

1 **Full title: Left-handed fighters are**
2 **overrepresented in combat sports and**
3 **are better fighters**

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5 **Short title: Left-handedness and fighting**
6 **SUCCESS**

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11 Left-handed fighters are overrepresented in combat 12 sports and are better fighters

13

14 Abstract

15 Left-handedness is a costly, sexually dimorphic trait found in all human populations. How the
16 handedness polymorphism is maintained is unclear. The fighting hypothesis argues that left-
17 handed men have a negative frequency-dependent advantage in fighting giving them a selective
18 advantage. In support of this, many studies have found that left-handed men are overrepresented
19 in combat sports, but studies typically find no difference in fighting success between left and right-
20 handed fighters. We studied over 9800 professional boxers and mixed martial arts fighters of
21 varying abilities in three of the largest samples to test this hypothesis to date, finding robust
22 evidence that left-handed fighters have greater fighting success. This held for both male and
23 female fighters and when considering percentage of fights won, and objective measures of fighting
24 ability. We replicated previous results showing the left-handed fighters are strongly
25 overrepresented in professional combat sports, but left-handed fighters did not show greater
26 variance in fighting ability, a hypothesis suggested in previous studies. Overall we find strong
27 evidence consistent with the fighting hypothesis.

28 Introduction

29 Left-handedness is a cross-culturally universal, heritable phenotype in humans [1] that is thought to
30 be associated with fitness costs ([2,3], reviewed in [4], but see [5]). Typically around 11% of the
31 population is left-handed [6] and though exact numbers vary with culture, [7] left-handers are
32 always a minority. Since left-handedness is under direct negative selection, its persistence in
33 humans is an evolutionary puzzle.

34

35 One explanation for the persistence of left-handedness is the fighting hypothesis [8]. This argues
36 that the polymorphism in human handedness is maintained due to a negative frequency-dependent
37 advantage that left-handedness confers to males in combat (see [9] for theoretical support, and [10]
38 for a review of empirical evidence as well as alternatives). According to this theory right-handed
39 males often lack experience fighting rare left-handed males, while left-handed males accumulate
40 plenty of experience fighting right-handed males, putting them at a selective advantage. Combined
41 with the intrinsic fitness costs of left-handedness, this would explain the universal pattern of low but
42 stable levels of left-handers in all studied populations. There is mounting evidence that intrasexual
43 contest competition such as fighting has been a key component of sexual selection on human
44 males [11]. Modern males may possess adaptations to assist them in fighting and assessing
45 opponents' fighting ability [12]. Handedness could therefore be considered a sexually selected trait
46 in males, and may be expressed in females a by-product [9].

47

48 Consistent with the fighting hypothesis, there is a wealth of evidence that left-handers are
49 overrepresented in combat sports. Sports are particularly relevant systems for testing theories
50 based on intrasexual competition, as they are thought to have evolved culturally as a display for
51 males to advertise fighting and competitive ability [13]. Overrepresentation of left-handers has
52 been seen in boxing (where it is referred to among coaches and fans as 'Southpaw Advantage':
53 [14-16], mixed martial arts or MMA [17-20], wrestling [21], Judo [22], and Karate and Taekwondo
54 [23]. Left-handers are also overrepresented in many other sports, though crucially only sports
55 requiring direct interaction with an opponent [24,25]. As they are rare, left-handers' may gain an
56 advantage because their actions are more difficult to predict [26-28], perhaps due to attentional
57 biases towards the right hand of an opponent [29]. If left-handed men are disproportionately
58 successful in combat sports when they are rare, it is not unreasonable to assume they would also
59 be successful in ancestral environments where physical violence and competition were likely much
60 more common than today [11].

61

62 Studies of the fighting hypothesis in martial artists typically do not find that left-handed fighters are
63 more likely to win fights (e.g., [17], though see [16]). However, previous studies have often used
64 small sample sizes (e.g. [14]) or only assessed the very best members of a particular sport (e.g.,
65 [16, 21]). Any advantages are likely to be small as a large advantage would rapidly lead to an
66 increase in the frequency of left-handed fighters until the advantage was nullified. Likewise, top
67 fighters are likely to have encountered enough left-handed opponents that any advantages due to
68 unfamiliarity would be diminished. Evidence for whether left-handed fighters perform better than
69 right-handed fighters is thus inconclusive. The present studies tested whether left-handed fighters
70 are better than right-handed fighters in 3 large samples consisting of professional fighters at a
71 variety of ability levels. In particular, one of our samples comprised the majority of boxers
72 professionally active at the time of writing.

73

74 Previous studies also used win percentage records, number of wins, or ranking from a single
75 tournament as proxies of fighting ability. These may fail to capture long term fighting performance,
76 particularly if fighters have 0 losses, (which gives a win percentage of 1 regardless of number of
77 fights). These metrics also do not weight wins by quality of opponent, and fail to include how
78 fighters beat their opponent. For example, winning a boxing match by having better judges' score
79 after 10 rounds may indicate less physical dominance than a win by knockout in the first round. In
80 our samples we excluded fighters who had few fights, and additionally compared left and right-
81 handed boxers on their BoxRec score, a comprehensive measure of fighting ability that takes into
82 account both the type of victory and the opponent quality (see supplementary materials for a
83 description of how a BoxRec score is calculated).

84

85 The fighting hypothesis for the evolution of left-handedness is based on male-male contest
86 competition, but there is no reason to expect the frequency-dependent advantage of left-
87 handedness in combat to be confined to males. However, there have been few studies of the
88 success of left-handed female fighters. To remedy this, one of our samples consisted exclusively of
89 female professional boxers and our sample of MMA fighters included women as well as men.
90 Additionally, comparison of the left-hand advantage in male and female fighters allows us to
91 investigate negative frequency-dependence. If there are fewer left-handed female fighters than
92 male ones, the fighting hypothesis would predict they would have a larger advantage.

93

94 Lastly, a previous study by Dochtermann et al., [19] demonstrated that left-handed MMA fighters
95 show greater variance in probability of winning a fight than right-handed fighters. They argue that
96 this is because the advantage left-handed fighters possess increases the probability that they will
97 reach professional level compared to right-handers even if they are less skilled. We attempt to
98 replicate this finding in our samples.

99

100 In summary, we investigated representation and fighting success of left-handers in 3 of the largest
101 samples tested thus far, consisting of professional male and female boxers and MMA fighters of
102 varying abilities. For boxers, we also tested the difference between left and right-handers in
103 BoxRec scores, a holistic measure of fighting ability. Our study provides the most powerful test of
104 the fighting hypothesis attempted to date.

105

106 Results

107 All statistics were run in R [31], and all data and analysis code is available on the open science
108 foundation [insert link here]. For all samples the number of fights left- and right-handed fighters had
109 participated in, fighter ages, win percentages and BoxRec scores were all non-normally distributed,
110 so nonparametric statistics were used throughout.

111

112 A Mann-Whitney U test showed that left-handed male boxers did not differ in age ($p = 0.36$) from
113 right-handed boxers. For female fighters, age was not analysed as some boxers were retired,
114 deceased or not currently active. Age was not available for the MMA fighters. Mann-Whitney U
115 tests found no significant differences in number of fights between left- and right-handed fighters
116 among male boxers ($p = 0.80$), female boxers ($p = 0.58$) or MMA fighters, though the difference
117 approached significance in the last group ($p = 0.054$). Additionally, t-tests showed that left- and
118 right-handed MMA fighters did not differ in overall weight, height or arm length (also known as
119 “reach”) (all $p > 0.16$). This data was not available for boxers.

120 Are left-handers overrepresented among professional fighters?

121 To test whether left-handed fighters were overrepresented in our samples we ran three separate,
122 one-tailed binomial tests against percentages of left-handers found in a large representative,
123 western population [6]. We tested the percentage of left-handed male boxers against the
124 percentage of left-handed men (12.6%) and female boxers against the percentage of left-handed
125 women (9.9%) in the general population. The MMA sample included both male and female fighters,
126 so was tested against the percentage of left-handed men, as this was the most conservative test of
127 our hypothesis. Table 1 shows that left-handed fighters were significantly overrepresented in all
128 three samples (all $p \leq 0.002$).

129

Table 1. results of Binomial tests of % of left-handed fighters against % of left-handed people in the general population

Sample	% left-handed fighters in	% left-handers in general	p-value
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	sample	population		
	Male boxers	17.3	12.6	< 0.0001
	Female boxers	12.6	9.9	< 0.002
	MMA fighters	18.7	12.6	< 0.0001

130 Do left-handed fighters possess greater fighting ability than right-handed
131 fighters?

132 We compared the fighting success of left- and right-handed fighters with one-tailed Mann-Whitney
133 U tests. Each of the 3 samples was compared separately by win percentages, and the samples of
134 male and female boxers were also compared by BoxRec scores. We calculated the measure of
135 stochastic superiority [32,33] as an effect size for each comparison. The measure of stochastic
136 superiority, represented by A , is the probability that a randomly selected left-handed fighter would
137 have a higher win percentage/BoxRec score than a randomly selected right-handed fighter.

138

139 Among male boxers, the probability that a randomly selected left-handed fighter would have a
140 higher BoxRec score than a randomly selected right-handed fighter was 53.7%, which a Mann-
141 Whitney test showed was significant ($p < 0.0001$). The measure of stochastic superiority for win
142 percentage was 52.5%, which was also significant ($p = 0.004$). Thus left-handed male boxers have
143 significantly higher BoxRec scores and win percentages than right-handed male boxers.

144

145 Among female boxers, the probability that randomly selected left-hander showed a higher BoxRec
146 score was 55.2%, which a Mann-Whitney test showed was significant ($p = 0.019$). The measure of
147 stochastic superiority for win percentage was 54.0%, which was not statistically significant
148 ($p = 0.057$). Thus left-handed female boxers showed significantly higher BoxRec scores but not win
149 percentages.

150

151 Among MMA fighters, the probability that a randomly sampled left-handed fighter showed a higher
152 win percentage than a randomly selected right-handed fighter was 53.3%, which was significant
153 ($p = 0.019$). Thus left-handed MMA fighters showed significantly higher win percentages than right-
154 handed MMA fighters.

155

156 **FIGURE 1 HERE**

157 *Figure 1: The probability that a randomly selected left-hander showed a higher (A) win percentage and (B)*
158 *BoxRec score than a randomly selected right-hander. Boxes indicate 50% and whiskers indicate 95%*
159 *bootstrapped confidence intervals (5000 samples).*

160 Do left-handed fighters show greater variance than right-handed fighters?

161 We compared the variance in BoxRec scores and win percentages among left- and right-handers
162 by bootstrapping differences in variance (10,000 samples), with bias correction and acceleration

163 following [34] to obtain robust p-values. All p-values are one-tailed. Left-handed male boxers
164 showed higher variance in BoxRec scores ($p = 0.0004$) but not in win percentages ($p = 0.9468$).
165 Left-handed female fighters did not differ from right-handed female fighters in the variance of their
166 BoxRec scores ($p = 0.4902$) or win percentages ($p = 0.7595$). Likewise left-handed MMA fighters
167 did not differ from right-handed MMA fighters in the variance of their win percentages ($p = 0.4601$).

168 Does the left-hand advantage show negative frequency-dependence?

169 The prevalence of left-handedness in female boxers was much lower than in male boxers (17.3%
170 vs 12.6%). If the advantage left-handed fighters have is negative frequency-dependent, then we
171 might expect left-handed female boxers to have a relatively larger advantage than left-handed
172 male boxers. To investigate this, we compared the measures of stochastic superiority in the
173 BoxRec scores of male and female boxers, and we bootstrapped a confidence interval around the
174 difference (10,000 samples). The difference in the advantage of left-handed female and male
175 boxers was not significantly different from 0 (bias corrected, accelerated p -value = 0.29). Thus, we
176 have no evidence that female boxers experience a greater left-hand advantage than male boxers.
177

178 Discussion

179 Across three samples, we found that left-handed boxers and MMA fighters are both
180 overrepresented in their respective sports and are better fighters. In male boxers, these effects
181 held for both win percentages and BoxRec scores, where BoxRec scores are a more
182 comprehensive measure of boxing ability. In female boxers we found that left-handed fighters
183 showed higher BoxRec scores but not higher win percentages. Our results are consistent with the
184 fighting hypothesis that left-handedness is maintained in populations because it provides a
185 negative frequency-dependent advantage in combat.

186

187 Our finding that left-handed fighters have better records than right-handed fighters in both male
188 boxers and MMA fighters contrasts to most previous studies (e.g. [15,17,18], but see [16]). Two
189 factors may have played a role. Firstly, the effect is small and may only be detectable in large
190 samples such as ours. Second, it may not be detectable in datasets with low variance in fighting
191 ability, such as when studies use samples of only elite fighters (e.g., [15]). The fact that we find
192 similar results in both win percentages and BoxRec scores, which are a more complete measure of
193 boxing ability, lead us to believe our results are robust.

194

195 Our positive finding for MMA fighters may be surprising, as a similar study [18] did not find a
196 significant advantage of left-handedness in a sample approximately 75% of the size of ours. The
197 study collected data from the same website we did ~6 years earlier, so its data set likely overlaps
198 with ours. The different results may be due to the choice of analyses, or to the fact that the study
199 did not exclude fighters with few fights as we did. It is noteworthy that in this study, left-handed

200 fighters had a non-significantly higher win percentage, so the trend reported is consistent with our
201 results.

202

203 We found that left-handed female boxers showed better BoxRec scores than right-handed female
204 boxers. As there were fewer left-handed fighters in the female sample than the male sample (12.6%
205 to male's 17.3%), we tested whether the left-hand advantage seen in female fighters was higher
206 than that of male fighters. Left-handed female fighters being less numerous and having greater
207 success than their male counterparts would be consistent with the fighting hypothesis, in that it
208 suggests a negative frequency-dependent advantage. However we did not find this. That the left-
209 handed advantage in combat is negative frequency-dependent remains to be convincingly
210 demonstrated, and is a crucial topic of future research. This might be investigated by comparing
211 fighting leagues with varying levels of left-handers, or by testing whether increased contact with
212 left-handed opponents over a fighter's career increases his/her probability of winning.

213

214 Unlike Dochtermann et al. [19], overall we found little evidence that left-handed fighters showed
215 higher variance in fighting ability. Across all samples, only male left-handed boxers showed
216 significantly higher variance, and then only in BoxRec scores. Differences in results could be
217 attributed to the fact that Dochtermann et al., tested variance in the probability of a fighter to win a
218 single given fight, whereas we examined variance in fighting success as measured by a fighter's
219 record over their career thus far. It is possible that coaches (many of whom may suspect the
220 existence of a left-handed advantage) or the left-handed fighters themselves adapt their training to
221 compensate for their fighter's lower skills. However we warn that cross sectional data, such as
222 ours and that of Dochtermann et al., are limited in their ability to answer this question. Longitudinal
223 work that tracks whether left-handed amateurs are more likely to reach professional level
224 regardless of initial skill would be valuable, and shed more light on this interesting hypothesis.

225 Conclusion

226 In conclusion, we present strong evidence that left-handed fighters show greater fighting success,
227 consistent with the fighting hypothesis. Our study also provides further evidence that left-handed
228 fighters are overrepresented in combat sports. We demonstrate these effects in 3 of the largest
229 samples to test the hypothesis to date, using both male and female fighters, and using multiple
230 measures of fighting competence. Future research linking fighting stance to fitness costs
231 associated with handedness, as well as more direct work investigating the negative frequency-
232 dependent nature of the left-hand advantage, is required.

233 Samples

234 Our first sample comprised every male professional boxer in the world listed as 'active' on
235 www.boxrec.com at the time of writing (January 2019). BoxRec.com is a community run boxing
236 website that aims to document the careers of every professional boxer to have ever taken part in a
237 recorded match. Boxers are listed as active if they have fought in an officially licensed bout in the
238 past 12 months. Our second sample comprised all professional female boxers listed on

239 www.boxrec.com for which stance data was available. For the female sample we included both
240 active and retired boxers, as this ensured a large sample. Finally our sample third comprised all
241 the MMA fighters listed on fightmetric.com at the time of writing. Fightmetric.com is a
242 comprehensive, respected MMA database that is the official statistics provider to the Ultimate
243 Fighting Championship (UFC).

244

245 For boxers we included every male boxer with a BoxRec score of 3 or higher. This was because
246 boxers with scores lower than this (the minimum score is 0) were typically fighters who had very
247 few professional fights, or fighters who had suffered a very high number of losses relative to their
248 number of wins. These latter fighters, typically called “tomato cans” in boxing slang, are
249 uncompetitive fighters who take matches with opponents they have little chance of beating simply
250 to earn money. They are often matched against young up-and-coming fighters in order to gain the
251 fighter more wins on their record. For these reasons their win percentage may not reflect their
252 fighting ability, and as such they were excluded. For the same reasons, we also removed boxers
253 and MMA fighters with a win percentage of 0. We also excluded fighters with fewer than 5 fights as
254 their fight record is too preliminary to reflect their fighting ability.

255

256 The final samples consisted of 6579 male boxers, (5442 right-handed and 1137 left-handed), 1178
257 female boxers, (1030 right-handed and 148 left-handed fighters) and
258 2114 MMA fighters (1718 right-handed and 396 left-handed fighters).

259 Acknowledgements

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261 this paper as well as the community of BoxRec.com and James Carr for insight into the world of
262 boxing.

263

264 References

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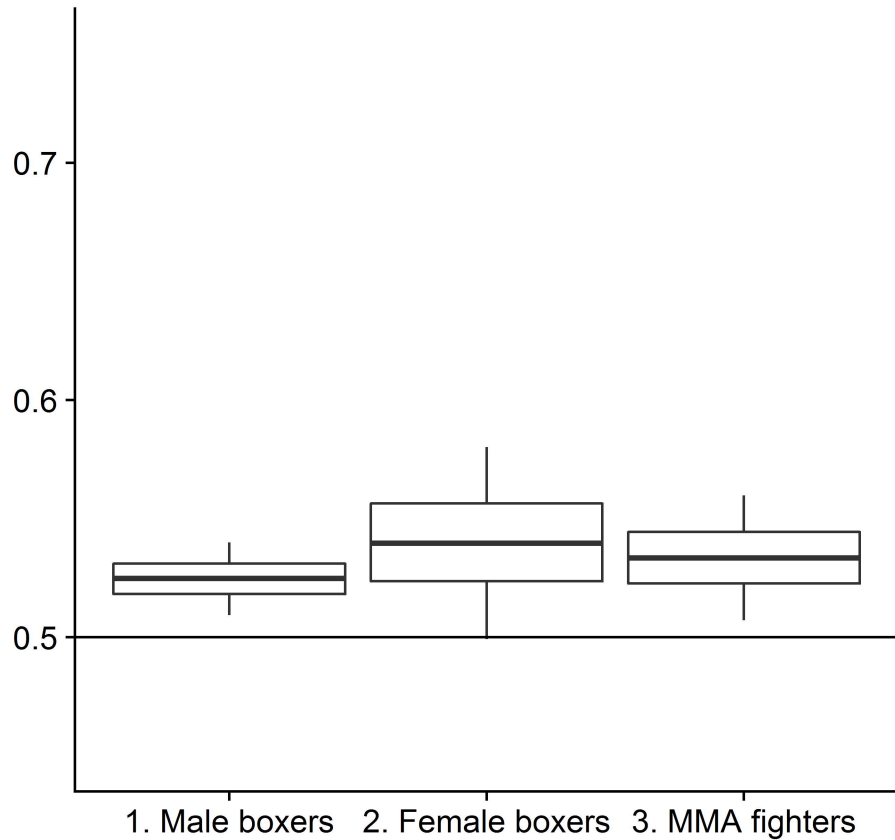
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347
348

A

P(left-handed fighter > right-handed fighter)

(Win percentage)

**B**

P(left-handed fighter > right-handed fighter)

(Boxrec score)

