# Association of Win-Loss Record With Neuropsychiatric Symptoms and Brain Health Among Professional Fighters

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**Objective:** Repetitive head impacts in professional fighting commonly lead to head injuries. Increased exposure to repetitive head trauma, measured by the number of professional fights and years of fighting, has been associated with slower processing speed and smaller brain volumes. The impact of win-loss outcomes has been investigated in other sports, with several studies suggesting that individuals on losing teams experience more head injuries. Here, the authors hypothesized that fighters with a worse fight record would exhibit poorer brain health outcomes.

**Methods:** The Professional Fighters Brain Health Study examined changes in neuropsychiatric symptoms, regional brain volume, and cognition among professional boxers and mixed martial arts fighters. These data were used to evaluate the relationship between win-loss ratios and brain health outcomes among professional fighters (N=212) by using validated neuropsychiatric symptom and cognitive measures and MRI data.

**Results:** Retired fighters with a better record demonstrated more impulsiveness (B=0.21, df=48) and slower processing speed (B=−0.42, df=31). More successful fighters did not perform better than fighters with worse records on any neuropsychiatric or cognitive test. Retired fighters with better fight records had smaller brain volumes in the subcortical gray matter, anterior corpus callosum, left and right hippocampi, left and right amygdala, and left thalamus. More successful active fighters had a smaller left amygdala volume.

**Conclusions:** These findings suggest that among retired fighters, a better fight record was associated with greater impulsiveness, slower processing speed, and smaller brain volume in certain regions. This study shows that even successful fighters experience adverse effects on brain health.

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Head injuries are commonly sustained among individuals participating in high-impact sports, such as professional boxing and football. The link between head injury exposure and adverse changes to the brain is well established (1, 2). In the short term, repetitive head impacts are associated with transient acute encephalopathy and associated subsyndromal delirium (3). For example, a study of West Point cadets found that scores on reaction time, attention, and concentration testing revealed significantly slowed performance following mild boxing-related concussions (4). In the long term, repetitive head impacts are associated with detrimental effects on neuropsychiatric symptoms and cognition, as well as increased risk of neurodegenerative disease (1, 5). Repetitive head impacts can lead to chronic traumatic encephalopathy, which involves widespread abnormal accumulation of hyperphosphorylated tau protein and can be diagnosed only postmortem (2, 6). Recent efforts made by a multidisciplinary panel of clinician-scientists defined key components of traumatic encephalopathy syndrome, the clinical correlate of chronic traumatic encephalopathy. Notably, these components include neurobehavioral dysregulation after substantial exposure to repetitive head impacts and often follow a progressive course (7).

The Professional Fighters Brain Health Study is an ongoing longitudinal cohort study that involves the assessment of neuropsychiatric symptoms, cognitive function, and regional brain volume data among professional boxers and mixed martial arts (MMA) fighters (8). Our earlier work showed that increasing exposure to repetitive head trauma measured by the number of professional fights and years of fighting was associated with slower processing speed and smaller brain volumes (9). Smaller brain volumes were observed in both cortical and subcortical structures among fighters with greater fight exposure, and this relationship was present among both boxers and MMA fighters. Another study by our group found that earlier age at first exposure to competitive fighting was significantly correlated with slower processing speed and smaller regional brain volumes (10).

One factor that may influence the burden of damage sustained during fight exposure is how often the fighter wins or loses, which has yet to be investigated in the context of neuropsychiatric symptoms and other brain health measures. Specific factors of competition may contribute to the frequency of head injuries (11). For example, the relationship between win-loss outcomes and concussions was examined among players in the National Football League, and the study found that being on the losing team of a football game was a significant predictor of concussion frequency (12). However, studies of players in the Australian Football League and the National Hockey League did not observe a significant association between win-loss outcomes and head injuries (1, 11).

Previous studies examining athletes' win-loss records and their brain health had mixed results, but these studies often lacked robust outcome measures (such as MRI data or formal assessments) and had not focused on neuropsychiatric symptoms. Furthermore, associations between win-loss records and neuropsychiatric symptoms have not been studied among professional fighters, a population at high risk for such sequelae. The primary objective of the present study was to define the relationship between the win-loss records of athletes in fighting sports and their neuropsychiatric symptoms, brain volumes, and cognitive function with data from the Professional Fighters Brain Health Study. We hypothesized that fighters with a worse fight record would exhibit worse neuropsychiatric symptoms and poorer brain health outcomes.

## METHODS

### Study Population

The methods that pertain to the Professional Fighters Brain Health Study as a whole have been previously described (8). The study involves human subjects research and has received appropriate institutional review board approval. Written informed consent was obtained from all participants. Briefly, professional fighters, including boxers, MMA fighters, and martial artists, were recruited for participation in the study. Participants were both active and retired fighters, with the requirement that retired fighters must have participated in at least 10 professional fights. For all participants, professional fighting records were verified by using standard online databases. Inclusion criteria were being age 18 or older, having a fourth-grade reading level, being fluent in English, and having no contraindications to undergoing a 3-T brain MRI scan. Participants were interviewed, and the following measures were collected: demographic characteristics, fight exposure, cognitive testing, neurological examination, psychiatric symptom scale scores, a blood draw for genetic analysis, and structural and functional MRI scans. Participants returned for annual visits where MRI and neurocognitive data were collected. Each follow-up visit was 1 year (±90 days) from the previous visit, and participants were allowed to continue in the study even if they missed a visit. For active fighters, all study visits had to be at least 45 days after sanctioned professional events to better differentiate chronic changes from acute injuries. Although the Professional Fighters Brain Health Study is ongoing, the cross-sectional data used for this study were collected from each participant's first visit, between 2011 and 2020. A flow diagram of study participants is presented in Figure S1 in the online supplement.

### Win-Loss Ratio and Total Professional Fights

In professional fighting, a higher win-loss ratio signifies that the fighter has a "better" professional fighting record, because the fighter has more wins than losses. Conversely, a lower win-loss ratio signifies a "worse" professional fighting record. In accordance with common practice, win-loss ratios were defined as follows: win-loss ratio=(wins+[0.5× draws]) / (total fights). The number of professional wins, losses, and draws and the resulting number of total fights were based on the participant's professional record, which was verified by using standard online databases (including www.boxrec.com for boxers and www.sherdog.com or www.mixedmartialarts.com for MMA fighters). Participants' win-loss ratios were calculated from their wins, losses, and draws recorded at the time of their first study visit. Martial arts independent of MMA were excluded from the statistical analyses because of a disproportionately small number of participants.

### Neuropsychiatric Symptoms

Neuropsychiatric measures were available for a subset of participants. The primary neuropsychiatric symptoms assessed were depressive symptoms and impulsiveness. Data were available from the Patient Health Questionnaire–9 (PHQ-9), a validated nine-question screening tool commonly used to assess the frequency of depressive symptoms over a 2-week period, with higher scores indicating greater frequency of symptoms (13). Data on impulsiveness were available from the Barratt Impulsiveness Scale, version 11 (BIS-11), a validated tool for assessing impulsivity and impulse control, with higher scores indicating impairment in impulse control (14).

### Cognition

Cognitive performance measures, based on several validated scales, were available for a subset of participants. Unless otherwise specified, the results of these tests are presented as composite scores. The CNS Vital Signs neurocognitive test battery was used to assess the following four domains: verbal memory, processing speed, psychomotor speed, and reaction time (15). Verbal memory was assessed on the basis of immediate and delayed recognition of a 15-item word list. Processing speed was assessed by using a symbol digit-coding task. The psychomotor speed assessment involved coding and finger-tapping tests. Reaction

**TABLE 1. Demographic and fight history characteristics among active and retired professional fighters**

| Characteristic | Active | | Retired | | |
|---|---|---|---|---|---|
| | Median | Interquartile range | Median | Interquartile range | p |
| Age (years) | 30.00 | 27.00–34.00 | 47.00 | 42.00–52.00 | <0.001 |
| Professional fights | 13.00 | 4.00–26.00 | 34.00 | 22.00–50.00 | <0.001 |
| Win-loss ratio | 76.92 | 59.49–92.58 | 79.41 | 64.29–86.17 | 0.60 |
| | N | % | N | % | p |
| Cohort sample size | 155 | 73 | 57 | 27 | |
| Male | 137 | 88 | 55 | 96 | 0.073 |
| Caucasian | 96 | 62 | 30 | 53 | 0.22 |
| Hispanic | 42 | 27 | 16 | 28 | 0.89 |
| Completed high school | 89 | 57 | 23 | 40 | 0.027 |
| Fighting style | | | | | <0.001 |
| Boxing | 61 | 39 | 47 | 83 | |
| Mixed martial arts | 88 | 57 | 7 | 12 | |
| Both | 6 | 4 | 3 | 5 | |

time was assessed by using the Stroop task. C3 Logix (iComet), another validated measure of neurocognitive function, was used to evaluate multiple neurocognitive domains among participants (16).

### Neuroimaging

At each visit, a high-resolution T1-weighted anatomical MRI scan was obtained for each participant with a 3-T MRI scanner (Siemens Verio [Munich], 2011–2015; Siemens Skyra [Munich], 2016–2020). Both scanners utilized a 32-channel head coil to acquire structural three-dimensional T1-weighted magnetization-prepared rapid acquisition gradient-echo images (repetition time=2,300 ms; echo time=2.98 ms; resolution=1×1×1.2 $mm^3$) and diffusion-weighted MRI data (71 directions; repetition time=7,000 ms; echo time=91; resolution=2.5×2.5×2.5 $mm^3$; diffusion-weighted b value=1,000 seconds/$mm^2$; number of non–diffusion-weighted images [b0] for each participant at both the baseline and follow-up=8; total imaging time=15 minutes). The imaging sequences were preprocessed for volume analyses with FreeSurfer software, version 5.3.0 (http://surfer.nmr.mgh.harvard.edu). A total of 113 structural features were obtained with each scan, including 68 thickness measures and 45 volumetric measures. From these 113 possible structural features, 13 brain regions were selected for analysis a priori, on the basis of a literature review indicating that these regions were likely to be most affected by the repetitive head impacts experienced by athletes in fighting sports. These regions included the thalamus (left and right), putamen (left and right), caudate (left and right), hippocampus (left and right), amygdala (left and right), subcortical gray matter, and corpus callosum (anterior and posterior).

### Statistical Analysis

In cross-sectional analyses, nonparametric Wilcoxon rank-sum tests were used to compare group differences in continuous variables between active and retired fighters. For categorical variables, Pearson's chi-square tests were used. Adjusted linear regression models were used to assess associations between win-loss ratios and brain volumes, cognitive performance, and clinical neuropsychiatric symptoms in two models. The first model included all study participants eligible for analysis, and the second model was stratified by active and retired fighter status. Both models were adjusted for the following covariates, which were selected a priori: age, education level, race, ethnicity, fighting style (boxing vs. MMA), and number of professional fights. In the models involving regional brain volumes, total intracranial volume and scanner type were added as covariates. We formally assessed interactions based on fighting status (i.e., active or retired status). All tests were two-tailed at an alpha level set a priori at 0.05. Consistent with recommendations in the statistical literature, no statistical corrections for multiple comparisons were performed where specific directional hypotheses were present a priori (17). All statistical analyses were performed with RStudio, version 1.4.1103 (RStudio, Boston).

## RESULTS

### Participant Characteristics

The majority of the sample (73%) were active fighters (N=155), and the other 27% were retired fighters (N=57) (Table 1). The retired fighters were older (median=47 years) than the active fighters (median=30 years). In addition, retired fighters had competed in more fights (median=34) than the active fighters (median=13). The retired cohort had a higher percentage of boxers than the active cohort (83% vs. 39%, respectively), and the active cohort had a higher percentage of MMA fighters than the retired cohort (57% vs. 12%, respectively). The win-loss ratio was similar in the two cohorts.

### Association of Win-Loss Record With Brain Volumes

For the model including both active and retired fighters, there was a significant negative association between

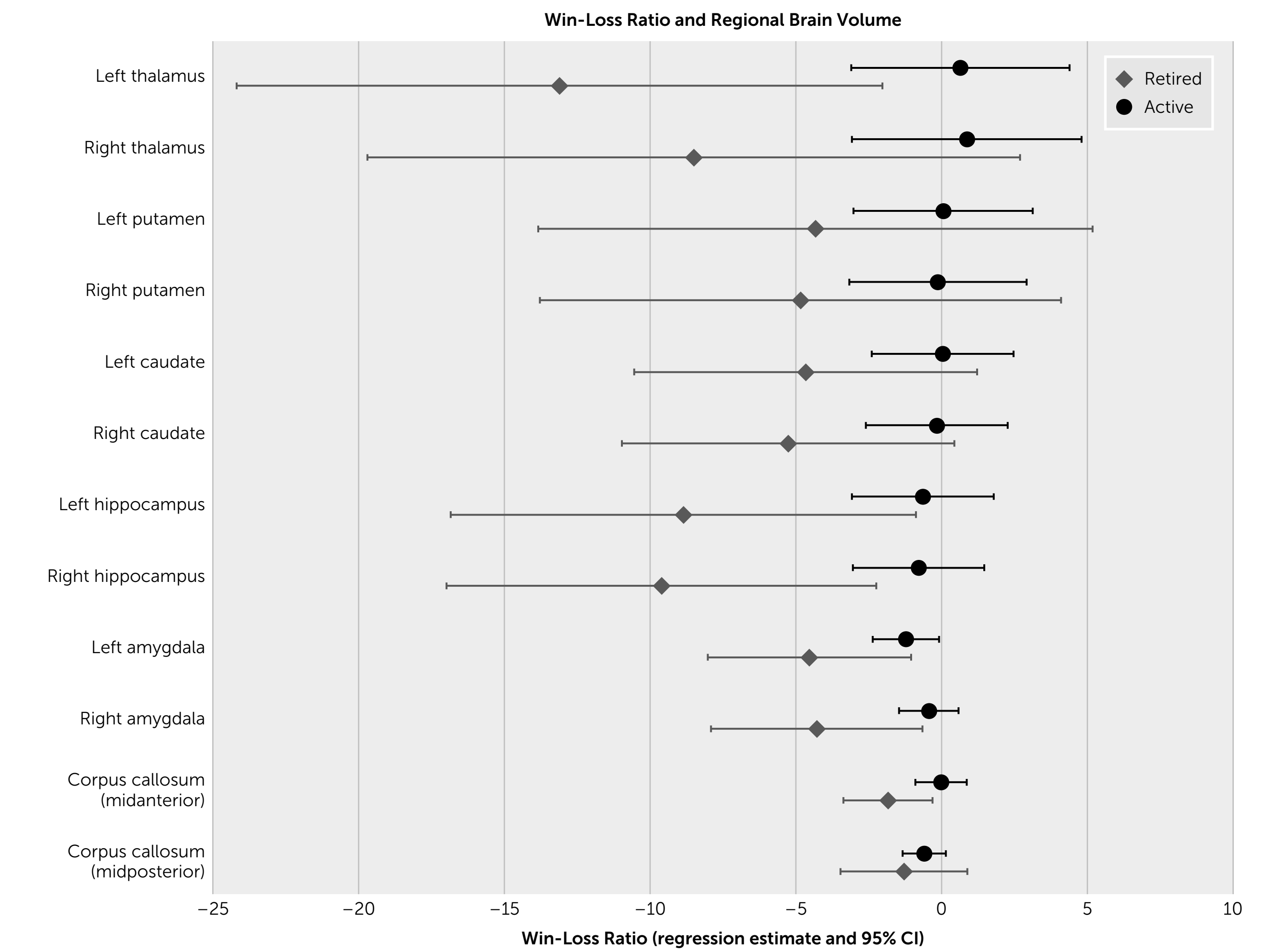
**TABLE 2. Association of win-loss ratio and regional brain volume among combined active and retired fighters (N=212)[a]**

| MRI region of interest | B | 95% CI | $p_{int}$ |
|---|---|---|---|
| Left thalamus | −1.27 | −4.90, 2.36 | **0.019** |
| Right thalamus | −0.34 | −4.06, 3.38 | 0.123 |
| Left putamen | −1.31 | −4.29, 1.67 | 0.260 |
| Right putamen | −1.41 | −4.31, 1.49 | 0.166 |
| Left caudate | −0.86 | −3.06, 1.34 | 0.198 |
| Right caudate | −1.15 | −3.33, 1.03 | 0.144 |
| Left hippocampus | −2.05 | −4.48, 0.38 | **0.042** |
| Right hippocampus | −2.28 | −4.53, −0.03 | **0.035** |
| Left amygdala | −1.97 | −3.09, −0.85 | 0.116 |
| Right amygdala | −1.25 | −2.33, −0.17 | **0.019** |
| Subcortical gray matter | −15.53 | −36.62, 5.56 | **0.011** |
| Midanterior corpus callosum | −0.33 | −1.07, 0.41 | 0.119 |
| Midposterior corpus callosum | −0.67 | −1.38, 0.04 | 0.300 |

[a] The data represent adjusted linear regression estimates (unstandardized beta and 95% confidence interval) for win-loss ratio and regional brain volume (in microliters). The $p_{int}$ values indicate the interaction effect of fighter status (active and retired) and win-loss ratio on regional brain volume. Boldfaced values indicate statistical significance at $p<0.05$.

win-loss ratio and the left thalamus and the left and right hippocampi. Analysis of the interaction between win-loss ratio and fighter status indicated that associations of the win-loss ratio with the volume of subcortical gray matter, left and right hippocampi, right amygdala, and left thalamus were stronger among the retired fighters than among the active fighters (Table 2). Stratified analyses demonstrated that among retired fighters, there was a significant negative association between win-loss ratio and brain volume in seven regions, such that the retired fighters with better fight records had smaller brain volumes in these regions. These regions included the subcortical gray matter, anterior corpus callosum, left and right hippocampi, left and right amygdala, and left thalamus (Figure 1) (see Table S1 in the online supplement). Among active fighters, the left amygdala was smaller among fighters with better fight records. Neither active nor retired fighters had any brain region for which a worse fighting record was associated with smaller volume.

**FIGURE 1. Association between win-loss ratio and regional brain volume stratified by retired (N=57) and active (N=155) fighter status[a]**




[a] Adjusted linear regression estimates (unstandardized beta, 95% confidence interval) for win-loss ratio are shown. Subcortical gray matter is not depicted to preserve appropriate scale (for details pertaining to subcortical gray matter, see Table S1 in the online supplement). All volume measurements in microliters (μL).

**TABLE 3. Association of win-loss ratio and neuropsychiatric symptoms and cognition among active and retired fighters (combined)[a]**

| Neuropsychiatric symptoms and cognitive domain | N | Instrument | B | 95% CI | $p_{int}$ |
|---|---|---|---|---|---|
| Impulsiveness | 208 | BIS-11 | 0.04 | −0.02–0.10 | **0.013** |
| Depressive symptoms | 210 | PHQ-9 | 0.001 | −0.018–0.021 | 0.888 |
| Processing speed | 132 | CNS VS | −0.17 | −0.35–0.01 | 0.190 |
| Psychomotor speed | 129 | CNS VS | −0.15 | −0.35–0.05 | 0.129 |
| Verbal memory | 129 | CNS VS | 0.16 | −0.08–0.40 | 0.068 |
| Reaction time | 132 | CNS VS | −0.06 | −0.26–0.14 | 0.177 |
| Balance errors | 155 | C3 Logix | 0.03 | −0.03–0.09 | 0.213 |
| Trail-Making Test, Part A | 156 | C3 Logix | 0.02 | −0.10–0.14 | 0.101 |
| Trail-Making Test, Part B | 149 | C3 Logix | 0.01 | −0.23–0.25 | **0.026** |

[a] The data represent adjusted linear regression estimates (unstandardized beta and 95% confidence interval) for win-loss ratio and neuropsychiatric symptoms and cognition. The $p_{int}$ values indicate the interaction effect of fighter status (active and retired) and win-loss ratio on neuropsychiatric symptoms and cognition. Boldfaced values indicate statistical significance at $p<0.05$. BIS-11=Barratt Impulsiveness Scale, version 11.0; CNS VS=CNS Vital Signs test battery; PHQ-9=nine-item Patient Health Questionnaire.

### Association of Win-Loss Record With Neuropsychiatric Symptoms and Cognitive Function

The model including both active and retired fighters did not reveal any significant associations between the win-loss ratio and neuropsychiatric symptoms or cognitive testing outcomes. Analysis of the interaction between win-loss ratio and fighter status indicated that the association of win-loss ratio with impulsiveness was stronger among retired fighters than among active fighters (Table 3). Stratified analyses demonstrated that retired fighters with better fight records had higher impulsiveness scores (Figure 2) (see Table S2 in the online supplement). Notably, no associations were found between the win-loss ratio and PHQ-9 scores for either active or retired fighters. On cognitive testing, retired fighters with a better record had slower processing speed than those with a worse record ($B=-0.42$, df=31, $p=0.016$).

## DISCUSSION

The results of this study suggest that winning more often does not prevent adverse neuropsychiatric sequelae or brain health outcomes among professional fighters. Our findings indicate that retired fighters with a higher win-loss ratio (i.e., better fight record) demonstrated higher degrees of impulsiveness, measured with the BIS-11. Because we used cross-sectional data, we cannot determine causality with respect to the greater degree of impulsiveness. However, because the association was observed only in the retired cohort and not the active cohort, it is possible that greater impulsiveness may be a longer-term result. These findings related to impulsiveness did not support our hypothesis that fighters with a worse fight record would exhibit greater degrees of neuropsychiatric impairment.

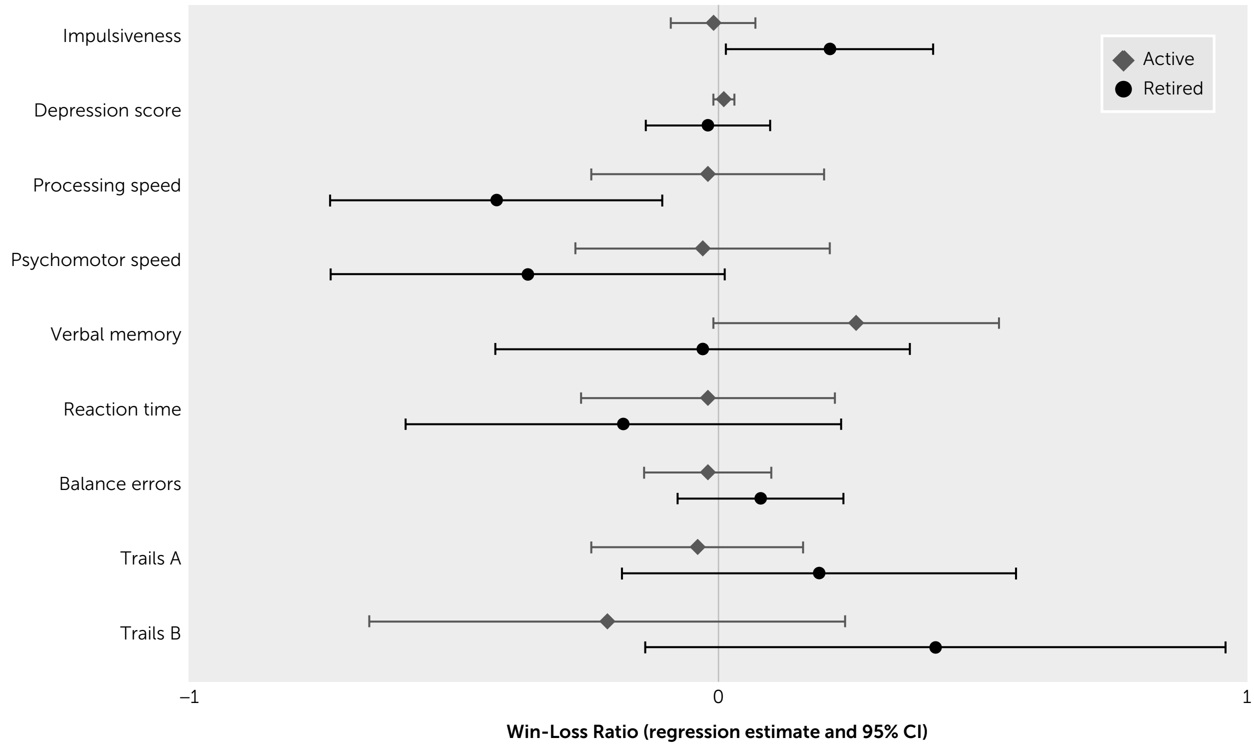
Another compelling finding in this study was the association between better fight records and smaller brain volumes in several notable regions. These associations were stronger among fighters in the retired cohort compared with those in the active cohort. In all models, we controlled for both age and the number of professional fights, which were verified in standard databases by the study team. Notably, imaging results from participants with worse fight records did not reveal any brain regions with significantly smaller volumes. Again, these findings did not support our hypothesis that fighters with a worse fight record would have smaller brain volumes.

Taken together, the findings of this study suggest two important conclusions. The first is that competitive fighters with a better fight record have poorer brain health. This conclusion deviates from previous findings obtained with National Football League athletes (12), and previous findings with athletes in both individual and team sports that have not shown that a better win percentage is associated with worse brain health. One explanation may involve the resiliency of winners in competitive fighting. To win a fight, the victorious fighter needs to be able to withstand numerous attacks from his or her adversary. Furthermore, fighters with winning records tend to be in fights that are scheduled for longer overall durations. This explanation is consistent with previous findings demonstrating an association between increased exposure to repetitive head impacts and decreased processing speed and regional brain volume (9). Alternative explanations could involve the damage experienced during training or damage experienced during nonprofessional fights, which we were unable to control for in this study.

Fighting style may also help explain our findings. Aggressive fighters with a winning record may be more susceptible to these adverse outcomes by virtue of receiving more high-impact blows, and defensive fighters may be able to avoid some of these hits. Similarly, fighters who are considered primarily strikers may be more susceptible to these changes than those who are grapplers, because strikers would be exposed to a greater number of blows in training sessions that occur multiple times per week. By contrast, grapplers sustain fewer blows. Ongoing research is being conducted on the effects of fighting style (18), and proposals have been made to track variables during a fight for more precise data collection.

The second conclusion is that these effects were more apparent among retired fighters. This finding lends support

**FIGURE 2. Association between win-loss ratio and neuropsychiatric symptoms and cognition stratified by fighter status (retired and active)[a]**




[a] Adjusted linear regression estimates (unstandardized beta, 95% confidence interval) for win-loss ratio and neuropsychiatric symptoms and cognition are shown. The sample sizes for each measure across fighter status categories are reported in Table S2 in the online supplement. Trails A=Trail-Making Test, Part A; Trails B=Trail-Making Test, Part B.

to the notion that traumatic brain injury is a disease process rather than an isolated event (19). Correspondingly, the effects experienced during the participants' professional fighting careers may be difficult to detect. As the disease process progresses, these changes become more impactful and, consequently, are detected with testing. This is similar to our understanding of the progressive nature of chronic traumatic encephalopathy (20).

Furthermore, our findings related to impulsiveness may have broad-reaching implications. Numerous athletes and former athletes make headline news each year for controversies related to impulsive behavior. Our findings suggest that the winner's circle is not a safe haven, and we hope that our data can lead to further discussion and research on treatment and assistance.

From a clinical standpoint, our study will help physicians to better understand the more specific behavioral and cognitive symptoms that can result after a career in professional fighting. These results can help guide medication management strategies and the choice of appropriate psychotherapeutic and cognitive rehabilitation interventions. Our study also provides important information for families regarding what symptoms to monitor. This awareness will lead to improvements in support for retired fighters and help provide important clinical information that may lead to earlier treatment and better outcomes.

From a policy standpoint, our data may help professional fighting organizations inform their aging fighters of the risks associated with prolonged exposure. Aging fighters who are past their prime and have a winning record may feel compelled to keep fighting for an extended period. Fighting organizations should inform their athletes that winning is not protective, as demonstrated in the present study. This important information will help fighters make an informed decision on whether to continue their professional career.

This study has several limitations. The cross-sectional nature of this study did not allow us to determine causal relationships. Additionally, when interpreting the findings based on the retired cohort, it is important to note that there were significantly more boxers in the retired cohort than in the active cohort. Over time, boxers may receive more cumulative blows to the head than MMA fighters do. Although we controlled for fighting style (boxing vs. MMA), age, and number of professional fights, the generalizability of our findings to MMA fighters may be limited. Furthermore, neuropsychiatric and cognitive data were available for only a subset of participants. A high number of participants were excluded from analysis because of missing data related to their win-loss records. To make our results as accurate as possible, we included only participants with complete and verified records. However, there is potential for selection bias given that fighters with better fighting records may be more likely to report their records completely and accurately. Because the win-loss ratio was generally high among the study participants, this may further limit the generalizability of our findings. Moreover, it is possible that fighters with a very low win-loss ratio may have experienced changes that make them less likely to participate in a research study. Finally, we did not control for the participants' histories of amateur fights and practice regimen because of incomplete and self-reported data (as opposed to the verified professional fighting record). Nevertheless, variations in amateur fighting or practice volume could have affected our findings. Although other variables linked to exposure to repetitive head impacts, such as age at first exposure to competitive fighting or weight class, have demonstrated associations with a fighter's brain health, these variables were not included in our multiple regression analysis to avoid overadjusting our model. Nevertheless, it is possible that some of these variables could have a mediating effect on the relationship between win-loss ratio and brain health. Furthermore, other exposure variables are being studied for their effects on brain health among fighters, and these factors may warrant further consideration for their relationship to win-loss ratios.

## CONCLUSIONS

Overall, our study helps inform competitive fighters, sport governing bodies, and clinicians of the potential risks associated with fighting sports. Our results suggest that among retired fighters, a better fight record was associated with greater impulsiveness, slower processing speed, and smaller brain volume in multiple brain regions. In addition, our findings suggest that even successful fighters experience adverse effects on brain health. Future research should be conducted on other variables obtained during a fight that may mitigate or exacerbate the effects of fighting on brain health.

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