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The relationship between brain morphology and psychopathy – literature review

Związek pomiędzy zmianami morfologicznymi mózgu a psychopatią – przegląd literatury

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Abstract

Introduction: Psychopathy is a neuropsychiatric disorder characterized by deficient emotional responses, lack of empathy, shallow affect and a greater tendency to be impulsive. Some studies suggest that there could be differences in e.g. the cavum septum pellucidum and amygdalae in psychopaths' brains compared to non-psychopaths.

Material and methods: The aim of this paper is to review current studies on cases of people with psychopathy. A PubMed search was conducted using keywords such as "Psychopathy" and "Psychopathy brain". In the selection of publications, brain structure that was examined, substance abuse as a covariate and the year of publication were important. Publications not available in English were excluded.

Results: Studies have shown that there are differences in the morphology of brain structures, for example the nucleus accumbens and amygdala, observed in people with psychopathy compared to controls. Psychopaths also showed cortical thinning, most significant in the left insula. In people with substance use disorder a reduced volume of gray matter was observed in the prefrontal cortex, the orbitofrontal cortex and in the premotor area of the cerebral cortex.

Conclusions: Structural differences in the brain were described in people with psychopathic traits. The conclusions of some of the analyzed studies were similar to each other, but others were not. Substance use disorder/substance abuse can affect the results of research and should be counted as a covariate. There is a need for further studies of described brain structures using same covariates for better understanding of the brain structure-psychopathy relationship.

Key words: amygdala, psychopathy, septum pellucidum, psychopaths, brain morphology.

Streszczenie

Wstęp: Psychopatia to neuropsychiatryczne zaburzenie, które charakteryzuje się m.in. zubożeniem reakcji emocjonalnych, wysokim intelektem i większą skłonnością do impulsywności. Narzędziem do oceny występowania tego zaburzenia jest skala psychopatii Hare'a (PCL-R). Część badań sugeruje, że u psychopatów mogą istnieć różnice w budowie niektórych struktur mózgu (np. ciała migdałowatego) w porównaniu z osobami bez psychopatii.

Materiał i metody: Dokonano analizy prac znajdujących się w bazie PubMed. W wyborze publikacji istotne było, by pacjenci opisani w danej pracy naukowej prezentowali cechy psychopatii (skala PCL-R, PCL-SV). We wszystkich publikacjach autorzy korzystali z obrazowania mózgu przy użyciu rezonansu magnetycznego. Kryterium wyboru było również to, jaka struktura była badana, analizowanie nadużywania substancji psychoaktywnych jako współzmiennej oraz rok publikacji. Wykluczono publikacje niedostępne w języku angielskim.

Wyniki: Przegląd piśmiennictwa pokazał, że istnieją różnice w budowie niektórych struktur mózgowia, np. ciała migdałowatego, u osób z psychopatią w porównaniu z grupą kontrolną. Stwierdzono też występowanie wyższych wskaźników psychopatii u dorosłych z jamą przegrody przezroczystej. U osób uzależnionych od substancji psychoaktywnych obserwowano zmniejszoną objętość istoty szarej w korze przedczołowej, korze okołooczodołowej i w obszarze pola przedruchowego kory mózgowej, czego nie odnotowano u osób z cechami psychopatycznymi.

Wnioski: U osób wykazujących cechy psychopatyczne opisano zmiany strukturalne w mózgu, takie jak ścieńczenie kory mózgu w niektórych obszarach, zmniejszenie objętości ciała migdałowatego. Uzależnienie od substancji psychoaktywnych może mieć wpływ na wyniki badań i dlatego należy je uwzględniać jako współzmienną. Konieczne są dalsze badania opisanych struktur mózgowia w celu lepszego zrozumienia ich związku lub jego braku z psychopatią.

Słowa kluczowe: ciało migdałowate, psychopatia, przegroda przezroczysta, psychopaci, morfologia mózgu.

Introduction

Psychopathy has traditionally been characterized as a disorder primarily of personality (particularly affective deficits) and, less often, behavior (e.g. antisocial behavior, impaired empathy, bold and egotistical traits) (Ogloff 2006; Patrick *et al*. 2009; Buzina 2012). In the past, the word "psychopathy" was used as a synonym for aggressive and irresponsible behavior (Buzina 2012), while psychopaths are frequently described as individuals who lack empathy and guilt, have shallow affect and violent antisocial behavior (Eslinger 2000) with a high intellect and greater tendency to be impulsive and angry (Minò 2019). Empathy is the ability to mentally put oneself in the place of another and imagine what the other person is experiencing emotionally. Patients diagnosed with psychopathy can understand others' feelings from an intellectual viewpoint but they are not able to feel as normal as a healthy person does in terms of more differentiated feelings (Morana *et al*. 2004). Nevertheless, Morana *et al*. claim that the term "psychopathy", which belongs to the sphere of forensic psychiatry and is not a medical diagnosis, may be understood as a "legal diagnosis" (Morana *et al*. 2004).

The American psychiatrist Hervey Cleckley identified 16 characteristics of psychopathy drawn from the literature and his clinical experience. Later, the Canadian psychologist Robert D. Hare repopularized the construct of psychopathy in criminology with his Psychopathy Checklist (now the Psychopathy Checklist-revised – PCL-R) (Patrick 2005; Partridge 1930). The PCL-R is one of the most common tools to measure the presence of psychopathy. Each of the 20 items in the PCL-R is scored on a three-point scale, with a rating of 0 if it does not apply at all, 1 if there is a partial match or mixed information, and 2 if there is a reasonably good match to the offender. Scores range from 0 to 40, and legal and mental health professionals sometimes rely on a cut-off score or threshold to classify individuals as psychopaths (Balsis *et al*. 2017). The cut-off for the label of psychopathy is 30 in the United States and 25 in the United Kingdom (Skeem *et al*. 2011; Semple 2005).

Some studies suggest that there could be differences in e.g. the cavum septum pellucidum and amygdalae in psychopaths' brains compared to nonpsychopaths. Neuropsychological and neuroimaging examination of individuals with this disorder showed that critical functions of these areas are compromised in individuals with this disorder (Blair 2008). However, Raine *et al*. emphasize that many other regions (e.g. the hippocampus, insula, angular gyrus) are likely to be significantly involved in antisocial and violent behavior (Raine and Yang 2004).

The amygdala is composed of distinct subareas or nuclei (anatomically, the amygdala is a part of the basal ganglia) involved in a wide range of normal behavioral functions and psychiatric conditions (LeDoux 2007). In the research of Gallagher and Chiba, different output pathways from the amygdala were delineated that mediate specific aspects of learning connected with positive and negative emotional states (Gallagher and Chiba 1996). The septum pellucidum is a thin, triangular double membrane separating the frontal horns of the right and left lateral ventricles of the brain. The cavum septum pellucidum (CSP) is a potential cavity between the membranous leaves of the septum pellucidum (Das and Dossani 2022).

This review focuses only on structural differences that can be observed in the brains of treatment groups and controls. The authors also chose to point out the influence of substance abuse as a covariate in the cited studies, though in different studies many different covariates were examined.

Material and methods

A PubMed search was conducted using the keywords "Psychopathy", "Psychopathy brain", "Psychopathy nucleus accumbens", and "Psychopathy cortical gyrification". A total of 322 papers were found, from which 28 were selected as sources for the following discussion. In the selection of publications, brain structure that was examined and substance abuse as a covariate were important. Articles were analyzed with a particular emphasis on the most recent publications. Other criteria included the size of the study group (cohort, case control and individual case studies), the number of citations of the article and the reliability.

Results

Research on brain morphology showed differences in the brain structures of psychopaths, but the results of the studies differ because of the different methods that were used (Boccardi *et al*. 2013). This literature review shows that there can be various changes in different brain structures in psychopaths that could be revealed in the brain imaging; in all reviewed studies it

was MRI imaging. Summaries of the conclusions of each study are presented in Table 1.

In the study carried out by Ly *et al*. (2012) the researchers examined 52 participants, who were male inmates from a medium-security Wisconsin correctional institution. They were divided into groups of psychopaths and non-psychopaths based on the PCL-R score (psychopathic – 30 or greater, non-psychopathic – 20 or less). Twenty-one of the inmates were assigned to the psychopath group and 31 inmates to the non-psychopath group. The researchers computed cortical thickness maps, using MRI data. The study showed a significantly thinner cortex in 13 of the areas, most significant in the left insula, left dorsal anterior cingulate cortex, bilateral precentral gyrus, bilateral temporal pole, and right inferior frontal gyrus in psychopaths (Ly *et al*. 2012). After a follow-up analysis concerning substance use disorder the researchers concluded that the observed results (cortical thinning) were due to different levels of psychopathy, rather than different rates of substance use disorder.

In another study conducted by Nummenmaa *et al*. the researchers examined a community sample of 100 (51 female) well-functioning people, rather than offenders. They assessed whether the psychopathic traits were connected with cortical density and brain activity when viewing highly naturalistic violent episodes (Nummenmaa *et al*. 2021). These people had

Table 1. Psychopathy

Authors	Methods	Number of patients	Main results	Main conclusion
Ly *et al*. 2012	MRI	52 (all males)	Thinner cortex in 13 of areas, most significant in left insula, left dorsal anterior cingulate cortex, bilateral precentral gyrus, bilateral temporal pole, and right inferior frontal gyrus in psychopaths	In comparison to people without psychopathy, psychopaths had significantly thinner cortex in a number of regions
Nummenmaa *et al*. 2021	MRI	Two groups: 1) 100 (49 males, 51 females) 2) 38 (all males)	Offenders with psychopathic traits had lower gray matter density in anterior insula, orbitofrontal cortex and secondary somatosensory cortex	Individuals from community sample with high psychopathic traits have similar structural brain characteristics to violent offender with high psychopathic traits
Yang *et al*. 2009	MRI	59 (51 males, 8 females)	In psychopaths compared to nonpsychopaths there is 17.14% volume reduction in the left amygdala and an 18.93% volume reduction in the right	There is a volume reduction in the amygdala in psychopaths
Boccardi *et al*. 2011	MRI	51 (all males)	Greater global volumes (mm^3) of the amygdalae in offenders than in controls as well as differences in morphology of amygdalae and cortical morphology	Further analysis is required
White *et al*. 2013	MRI	59 (44 males, 15 females)	Cavum septum pellucidum present only in youths with disruptive behavior disorder compared to healthy controls, but there were not significantly higher levels of psychopathic traits and aggression when comparing groups of youths with DBD	It is possible that early brain maldevelopment increases the risk of a DBD diagnosis, but is not a marker of a particularly severe form of DBD
Raine *et al*. 2010	MRI	87 (75 males, 12 females)	Participants with cavum septum pellucidum had significantly higher levels of psychopathy compared to controls	Early maldevelopment of limbic and septal structures can be predictive for various antisocial behaviors
Boccardi *et al*. 2013	MRI	51 (all males)	Bilateral tissue deficit of 13% in the accumbens nuclei in psychopaths compared to control group	Hypotrophy of the nucleus accumbens in offenders with psychopathy
Miskovich *et al*. 2018	MRI	716 (all males)	Negative associations between PCL-R scores and LGI in several brain areas, specifically in two clusters in the right hemisphere	Negative associations between PCL-R scores and LGI in several brain areas

no history of substance or alcohol abuse. However, the authors also compared 19 offenders (all male) with psychopathic traits vs. 19 healthy controls (different from described above, all male), checking whether these traits matched with corresponding structural and functional alterations. In this review a functional connection was excluded. The Levenson Self-Report Psychopathy Scale (LSRP) was used to assess psychopathic traits in controls and the PCL-R was used in the case of offenders. MRI was conducted. The study showed that offenders with psychopathic traits had lower gray matter density (GMD) in the anterior insula, orbitofrontal cortex and secondary somatosensory cortex. In the community sample there was a negative association with primary LSRP scores in the same regions. Additional effects were observed in the primary somatosensory cortex, paracentral lobule and midcingulate cortex (Nummenmaa *et al*. 2021). No associations were found with secondary psychopathy. Analysis of WM segments showed lowered density in the cerebellum and around the lingual gyrus in the psychopathic group, but no association was found in the community sample (Nummenmaa *et al*. 2021).

Yang *et al*. focused their study on amygdala volume. Their study included 27 psychopathic individuals and 32 non-psychopathic controls recruited from temporary employment agencies in Los Angeles, California (Yang *et al*. 2009). The PCL-R was used to assess psychopathy (individuals with a psychopathy score higher than 23) and MRI was used to obtain brain imaging. The study showed that in psychopaths there is significant volume reduction in the amygdala (a 17.14% volume reduction in the left amygdala and an 18.93% volume reduction in the right). These results remained significant after correction for the whole-brain volume, socioeconomic status, and substance/alcohol dependence. The researchers also found bilateral shape differences of the amygdala that were consistent with the volumetric findings, but little evidence could be found for deformations in the vicinity of the accessory basal nuclei, basomedial nuclei, medial amygdaloid nuclei, or piriform cortex. Considering 9 other nuclei, the strongest evidence was found for deformations in the approximate locations of the anterior and posterior cortical and central nuclei (superior view) and the basolateral and lateral nuclei (superior and inferior view) of the amygdala (Yang *et al*. 2009). The authors stated that one of the limitation of the study was the possibility of confounding factors contributing to the amygdala structural alterations.

Amygdala volume was also the subject of a study performed by Boccardi *et al*. (2011). They examined 26 male offenders and 25 male controls: PCL-R was used to assess psychopathy, and MRI scans and case record files from offenders were obtained retrospectively from hospital files. Furthermore, the offenders presented substance abuse, while controls did not. The study showed that the global volumes (mm^3) of the amygdalae were significantly greater in offenders than in controls in the *t*-test (Boccardi *et al*. 2011) and there were also differences in morphology: in offenders increased tissue was observed in the central, in the basolateroventromedial and in the lateral nuclei, bilaterally, while there was reduced tissue in the basolateral nucleus. The global map of local differences on the right side was significant, while on the left side local changes achieved a significance of up to $p < 0.001$, uncorrected. Also there were found significant cortical morphology differences: in offenders tissue reductions were found in the orbitofrontal and ventromedial-anterior cingulate, cuneus and precuneus, and the parahippocampal and superior frontal gyrus, medially, were also involved. Minor reduction effects were observed dorsally, in the cortical mantle, and these involved the motor-sensory cortex and BA 45 on the right (Boccardi *et al*. 2011). However as the authors acknowledge, the main weakness of the study was the presence of substance abuse in the offenders. After another analysis of subgroups (users and non-users of amphetamine and of polysubstances independently compared to controls, as well as high psychopathy severity compared to medium psychopathy severity) the results were consistent with the main comparisons and with a main effect of psychopathy rather than substance abuse on brain morphology. Nonetheless, the authors point out that further analysis is required (Boccardi *et al*. 2011).

The study conducted by White *et al*. evaluated the relationship between a large cavum septum pellucidum (CSP) and symptom severity in disruptive behavior disorders (DBD, including conduct disorder and oppositional defiant disorder) in adolescents (White *et al*. 2013). Participants were 32 youths with DBD and 27 healthy controls; two adolescents met the criteria for substance abuse (history of substance dependence was one of the exclusion criteria). MRI was acquired and a large CSP was defined as presence of a CSP of 4 mm or greater length. The study showed that a CSP was present only in youths with DBD (7/32, 22%) and was not

observed in the control group. However, when comparing youths with DBD who had a CSP to those who did not, significantly higher levels of psychopathic traits and aggression were not found. There is a lack of statistical power in these analyses due to the small number of youth with a large CSP (White *et al*. 2013). Conduct disorder is predictive of adult psychopathy (Nummenmaa *et al*. 2021).

Raine *et al*. studied adults with psychopathy: they recruited 75 male and 12 female subjects from five temporary employment agencies, of whom 30 males and 2 females were diagnosed with psychopathy using the PCL-R (score of 23 or more) (Raine *et al*. 2010). Also, 17 males and 1 female fulfilled the antisocial personality disorder (ASPD) criteria. In this study participants were also checked for criminal offending, but it was decided not to mention these results in this review. MRI imaging was conducted. Nineteen of the participants (14 male, 5 female) had a CSP, which was defined as a CSP of 6 mm or greater length. The psychopathy scores were higher in the CSP group and a significant CSP × gender interaction was found, particularly higher psychopathy scores in females with a CSP. Nevertheless, the authors stipulate that this interaction must be treated with caution (Raine *et al*. 2010). Also antisocial personality disorder scores were higher in the group with a CSP, but in this case without a CSP × gender interaction (although males had higher antisocial personality disorder scores than females) (Raine *et al*. 2010). The authors also checked the possibility that alcohol and substance dependence (as well as schizophrenia-spectrum disorders, psychotic disorders and mood disorders) may be comorbid disorders accounting for the CSP–antisocial relationship. After simultaneous entry of all these covariates, the main effects of CSP remained significant for psychopathy and antisocial personality disorder (Raine *et al*. 2010). There was also detected a longer CSP in participants without ASPD but with a history of arrests than in participants without ASPD and without a history of arrests.

Boccardi *et al*. examined 26 male subjects with psychopathy (the PCL-R was used to assess psychopathy) and 25 non-psychopaths (they were also free from current or past substance abuse), which was the same group as mentioned above in the study by Boccardi *et al*. (2011). They focused on the nucleus accumbens, and, as the authors mentioned, this structure had not received specific attention yet (Boccardi *et al*. 2013). Also a PubMed search did not reveal other papers about nucleus accumbens morphology. In the Boccardi *et al*. study MRI scans of the offenders were obtained retrospectively from hospital files. The researchers observed in global volumetric analyses a significant bilateral tissue deficit of 13% in the accumbens nuclei in psychopaths compared to the control group. Local analyses showed a symmetrical pattern of reduction and enlargement effects. Reduction was observed mainly in the rostral part, but there was also a midline reduction and caudal deficit. Small hypertrophic regions were also found and they resulted in a more rounded shape of the accumbens in psychopaths (Boccardi *et al*. 2013). The authors conducted checks for substance abuse, comparing users and non-users of polysubstance (any substance except alcohol) vs. controls, amphetamine users and non-users vs. controls and polysubstance users vs. polysubstance non-users. In the comparisons of subgroups vs. controls the same pattern as in the main comparisons was observed, suggesting that the observed alterations are not specific to substance abuse. In the case of amphetamine abuse the result of the analysis was the same (Boccardi *et al*. 2013). The last comparison of polysubstance users versus polysubstance non-users (only alcohol abuse) yielded negative results. The very circumscribed regions of significant tissue difference did not survive the permutation test. The authors concluded that these comparisons support the interpretation that their main findings were not due to substance abuse (Boccardi *et al*. 2013).

A study conducted by Miskovich *et al*. focused on cortical gyrification and was one of three studies found in the PubMed database using the phrase "cortical gyrification psychopathy". The authors examined 716 adult male inmates from forensic institutions and correctional facilities in Wisconsin and New Mexico. The PCL-R was used to assess psychopathy and MRI was conducted. The researchers used a 3D measurement of folding of the cortical surface, the local gyrification index (LGI). The analysis concerned the relationship between LGI and PCL-R total scores (also PCL-R factor scores). Diagnosis of alcohol or substance dependence was one of the covariates. The study revealed negative associations between PCL-R scores and LGI in several brain areas, specifically in two clusters in the right hemisphere including the midcingulate cortex, extending into the dorsomedial frontal cortex and lateral superior parietal cortex (Miskovich *et al*. 2018). Analysis of subjects without substance dependence was significant for the

midcingulate cortex (in the right hemisphere), though the cluster was smaller, but it was not significant for the superior parietal cluster. No LGI differences were found between those with and without a substance dependence diagnosis (Miskovich *et al*. 2018).

Discussion

As outlined above, studies show differences in various brain structures between psychopaths and people without psychopathy. But in comparison there are also studies that check brain structure changes in correlation to other disorders connected with violent behavior, such as conduct disorder, antisocial personality disorder and schizophrenia. Firstly, conduct disorder is, as mentioned above, predictive of adult psychopathy (Nummenmaa *et al*. 2021). Secondly, it is a psychiatric condition that is characterized by increased aggressive and antisocial behavior (Fairchild *et al*. 2011). In two performed studies researchers examined brain structures in separately male and female participants with conduct disorder. The first study (Fairchild *et al*. 2011) compared male adolescents with conduct disorder (separated into early-onset and adolescent-onset groups, which was excluded in this review) to healthy controls. The researchers observed reduced gray matter volume in e.g. the bilateral amygdala, extending into the ventral insula on the left side, left dorsomedial prefrontal cortex, and bilateral caudate nucleus (Fairchild *et al*. 2011) (the effect in the left insula was no longer significant when controlling for ADHD symptoms or age). There was also found a positive correlation between self-reported callous-unemotional traits and volume in the caudate nucleus and ventral striatum, which remained significant when adjusting for conduct disorder symptoms and which is consistent with a study that reported increased striatal volume in adults with psychopathy (Fairchild *et al*. 2011). There was also a positive correlation between self-reported psychopathic traits and right caudate volume. In the second study (Fairchild *et al*. 2013) the researchers examined girls with conduct disorder. The study showed reduced grey matter volume in the bilateral anterior insula and right striatum in females with conduct disorder compared to controls. Also aggressive conduct disorder symptoms were negatively correlated with right dorsolateral prefrontal cortex volume, and it was mentioned that another study described reduced dorsolateral prefrontal cortex volume in antisocial populations. It was reported that male and female adolescents with conduct disorder show statistically equivalent reductions in amygdala volume, but the relationship between conduct disorder and anterior insula volume differs between the sexes (Fairchild *et al*. 2013).

Another study focused on people with violent antisocial personality disorder or schizophrenia (Narayan *et al*. 2007). Participants were divided into groups: those with 1) antisocial personality disorder with a history of violence (but without psychopathic personality traits), 2) schizophrenia and a history of violence, 3) schizophrenia without a history of violence and 4) a healthy nonviolent comparison group. In the study the main effects of violence were associated with thinning of the prefrontal cortex in the medial inferior frontal area (larger extent in the left hemisphere), the lateral sensory motor cortex and surrounding association areas (larger extent in the right hemisphere) and in areas surrounding the posterior region of the intraparietal sulcus bilaterally in violent participants in comparison to nonviolent participants (Narayan *et al*. 2007). There were also visible changes in cortical thickness surrounding the medial inferior frontal cortices in groups with a diagnosis of schizophrenia and with violent behavior. In brain images of people with antisocial personality disorder there can be seen significant thinning of the medial inferior frontal cortices bilaterally and thinning of sensory motor areas in the right hemisphere in comparison to healthy participants. Subjects with schizophrenia and violent behavior showed deficits in sensory motor areas in comparison to nonviolent schizophrenia subjects (Narayan *et al*. 2007). To sum up, cortical thinning that is examined in participants with antisocial personality disorder and schizophrenia, both with a history of violent behavior, is regionally specific and partially different in these groups.

During preparation for this review the authors found out that it is important to check how substance use disorder may influence the results of brain studies. For example, Schiffer et al. conducted a study in which four groups of men were compared: 12 violent offenders (people who exhibit violent behavior) with substance use disorder (SUDs), 12 violent offenders without SUDs, 13 nonoffenders (people who did not exhibit violent behavior) with SUDs and 14 nonoffenders without SUDs. The duration of SUDs was similar and also urine analysis showed that no participant had consumed any substance in the year prior to study entry, meaning there was no current substance abuse (Schiffer et al. 2011).

Diagnoses of SUDs were confirmed by interviews using the Structured Clinical Interview for DSM-IV, and the Michigan Alcohol Screening Test and the Drug Abuse Screening Test was used to provide scores of lifetime use of alcohol and illicit drugs. Psychopathic traits were assessed using the PCL-SV; violent offenders obtained higher PCL-SV scores than did the nonoffenders. MRI was acquired. The study showed that violent offenders compared with nonoffenders exhibited greater gray matter volume in the left nucleus accumbens, the bilateral amygdala, and the right caudate head. Smaller gray matter volumes were observed in the left anterior insula. No differences were detected in gray matter volumes of the prefrontal cortex or orbitofrontal cortex (Schiffer *et al*. 2011). In the analysis comparing participants with SUDs with participants without SUDs there were significantly reduced gray matter volumes in the medial orbitofrontal cortex, the ventromedial prefrontal cortex and the premotor area. None of the interaction terms were significant (Schiffer *et al*. 2011). The analysis also revealed a positive correlation between PCL-SV scores and left amygdala and left nucleus accumbens volume (comparison between violent offenders and nonoffenders). However, there was a negative correlation between PCL-SV score (both factors) and left insula volume. The authors concluded that greater gray matter volume in the mesolimbic reward system may be associated with violent behavior, but reduced gray matter volumes in the prefrontal cortex, orbitofrontal cortex, and premotor area are observed in men with substance use disorder (Schiffer *et al*. 2011).

Conclusions

Psychopathy is a neuropsychiatric disorder with deficient emotional responses, poor behavioral controls, shallow affect, lack of empathy and high intellect.

Various studies have revealed differences in several brain structures in people with psychopathy in comparison with nonpsychopaths.

There is a need for further studies, describing brain structures when using certain covariates for better understanding of the brain structure-psychopathy relationship.

Further research on psychopathy should involve substance abuse as a covariate.

In people without psychopathy, but with disorders connected with violent behavior, e.g. conduct disorder and antisocial personality disorder, differences in brain structures can also be observed in comparison to healthy controls.

There is a need for further studies of different disorders connected with violent behavior related to brain changes.

Disclosure

The authors declare no conflict of interest.

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