Brain structural correlates of psychopathic traits in elite female combat-sports athletes

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Abstract

Psychopathy is characterized by glibness and superficial charm, as well as a lack of empathy, guilt, and remorse, and is often accompanied by antisocial behavior. The cerebral bases of this syndrome have been mostly studied in violent subjects or those with a criminal history. However, the antisocial component of psychopathy is not central to its conceptualization and, in fact, psychopathic traits are present in well-adjusted, non-criminal individuals within the general population. Interestingly, certain psychopathy characteristics appear to be particularly pronounced in some groups or professions. Importantly, as these so-called adaptive or successful psychopaths do not show antisocial tendencies or have significant psychiatric comorbidities, they may represent an ideal population to study this trait. Here we investigated such a group, specifically elite female judo athletes, and compared them to matched non-athletes. Participants completed psychopathy, anger, perspective-taking and empathic concern questionnaires and underwent structural magnetic resonance imaging (MRI). Grey matter volume (GMV) was computed using voxel-based morphometry from the T1-weighted images. Athletes scored significantly higher in primary psychopathy and anger, and lower in empathy and perspective taking. They also exhibited smaller GMV in the right Temporal Pole, left Occipital Cortex, and left Amygdala/Hippocampus. GMV values for the latter cluster significantly correlated with primary psychopathy scores across both groups. These results confirm and extend previous findings to a little-studied population and provide support for the conceptualization of psychopathy as a dimensional personality trait which, not only is not necessarily associated with antisocial behavior, but may potentially have adaptive value.

Introduction

Psychopathy is characterized by a series of affective, interpersonal and behavioral traits, including arrogance, superficial charm, glibness, grandiosity, as well as a lack of empathy, guilt and remorse, often accompanied by shallow affect and impulsivity (Cleckley, 1941; Hare & Neumann, 2010; De Brito et al., 2021). In many, but not all, cases, this leads to antisocial and criminal behavior (Sanz-García et al., 2021; Skeem & Cooke, 2010). In fact, although initially conceptualized as a taxon, it is now generally accepted that psychopathy is a (multi)dimensional trait, present to various degrees in the general population, with the violent psychopath representing an extreme of the continuum (Edens et al., 2006; Guay et al., 2018; Sanz-García et al., 2021).

Interestingly, a number of studies have begun to identify a pattern of common characteristics in well-adjusted, non-criminal individuals high in psychopathy. For instance, such traits are found more often in people holding leadership and management positions, as well as with those in high-risk occupations, such as police and firefighters (Falkenbach et al., 2018; Lilienfeld et al., 2014). Athletes may be another such group: several studies have found that they exhibit higher psychopathic traits, especially in the case of those competing at high or professional level in individual sports (González-Hernández & Martínez-Martínez, 2020; Greitemeyer, 2022; Ueno et al., 2017; Vaughan et al., 2019). It has been argued that these individuals can "channel" some of their personality traits to succeed in their professions, and are therefore often referred to as *adaptive* or *successful* psychopaths (Babiak et al., 2010; Hall & Benning, 2006; Lilienfeld et al., 2015). As such, they could be particularly well-suited to study the neurocognitive correlates of "pure" psychopathic traits, as not only are they typically well-adjusted members of society, but they are unlikely to exhibit some of the potentially confounding effects of comorbidities (e.g., substance use disorders; Werner et al., 2015) or early life adversity (e.g., Lovallo, 2013), often present in the violent individuals (typically men in the prison system) tested in the majority of previous studies, and which have been shown to affect brain regions also associated with psychopathy (Gard et al., 2017; Navarri et al., 2022; Paulus, 2022; Pollok et al., 2022). However, to our knowledge, no studies have investigated the brain correlates of psychopathy in this population.

Nonetheless, several studies have examined the structural and functional underpinnings of psychopathy, mainly in violent individuals (mostly men) and, to a lesser extent, in the general population. Functional magnetic resonance imaging (MRI) studies using a variety of emotional, moral and social evaluation and decision-making tasks have identified abnormal activity associated with psychopathy in several regions, including the amygdala, ventromedial prefrontal cortex, insula and basal ganglia (Johanson et al., 2020). Likewise, structural MRI studies have reported that psychopathy, operationalized as categorical (psychopaths vs. controls) or parametric (using scores from various psychopathy scales) factors, is associated with reduced volume and/or grey matter density in some of the same structures, such as orbitofrontal cortex, insula and temporal pole, as well as the amygdala/hippocampus (for reviews, see De Brito et al., 2021; Johanson et al., 2020), although the results for the latter appear somewhat inconsistent (Deming et al., 2022).

Whether these findings also apply to non-violent individuals high in psychopathy traits remains to be determined. Moreover, the vast majority of these previous studies tested only men, and most of those that did include women did not consider sex as a factor of interest, thus limiting the generalizability of the findings. This is particularly relevant given the sex differences reported, on the one hand, in terms the emotional and cognitive correlates of psychopathic traits

(Efferson & Glenn, 2018), on the other, in brain morphology of several regions putatively affected in psychopathy, particularly the amygdala (for a review and discussion of this topic, see (DeCasien et al., 2022)

Here, we aimed at filling some of these gaps by investigating psychopathic traits and their relationship with brain morphology in female elite judo athletes, comparing them to a group of healthy young female non-athletes. We hypothesized that athletes would exhibit have higher levels of aggressiveness and psychopathy, which should be associated with decreases in grey matter volume in some of the previously reported regions, such as the amygdala and frontal cortex.

Materials and methods

Participants

Twenty-three high-performance elite female judo athletes (AT) were recruited at the *Escuela Superior de Formación de Atletas de Alto Rendimiento (ESFAAR) "Cerro Pelado"* (age M=21.4, SD=4.1 years). The average number of years of practice of the sport was 13.6 (SD=4.8 years). Thirteen of them were previous medalists at international and/or national tournaments. One of them withdrew from the study as she could not lie comfortably in the scanner. Twenty-two healthy female non-athletes (age: M = 22.4, SD = 3.2 years) served as the control group (CT). None of the participants had a history of diagnosed neurological or psychiatric disorders. In terms of education, all subjects were pursuing (19 athletes and 11 controls) or had completed (3 athletes and 11 controls) post-secondary degrees.

Behavioral scales

To assess anti/pro-social attitudes and aggressive behavior, the following scales were applied: (1) Novaco Anger Scale (NAS) and Provocation Inventory (PI) (Novaco, 1994). The former consists of 48 items scored on a 3-point (*Never* to *Always true*) scale designed to measure anger disposition (e.g., "When I get angry, I stay angry; reliability: .92), whereas the latter is a 4-point 25-item self-report scale (*Not at all* to *Very angry*) designed to measure anger intensity across a range of situations (e.g. "You lend someone an important book or tool and they fail to return it"; reliability: .94); (2) Levenson Self-reported Psychopathy scale (LSRPS; Levenson et al., 1995), a 5-point (*Strongly disagree* to *Strongly agree*) scale with Primary (F1: interpersonal/affective component; 16 items, e.g., "In today's world, I feel justified in doing anything I can get away with to succeed"; reliability: .82) and Secondary (F2: impulsive/antisocial behavior; 10 items; e.g., "I find myself in the same kinds of trouble, time after time"; reliability: .63); and (3) the Perspective Taking (PT, e.g., "I sometimes try to understand my friends better by imagining how things look from their perspective"; reliability: .73) and Empathic Concern (EC, e.g., "When I see someone being taken advantage of, I feel kind of protective towards them"; reliability: .70) sub-scales of the Interpersonal Reactivity Index (IRI; Davis, 1980), each consisting of 7 items rated on a 5-point scale (*Does not describe me well* to *Describes me very well*).

<u>MRI image acquisition.</u>

Structural images were obtained using a 3 Tesla Siemens MRI scanner (MAGNETOM Allegra, Syngo MR A35; Siemens, Erlangen, Germany) with a one-channel phased-array head coil. Whole-brain, high resolution T1-weighted, anatomical images were acquired using a standard MPRAGE sequence (TR = 1940 ms, TE = 3.93 ms, TI = 1100 ms, FOV: 256 mm, flip angle = 9 degrees, matrix size = 256 × 256; voxel = $1mm^3$ isotropic).

MRI data processing and analysis

Images were processed with the *Computational Anatomy Toolbox* (CAT12; Structural Brain Mapping Group, Jena, Germany; (Gaser et al., 2022) for SPM12 (Wellcome Trust Centre for Neuroimaging, London, UK) using their suggested procedure and parameters. Briefly, images were segmented, normalized to the MNI template and modulated (so that final voxel intensity represented gray matter volume). Finally, images were spatially smoothed using an isotropic 6-mm FWHM Gaussian kernel. Voxel-based morphometry analysis (VBM) was performed in SPM12 by entering the processed images in an ANCOVA with group as the main factor and subjects' total intracranial volume (TIV) as a covariate. All analysis was conducted using an inclusive mask of the entire brain constructed from AAL3 (Automated Anatomical Labeling); (Rolls et al., 2020). Two contrasts were computed: AT>CT and AT<CT. Statistical significance was established using a $p<.05$ corrected for multiple comparisons at the cluster level using the *Probabilistic Threshold-free Cluster Enhancement* toolbox (pTFCE; Spisák et al., 2019) implemented in SPM12. For post-hoc analyses, the Holm-Bonferroni criterion was applied to correct for multiple comparisons across variables and/or clusters when appropriate.

To ensure robustness of any significant effects, and to minimize possible influences of high-leverage points, data non-independence and p-value inflation, we applied a leave-one-subject-pair-out (LOSPO) cross-validation procedure (Esterman et al., 2010). Specifically, we constructed 22 whole-brain GLMs similar to the original one, each including all but one subject of each group, and parameter estimates for the significant clusters were extracted for the left-out subjects. The independently obtained values were then entered into a t-test (group comparison) or regression (relation to personality scores) analysis.

Results

Personality scales.

Table 1 shows the average scores of the different scales for the two groups, as well as the p-values of the comparison (independent samples t-tests with Holm-Bonferroni correction for multiple testing). Athletes exhibited significantly higher scores for LPSP-F1 and NAS, and lower for IRI-EC and IRI-PT. In contrast, there were no significant group differences for LPSP-F2 or NPI.

Grey matter VBM analysis

A significant group difference was found for the AT<CT contrast in 3 clusters (Figure 1) located in the right temporal pole (xyz=[30, 16, -48], k_E =483, z-score=5.97), left occipital cortex (xyz= [-2, -100, -3], k_E =103, z-score =5.34; xyz= [-3, -87, 4], k_E =54, z-score=5.26), and left amygdala (xyz= [-24, -10, -26], k_E=203, z-score =5.64). The corresponding effect sizes were $1.92 \le d \le 2.31$ ($1.21 \le LCI_{95\%} \le 1.54$, $2.63 \le UCI_{95\%} \le 3.07$) No significant voxels were found for the contrast AT>CT.

The group differences in the amygdala and temporal pole clusters were confirmed by the LOSPO cross-validation procedure ($p_{HB}<.0001$ and $p_{HB}=.014$, respectively; see Methods), although those of the occipital cortex failed to reach statistical significance ($p_{HB}=.13$).

Correlation between grey matter volume and personality traits

In order to further explore relation between brain structure and personality, we extracted the cluster-averaged data (partialling out the TIV values) for each of the significant clusters and entered each of them in a linear regression model with the behavioral scales that were significantly different between groups --namely LSRP-F1, NAS-I, IRI-PT and IRI-EC-- as independent variables. The only significant (partial) correlation was between the amygdala/hippocampus cluster and LSRP-F1 scores ($r = -.40$, $p_{HB} = .02$; Figure 2). This correlation remained significant when applying the LOSPO cross-validation procedure ($r = -.38$, $p_{HB} = .02$). Importantly, when included together in a linear model, both the group and LSRP-F1 main effects remained significant ($p < .0001$ and $p = .016$, respectively), without a significant interaction between them ($p = .2$).

Anatomically-defined regions

Because one of the clusters included amygdala and hippocampus and, given the questions recently raised regarding the precise location of functional and structural findings in psychopathy (Deming et al., 2022), we performed a supplementary analysis in which we extracted unsmoothed data from anatomically defined structures obtained from the Automated Anatomical Labeling atlas v3 (Rolls et al., 2020). In the case of the left amygdala, there was a significant group difference ($t(42) = 3.80$, $p = .0005$) and correlation with LSRP-F1 ($r = -.505$, $p = .0006$; partial $r = -.372$, $p = .017$ with group effects removed). In contrast, no significant group differences or correlations were observed for the left hippocampus or parahippocampal gyrus (p's>.2).

Discussion

The objective of this study was to investigate the relationship between brain morphology and psychopathic traits in two groups, socially adjusted elite female Judo athletes and healthy non-athlete controls.

The athlete group scored significantly lower in empathic concern and perspective taking and displayed higher levels of anger and psychopathy than the control group. Interestingly, the latter was specific to Factor 1 of the LSRP, related to callous, manipulative, selfish, and deceptive personality traits. In contrast, no significant group differences were observed for Factor 2, which reflects antisocial behavior and has been shown to be associated with impulsivity, aggression and risk-taking (Dean et al., 2013; Weiss et al., 2016). Consistent with this, the group difference in anger experience did not extend to situational anger reactivity, as indexed by the Novaco Provocation Index. Our results are in agreement with those of Sherrill & Bradel (2017) who found that men who participated in contact sports displayed higher instrumental, but not hostile (reactive), aggression compared to a control group. Similarly, Ueno and colleagues (2017) observed a difference in the Machiavellianism component of the Dark Triad (Paulhus & Williams, 2002), which strongly correlates with primary psychopathy (Jakobwitz & Egan, 2006), in athletes as a function of their competitive level. Because of the characteristics of combat sports, defeating the opponent requires, in addition to overt aggressive behavior, planning and emotional coldness. That is, aggression needs to be expressed within a framework of strict rules, and therefore impulsive tendencies will likely be counterproductive (Li et al., 2020; Zhang et al., 2019). Thus, it would seem that successful performance in combat/contact sports would require certain traits associated with a psychopathic profile, such as an egocentric and antagonistic interpersonal style, but without the antisocial or impulsive components (Abrams, 2010).

The group difference in personality profiles was accompanied by a significant reduction in gray matter volume observed in the athletes in the occipital cortex, temporal pole and, notably, the amygdala. Several studies have reported decreased temporal pole grey matter density or volume in psychopathy (Müller et al., 2008; Ermer et al., 2012; Gregory et al., 2012; Ly et al., 2012;

Cope et al., 2014). Interestingly, temporal pole grey matter concentration was also found to be negatively correlated with spontaneous (but not reactive or impulsive) aggression in men practicing martial arts (Breitschuh et al., 2018). This is in line with the fact that athletes in our study had significantly higher scores than controls in LSRP-F1 but not F2. Although the precise role of the temporal pole is still unclear, it has been shown to be involved in a variety of high-level cognitive functions (Herlin et al., 2021), particularly in semantic processing and social cognition, including empathy and perspective taking, which are both negatively related to psychopathy. Consistent with this, a recent meta-analysis of fMRI studies of emotional and moral tasks revealed enhanced activity in the temporal pole, among other regions, in psychopathy (Deming & Koenigs, 2020).

We also observed reduction of grey matter volume in the occipital cortex. While this finding may be counterintuitive, given that this area is not thought to play a key role in emotional or social processing, group differences in this region have been reported (e.g., (Bertsch et al., 2013; Ly et al., 2012). Some authors (Boccardi et al., 2011) have interpreted this finding in the context of a hypoactivity of this area in response to emotional faces (Deeley et al., 2006) and impaired integration of bottom-up (sensory) and top-down (attentional) information (Newman 2007) in psychopathy. Nonetheless, this unanticipated result did not survive the LOSPO cross-validation procedure, and therefore needs to be further replicated, and, if consistently found, related to functional and/or clinical features, before any definitive conclusions can be drawn.

The amygdala/hippocampus finding is of particular interest, as this structure has been highlighted as playing a key role in socio-affective processing in general (Fossati, 2012) and in the psychopathology of psychopathy in particular (Kiehl, 2006; Moul et al., 2012; Blair, 2022). Indeed, the amygdala and anterior hippocampus have been reported to exhibit decreased activity and/or connectivity in emotion/moral tasks, as well as reduced volume and/or grey matter density, both in categorical (psychopaths vs. controls) and parametric (correlations with psychopathy scores) designs (for a review, see Johanson et al., 2020; but see Deming et al., 2022). Here we confirmed those findings in a well-adjusted population high in primary psychopathy traits but without significant comorbidities. Subsidiary analyses using unsmoothed data and anatomically-defined regions suggest that the difference is mainly within the amygdala, although further studies, using higher spatial resolution acquisition, are necessary to confirm this observation. Importantly, this reduced grey matter volume seems unlikely to be consequence of practicing the sport: first, amygdala volume scores did not correlate with years of training or overall age; second, the negative correlation between amygdala volume and LSRP-F1 was present for the control group as well (see Figure 2). Thus, we speculate that these personality and brain patterns are already present in early life and, in the case of athletes, drives them to practice, and excel in, combat sports. As they are well adjusted and low in actual aggressive behavior in everyday life (as evidenced by the lack of difference in LSRP-F2 or NPI with controls), these findings would support the hypothesis that such activity provides a healthy way to channel aggressive personality (Lafuente et al., 2021), although longitudinal studies would be needed to directly test this hypothesis.

There are some limitations to take into account when considering the findings reported here. First, the sample size is admittedly small. This is the result of a trade-off: choosing a fairly unique and limited population, namely elite female combat-sports athletes, with high levels of psychopathic traits but without many of the confounding factors of the more often studied groups of incarcerated or violent individuals. Nonetheless, as it is always the case in scientific research, further replicability of our results is necessary before any definitive conclusions can be drawn. In particular, a larger sample with a more thorough characterization (e.g., other personality traits, developmental trajectories, social and family environment) would help assess whether other potential, to-date unknown differences between groups could contribute to the observed effects. Indeed, the difference in amygdala volume remained significant after controlling for the influence of the personality variables measured in our study, suggesting that these cannot fully explain the reduced volume in this structure observed in athletes. Moreover, it is important to determine whether the current results also apply to males, and whether they extend to other combat sports, especially those not related to martial arts (thought to be particularly suited for reducing overt aggressive tendencies; (Harwood et al., 2017; Kostorz & Sas-Nowosielski, 2021), such as boxing, whose practitioners may exhibit higher levels of aggressive behavior (Kuśnierz et al., 2014). Finally, as mentioned earlier, the cross-sectional nature of the study does not allow to us to determine the causal relation between the higher levels of primary psychopathic traits and associated reduction in amygdala grey matter volume, and the practice of sports. To answer that question, longitudinal approaches are needed.

In conclusion, our study revealed that elite female judo athletes exhibit significantly higher primary psychopathy and anger, and, and lower perspective-taking and empathic concern scores than matched controls. Critically, athletes exhibited reduced grey matter volume in the left amygdala/anterior hippocampus, which was partly driven by individual differences in primary psychopathy scores. These results confirm and extend findings suggesting specific brain structural differences associated with psychopathy, previously obtained mainly in antisocial and/or violent individuals, to a group that, despite exhibiting high levels of instrumental aggressive behavior, are highly functional and well-adjusted members of society. In that sense, our findings highlight the importance of environmental factors in mediating the relation between brain structure and behavior. Indeed, in the case of elite judo athletes, a reduced amygdala volume and high levels of anti-social-related traits did not lead to increased antisocial behavior; instead, it appears that when channeled appropriately, these characteristics may be adaptive and help individuals lead a successful professional life. In more general terms, our study confirms the usefulness of studying populations such as combat-sports athletes in order to gain further knowledge in the neural correlates of aggression.

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Author Contribution

Eduardo González-Alemañy: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; supervision; visualization; writing - original draft; writing - review & editing. **Anelin Dayris Rodríguez Olivera:** Resources; project administration. **María A. Bobes:** Conceptualization; funding acquisition; supervision; writing - review & editing. **Jorge**

L. Armony: Conceptualization; formal analysis; methodology; funding acquisition; supervision; writing - original draft; writing - review & editing.

Data availability

Data are available upon reasonable request.

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