, symptoms of depression and anxiety did not account for hippocampus volume reduction. Although additional study to confirm causality between hippocampus volume reduction and VA experiences, we suspect that small hippocampus volume related to VA experiences is an objective risk factor that makes the brain more vulner-

able to psychiatric illnesses. Therefore, we suggest that adolescents with VA experiences and related volume reduction in the hippocampus are should be closely observed to prevent or detect future psychiatric illnesses.

While no significant group difference was reported in white matter connectivities, the MD of the splenium of the corpus callosum involving the right posterior corona radiata was positively related to the total VAQ scores. In studies of normal healthy people, 11-12 years of age is the starting point where the growth of the posterior part of the corpus callosum is dominant over the anterior part⁸⁰⁾; the MD of the splenium of the corpus callosum is lower in young adults than in children in the age range 9.4 to 11.5 years⁸¹⁾ or 8 to 12 years.⁸²⁾ In a longitudinal DTI study, a large percentage of subjects in 15 to 22 years group had decreasing the MD in splenium of corpus callosum.⁸³⁾ Therefore, the MD of the splenium may decrease throughout the period of mid to late teens in normal development, and decrement of MD seems to be related to maturation. Further, our results support previous studies that showed alterations of the splenium of the corpus callosum in victims of peer VA²⁸⁾ and neglect.⁸⁴⁾

It is unclear whether the changes in the hippocampal subfields and corpus callosum are associated or independent in our cross-sectional design. However, the hippocampal commissure is closely related to the splenium of the corpus callosum⁸⁵⁾ and crosses the midline under the splenium.⁸⁶⁾ In mouse studies, the hippocampal fissure is formed earlier than the splenium of the corpus callosum, and it seems to be mediated by a growth substrate.^{87,88)} In studies of early Alzheimer disease, which representatively affects hippocampal region alteration, abnormalities of the hippocampus and splenium of corpus callosum simultaneously occur⁸⁹⁾ and represent a direct correlation when applying a permissive threshold.⁹⁰⁾ Our correlation result also supports the relationship between the changes of the splenium and hippocampal subfields. However, the causality or trajectory of these changes should be investigated in future longitudinal studies.

Our study has several limitations. First, our results cannot be generalized to females because only male subjects were studied, and there appear to be significant gender differences in hippocampal susceptibility to maltreatment.^{7,74)} Second, due to the cross-sectional design, our results only explain current states that may vary with brain development and cannot confirm the effects of small hip-

pocampus on future psychiatric illnesses. Also, it is possible that subjects with small hippocampus or altered anatomical connectivity may be vulnerable to abuse experiences. Our study cannot verify the causality among hippocampus volume, anatomical alteration, and VA experiences. Thus, a longitudinal design is needed to track the development of psychiatric illnesses and the changes in the volume of hippocampal subfields, white matter connectivity, and cortical structures. Third, although hippocampal volume findings were correlated with degree of exposure to VA, we cannot conclude that VA was the primary determinant as degree of exposure to other types of maltreatment were not quantified, and there are significant correlations between degree of exposure to peer and parental VA and other forms of maltreatment.⁹¹⁾ In particular, adolescents who experience peer VA have often been exposed to earlier abusive experiences, and peer victimization may mediate the association between early abuse and psychopathology.⁹²⁾ Prior studies reporting significant associations between parent and peer VA and brain measures specifically eliminated subjects who were exposed to any other forms of maltreatment.^{24,27,93)} Fourth, although we set the cutoff score based on previous studies with young adults,^{27,28,36)} the cutoff score in VAQ of 40 is not rigorously validated in adolescents. To compensate this limitation, cluster analysis was used to define high or low VA groups. In the aspect of the continuum of the VAQ score, we also conducted group comparison analysis as well as correlation (regression) analysis. Fifth, our small sample size could reduce explanatory power of our results.

In spite of the limitations, our results provide further support for maltreatment related effects on hippocampal development and show that they are discernible in male high school freshman. As the hippocampus plays an important role in formation and retrieval of memories this may have important implications for school performance. Members of our society need to put more effort into protecting our children, especially during developmentally sensitive periods, from emotional abuse in order to promote healthy hippocampal development.

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