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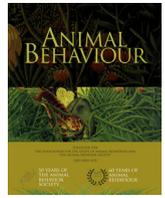
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Born to win? Testing the fighting hypothesis in realistic fights: left-handedness in the Ultimate Fighting Championship



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Given the heritability of human left-handedness and its purported associations with fitness-lowering traits, the persistence of the minority of left-handedness in human populations is an evolutionary puzzle. The fighting hypothesis proposes that these negative fitness costs are offset by fitness gains for left-handers when involved in fights with right-handers, as being a minority would generate a surprise effect increasing the chance of winning. The finding that left-handers are overrepresented in many combat sports is interpreted as evidence for this hypothesis. However, few studies have examined sports that show good similarity with realistic fights and analysed winning chances in relation to handedness of both fighters. We examined both, in a sample of the Ultimate Fighting Championship (UFC), a fierce fighting sport hardly constrained by rules. Left-handers were strongly overrepresented as compared to the general male population but no advantage for left-handers when facing right-handers was found, providing only partial evidence for the fighting hypothesis.

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Handedness is the most obvious expression of lateralization of behaviour in humans. Although lateralization is now recognized as a fundamental principle in the organization of brain and behaviour throughout the animal kingdom, very few species show such a strong bias in limb preference as humans (Groothuis et al. 2013). Human left-handedness has always occurred at a clear minority throughout human history and across cultures (Steele & Uomini 2005), and large populations seldom exceed proportions of 10% left-handers. This is in contrast with data from other primates, including great apes, where the population bias for hand preference is much less strong and appears more variable (Hopkins et al. 2011; see Cashmore et al. 2008 for a review). The low relative frequency of human left-handedness has been explained by its association with traits that lower Darwinian fitness such as low birth weight, higher prevalence of some diseases and delayed maturation (for a review see Laurens et al. 2009). Human handedness has furthermore been shown to be heritable, with a (broad) heritability estimate of 25.9% (Medland et al. 2006; also see Sicotte et al. 1999; Francks et al. 2002), giving rise to the question of why left-handedness did not disappear from human populations by natural selection.

One evolutionary hypothesis for the persistence of the minority in human left-handedness is ‘the fighting hypothesis’ (Raymond et al. 1996; Faurie & Raymond 2013; see Groothuis et al. 2013 for a review). This hypothesis suggests that the fitness-adverse effects of left-handedness are balanced by its advantage in (male–male) physical aggression. This advantage arises because most males in the population are right-handed, and therefore trained in combat against right-handed fighters, providing left-handers a competitive advantage partially because of a surprise effect when fighting. Because the advantage of left-handedness is due to its low frequency, the advantage is upheld only when the number of left-handers in the population remains a minority: a case of negative frequency-dependent selection (Raymond et al. 1996; Faurie & Raymond 2005). An alternative mechanism to a surprise effect as a mechanism for a frequency-dependent advantage could be that right-handers have an impaired domain-specific perceptual-cognitive performance such as a reduced ability to predict a left-hander’s action outcome (e.g. McMorris & Colenso 1996; Hagemann 2009; Loffing et al. 2012a) or maladaptations in game play behaviour (Loffing et al. 2010).

Some preliminary evidence for the fighting hypothesis does exist, as left-handers are often overrepresented in combat sports, such as boxing, karate and judo, compared to the general population (Raymond et al. 1996; Grouios et al. 2000). This overrepresentation of left-handers does not seem to be restricted to combat sports, but extends to noncombat sports such as badminton

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(Raymond et al. 1996), tennis (Grouios et al. 2000; Holtzen 2000) and cricket (Wood & Aggleton 1989), to name a few (see Grouios et al. 2000 for a review). Few studies, however, address the question whether left-handers have a higher likelihood of winning, as would be expected on the basis of the 'fighting hypothesis'. One study examining handedness in tennis did find evidence for a left-handed advantage, and also found, in accord with the hypothesis, that the advantage attenuated with more experience of the players (Loffing et al. 2012b). Two studies investigated other noncombat sports, cricket (Brooks et al. 2004) and baseball (Goldstein & Young 1996), and only in cricket was there some evidence for a frequency-dependent advantage of left-handers, with left-handed batsmen having more success than right-handed batsmen, especially when playing against low-ranking teams that might have less experience with left-handers. These three sports are clearly not dyadic physical combat sports, but a similar left-handed advantage has been documented in a true combat sport, boxing (Gursoy 2009), although this study had a very small sample size. Based on a much larger sample size Ziyagil et al. (2010) reported that in wrestling left-handers had a higher likelihood of winning than right-handers.

A potential problem with the study of the sports mentioned above is that these sports are ritualized fights based on clear rules, in contrast to real fighting. (This might be somewhat less important for boxing (Gursoy 2009), but in that study the sample size was very small.) This lack of rules is important as it has been argued that other interactive sports are difficult to interpret in the light of the fighting hypothesis owing to an extensive set of rules and to characteristics of the playing field that could favour left-handers (Aggleton & Wood 1990; Edwards & Beaton 1996; Grondin et al. 1999). In this study we tested the fighting hypothesis, using data from the Ultimate Fighting Championship (Ultimate Fighting Championship 2012a). UFC is a (televised) mixed martial art competition and draws regular crowds of over 50 000 live spectators. UFC rules allow virtually any combat technique and UFC is considered to be one of the most violent, aggressive combat sports. Many techniques (such as elbows and knees to the head), which are not allowed in other combat sports, are allowed in UFC (Ultimate Fighting Championship 2012b).

Fights are scheduled for three 5 min rounds with the exception of championship bouts and some main events which last 5×5 min (Ultimate Fighting Championship 2012a). The outcome of a fight is determined by knockout, technical knockout (referee stops the fight), submission (or 'tapout'; a fighter is forced to tap out as he is in a (choke) hold) or decision by three judges. Fighters from many different backgrounds, such as Greco-Roman wrestling, boxing, (Brazilian) jiu-jitsu, karate, muaythai, and even street fighters, take part and are offered large sums of money (Reuters 2007; Foxx 2012). It is important to note that, unlike a tennis tournament for example, opponents are generally of similar skill and quality. There is little incentive in organizing lopsided fights, as these would be very short and would pose substantial risk to the UFC (e.g. fighters suffering dramatic injuries or even dying in the cage) and people would simply not want to pay for ill-matched fights.

In 2007, the British Medical Association asked for UFC to be banned because of the physical risks involved in this competition (Reuters 2007). Although 'only' two UFC fighters have reportedly died of the consequences of fighting since its inception (CBS News 2010), fighters regularly suffer severe injuries, such as head trauma, similar to those in boxing and other martial arts (Landa 2004; Reuters 2007). Given the very minimal rules and the very aggressive nature of the sport, we consider the UFC to be a suitable arena for testing the fighting hypothesis for left-handedness. While hand-to-hand combat might have taken many forms throughout human history and across the globe, most fighting styles are present in UFC. As such one could view UFC as a proxy of 'brawling' and fighting as

it has occurred in human history. An additional advantage to study ultimate fighting is that both costs and benefits are substantial, as it would be in fighting over important resources in our evolutionary history. Ultimate fighters regularly suffer grave injuries in their career, whereas the gains are also very substantial; many of the UFC fighters are professionals who can earn large sums of money (Foxx 2012). For example, one fighter is reported to make \$400 000 for a single fight (MMAjunkie 2011). Moreover, using data from real combat competitions might counter some of the limitations of self-reporting of fighting experience by students (Faurie et al. 2011). With respect to the fighting hypothesis, our aims were twofold: we tested first whether there is an overrepresentation of left-handers in ultimate fighting and second whether or not left-handers have an advantage when facing a right-hander.

METHODS

Videos of 210 UFC fights (UFC broadcasts 118–148; August 2010–July 2012) were coded by the first author for handedness with handedness classification (right or left) based on predominant fighting stance during the fight: 'orthodox' versus 'southpaw', in a similar way as is done for boxing. Fighting stance is a good proxy for handedness as in boxing as well as other martial arts, it is recommended that the 'power hand', indicating hand preference, corresponds to the back leg, rather than the lead leg. From observing over 40 h of these fights, we found that this pattern is also clearly present in the UFC (and is frequently commented upon by the UFC's commentators). Fighters use the hand in front to jab and/or measure the distance to their opponent, while using the hand corresponding to the back leg for more heavy punches. UFC fighters only rarely switch between stances within or between fights unless their lead leg is so severely injured that they have to switch.

Fighters participate in multiple fights, so we had 246 fighters rather than 420 fighters (137 fighters fought one fight, 62 fought two fights, 31 fought three fights, 14 fought four fights and two fought five fights). One fighter (Jon Jones) switched stances often during his fights, although he predominantly used a southpaw stance; he was therefore coded as southpaw, but could be coded as ambidexter. Excluding this fighter does not alter the results reported below qualitatively. There was only one fighter (Claude Patrick) who switched handedness between fights: we excluded the two fights in which he fought.

The proportion of left-handers in males was tested against the expected frequency of 12.6% of left-handed males, based on a large population sample (>1000000 males; Gilbert & Wysocki 1992) using a binomial test. This baseline sample was recruited via National Geographic magazine and the estimate of 12.6% is based on self-reported writing and throwing (Gilbert & Wysocki 1992). This value is likely to be an overestimate of the actual percentage of left-handers in the general population, as using a left hand for either writing or throwing would be coded as left-handed. The estimate of 12.6% is thus conservative with respect to the fighting hypothesis. Another large internet study covering over 250 000 individuals found, based on just writing hand preference, estimates for exclusive left-handedness in males ranging from 7% to 11.8% across various ethnic groups (Peters et al. 2006). For our purpose we used the most conservative estimate: the 12.6% from Gilbert & Wysocki (1992). This study not only used a much larger data set, but also included throwing, more relevant for estimating handedness in a fighting context than writing.

Three fights ended in a draw, which we excluded from the analyses on success, leaving 205 fights available (also excluding the two fights by Claude Patrick): 11 left–left fights, 68 left–right fights, and 126 right–right fights. We used two different types of

analyses to examine a possible left-handed advantage. First, using a binomial test we examined whether left-handers were more likely to win a fight against a right-hander. More specifically, we investigated how many fights between a left-handed fighter and right-handed fighter ($N = 68$) were won by the left-hander. This analysis, however, does not account for the fact that fighters engage in multiple fights. To account for this nonindependence, we took a randomization approach. First, we determined how many of the 205 fights were won by a left-hander ($N = 45$). Then, we randomized the handedness of all fighters, while retaining similar values of both the number of fights and the number of victories for each fighter. In this way, the likelihood of winning with respect to handedness was purely based on chance. We kept the number of left-handers and right-handers in every randomization similar to that in the actual fights (50 left-handers and 194 right-handers). We performed 1000 randomizations and, from these, calculated the median value and 95% range of left-handed wins. If the 45 times that a left-hander won in the 205 fights falls outside (and above) the 95% range of the simulations, we can conclude that left-handers are significantly more likely to win a fight against a right-hander.

RESULTS

Among UFC fighters, 20.4% were left-handed (50 of 245 fighters), which is a significantly higher percentage compared to that of the general male population (proportion left-handers: 0.204 versus 0.126, respectively; binomial test: $P < 0.001$; Fig. 1a).

When examining the proportion of fights won by left-handers (thereby ignoring the nonindependence in the data introduced by fighters participating in more than one fight), we gain an easy to interpret effect size for the left-hander advantage. Limiting the sample to only those fights in which a left-hander faced a right-

hander, we found that left-handers won exactly half (34 of 68 fights; one-tailed binomial test: $P = 0.5$; Fig. 1b). Sensitivity power analysis indicates that we should be able to detect a relatively weak effect at a power of 0.8 (odds ratio: 1.94 (proportion of 0.66 versus 0.5); one-tailed; Faul et al. 2007).

Via our randomization approach, we found that left-handed fighters were predicted to win 42 fights (median of 1000 randomizations), with a 95% range between 31 and 53. The observed value of 45 left-handed victories is both very close to this median value and falls well within the 95% range, and is therefore not different from chance (one-tailed $P(x \geq 45) = 0.303$; Fig. 2).

DISCUSSION

We found that left-handers are substantially overrepresented among the mixed martial art fighters from the UFC, as in other combat sports (e.g. Raymond et al. 1996; Gursoy 2009). However, unlike a previous finding from boxing (Gursoy 2009), evidence for significant elevated winning chances for left-handers, as predicted by the fighting hypothesis, were not found. In contrast to other popular combat sports, which are more restricted by rules, we believe that fights within UFC more closely emulate fights as they would (have) occur(red) in natural settings throughout human history. Moreover, the UFC incorporates and combines a wide range of fighting styles such as wrestling, boxing, muaythai, Brazilian jiu-jitsu, judo and many more, which have been practised in many different cultures and are 'proven' combat styles over time.

The overrepresentation of left-handers among the UFC fighters could potentially be explained by the left-handers having a competitive advantage relative to right-handed fighters. However, this was not the case in our sample, as left-handers did not have a higher likelihood of winning a fight against a right-hander,

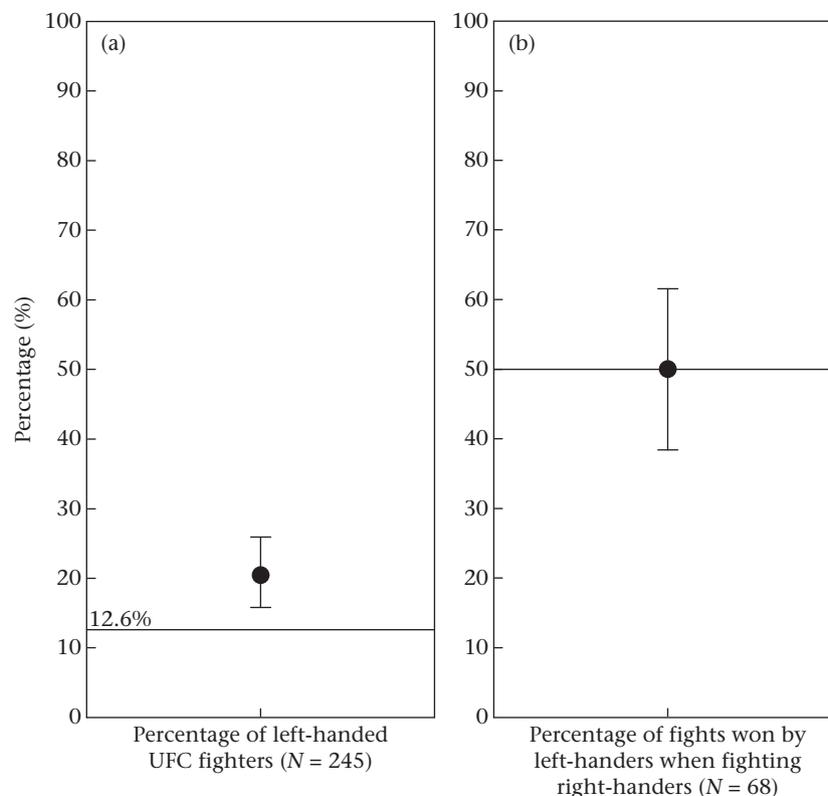


Figure 1. (a) Percentage of left-handed UFC Fighters and (b) percentage of fights won by a left-hander when facing a right-hander; 12.6% is based on a population estimate by Gilbert & Wysocki (1992). Error bars represent 95% confidence intervals based on the Agresti–Coull method.

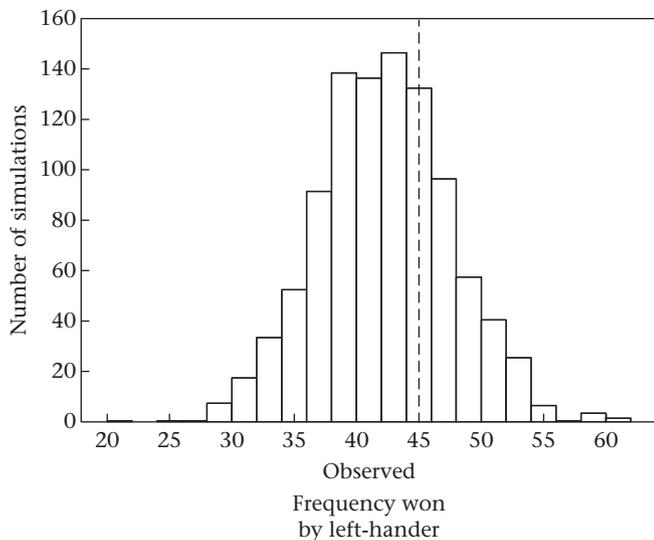


Figure 2. Histogram of the frequency of fights won by left-handers when handedness is assigned at random in our sample of 205 fights in 1000 simulations. The dashed line indicates the observed frequency of fights won by left-handers in the sample ($N = 45$).

suggesting that there is little evidence for a competitive advantage for left-handers in UFC professionals. Our results are based on both a simple binomial test and a simulation approach, which both show no evidence for a left-handed advantage.

Our tests do not necessarily indicate that left-handedness provides no competitive advantage at all in physical combat; it is possible that left-handers at nonprofessional levels enjoy a competitive benefit, leading to selection into professional UFC by increased chances of winning (which would lead to the overrepresentation of left-handers in our sample), whereas the benefits of left-handedness cease to exist when competing at the highest level. There are two nonmutually exclusive explanations for this possibility. First, left-handers may be prevalent to such a high degree within the UFC, that the advantage of left-handedness is diminished because right-handed fighters regularly have to deal with left-handed fighters. Second, professional right-handed fighters may themselves realize the left-hand advantage, and will regularly train against 'southpaws'. Amateurs, in contrast, may not have the time, resources or dedication to train similarly against left-handers, which would lead to a competitive advantage of left-handedness in the amateur setting. This advantage, in turn, could potentially make them more likely to be selected into the UFC. This possibility is in line with a recent study on handedness in tennis (Loffing et al. 2012b). This study showed that the beneficial effect of left-handedness in male professional tennis has decreased over the past 40 years and the authors suggest that this is because, as training regimes continue to improve, any benefits that left-handers might have become attenuated. Moreover, cross-sectional data from this study suggest that, in contrast to professional tennis, in nonprofessional tennis left-handers perform better than right-handers. A different study by Schorer et al. (2012) on penalties in handball also suggests that, with training, negative frequency-dependent effects can be minimized.

While the current study is partially in line with the fighting hypothesis, alternative explanations for the overrepresentation of left-handers in combat sports can also account for our results. Rather than the frequency-dependent advantage left-handed fighters have when fighting right-handers, selection of left-handers into ultimate fighting could also be the result of their potential innate superiority (Grouios et al. 2000), more specifically

caused by their potentially superior motor skills (e.g. Judge & Stirling 2003). For example, data from fencing suggest that left-handers have improved hand–eye coordination over right-handers (Taddei et al. 1991). There is also some evidence pointing to an advantage for left-handers in motor performance in the nondominant hand (Judge & Stirling 2003), as well as advantages in visual ability for left-handers when focusing on points (Dane & Gümüstekin 2002). More data on neuropsychological performance on left-handers versus right-handers in acts relevant for fighting would be necessary to test this alternative explanation further. However, one could argue that an 'innate superiority' explanation would suggest an overrepresentation of left-handers not only in combat sports but also in noninteractive sports involving fine motor skills but this is not the case (Grouios et al. 2000; see Loffing et al. 2012a). Yet, many noninteractive sports tend to require much slower motoric adjustments than interactive sports so that right-handers have to keep compensating for poor motor skills by taking more time (e.g. in darts, golf). Since left-handers did not have an advantage in fights in our data set, we did not find direct evidence for the innate superiority hypothesis either, as left-handers were not more likely to win fights than right-handers. The finding that left-handers are overrepresented, but do not win more fights in our sample could thus be explained by both innate superiority and the existence of a frequency-dependent advantage. We believe the latter explanation to be more likely, based on the above-mentioned literature that suggests that the advantage of left-handedness is apparent in amateurs but not in highly trained professionals that will have extensive experience with left-handed players. This is consistent with the lack of winning advantage we found here in the UFC.

Another explanation for the overrepresentation of left-handers in UFC is that left-handers may simply have more affinity with fighting sports or are more aggressive than right-handers. In this case the overrepresentation of left-handers is due to their motivation, rather than their handedness per se, which may not lead to higher winning chances and therefore fit our data best. In line with this, Dane & Şekertekin (2005) showed that left-handed football players were more aggressive and less tolerant than right-handers.

Both the 'innate superiority explanation' and the 'increased aggression' explanation are different from the fighting hypothesis in that only the latter assumes negative frequency-dependent selection: the success of left-handers is dependent on the proportion of left-handers in the population. To distinguish between these alternative explanations one could, for instance, analyse the effect of training and experience: if left-handers are simply superior or more aggressive than right-handers, then no amount of training against left-handers by right-handers will change the likelihood of winning against left-handers. More longitudinal data on the effect of fighting experience with left-handers is necessary to distinguish between these alternative explanations. In addition, experiments manipulating such experience with animal species other than humans may be helpful (Groothuis et al. 2013). For now we have shown that while there is substantial overrepresentation of left-handers in UFC fighters, left-handers have no advantage in fights that may closely resemble the way of fighting in human history.

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References

- Aggleton, J. P. & Wood, C. J. 1990. Is there a left-handed advantage in 'ballistic' sports? *International Journal of Sport Psychology*, **21**, 46–57.
- Brooks, R., Bussiere, L. F., Jennions, M. D. & Hunt, J. 2004. Sinister strategies succeed at the cricket World Cup. *Proceedings of the Royal Society B*, **271**, S64–S66.
- Cashmore, L., Uomini, N. & Chapelain, A. 2008. The evolution of handedness in humans and great apes: a review and current issues. *Journal of Anthropological Science*, **86**, 7–35.
- CBS News. 2010. Michael Kirkham, mixed martial arts fighter, dies after fight: is sport safe? http://www.cbsnews.com/8301-504763_162-20009164-10391704.html. Read: 21 January 2012.
- Dane, Ş. & Gümistekin, K. 2002. Correlation between hand preference and distance of focusing points of two eyes in the horizontal plane. *International Journal of Neuroscience*, **112**, 1141–1147.
- Dane, Ş. & Şekertekin, M. A. L.I. 2005. Differences in handedness and scores of aggressiveness and interpersonal relations of soccer players. *Perceptual and Motor Skills*, **100**, 743–746.
- Edwards, S. & Beaton, A. 1996. Howzat?! Why is there an over-representation of left-handed bowlers in professional cricket in the UK? *Laterality*, **1**, 45–50.
- Faul, F., Erdfelder, E., Lang, A. G. & Buchner, A. 2007. G* Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, **39**, 175–191.
- Faurie, C. & Raymond, M. 2005. Handedness, homicide and negative frequency-dependent selection. *Proceedings of the Royal Society B*, **272**, 25–28.
- Faurie, C. & Raymond, M. 2013. The fighting hypothesis as an evolutionary explanation for the handedness polymorphism in humans: where are we? *Annals of the New York Academy of Sciences*, **1288**, 110–113.
- Faurie, C., Lauretens, V., Alvergne, A., Goldberg, M., Zins, M. & Raymond, M. 2011. Left-handedness and male-male competition: insights from fighting and hormonal data. *Evolutionary Psychology*, **9**, 354–370.
- Foxx, J. 2012. UFC Career Fighter Earnings. *MMA manifesto*: <http://www.mma-manifesto.com/ufc-fighter-salary-database/salary-main/ufc-career-fighter-earnings.html>. Read: 1 October 2012.
- Francks, C., Fisher, S. E., MacPhie, I. L., Richardson, A. J., Marlow, A. J., Stein, J. F. & Monaco, A. P. 2002. A genomewide linkage screen for relative hand skill in sibling pairs. *American Journal of Human Genetics*, **70**, 800–805.
- Gilbert, A. N. & Wysocki, C. J. 1992. Hand preference and age in the United States. *Neuropsychologia*, **30**, 601–608.
- Goldstein, S. R. & Young, C. A. 1996. 'Evolutionary' stable strategy of handedness in major league baseball. *Journal of Comparative Psychology*, **110**, 164–169.
- Grondin, S., Guiard, Y., Ivry, R. B. & Koren, S. 1999. Manual laterality and hitting performance in major league baseball. *Journal of Experimental Psychology: Human Perception & Performance*, **25**, 747–754.
- Groothuis, T. G. G., McManus, I. C., Schaafsma, S. M. & Geuze, R. H. 2013. Fighting the fighting hypothesis: how well does the fighting hypothesis explain the existence of left-handed minorities in human populations? *Annals of the New York Academy of Sciences*, **1288**, 100–109.
- Grouios, G., Tsobatzoudis, H., Alexandris, K. & Barkoukis, V. 2000. Do left-handed competitors have an innate superiority in sports? *Perceptual and Motor Skills*, **90**, 1273–1282.
- Gursoy, R. 2009. Effects of left- or right-hand preference on the success of boxers in Turkey. *British Journal of Sports Medicine*, **43**, 142–144.
- Hagemann, N. 2009. The advantage of being left-handed in interactive sports. *Attention, Perception, & Psychophysics*, **71**, 1641–1648.
- Holtzen, D. W. 2000. Handedness and professional tennis. *International Journal of Neuroscience*, **105**, 101–119.
- Hopkins, W. D., Phillips, K. A., Bania, A., Calcutt, S. E., Gardner, M., Russell, J., Schaeffer, J., Lonsdorf, E. V., Ross, S. R. & Schapiro, S. J. 2011. Hand preferences for coordinated bimanual actions in 777 great apes: implications for the evolution of handedness in hominins. *Journal of Human Evolution*, **60**, 605–611.
- Judge, J. & Stirling, J. 2003. Fine motor skill performance in left- and right-handers: evidence of an advantage for left-handers. *Laterality*, **8**, 297–306.
- Landa, J. 2004. Risk and injuries in contact fighting. *Journal of Combative Sports*. http://ejmas.com/jcs/2004jcs/jcsart_land_0804.htm. Read: 1 October 2012.
- Lauretens, V., Raymond, M. & Faurie, C. 2009. Why are some people left-handed? An evolutionary perspective. *Philosophical Transactions of the Royal Society B*, **364**, 881–894.
- Loffing, F., Hagemann, N. & Strauss, B. 2010. Automated processes in tennis: do left-handed players benefit from the tactical preferences of their opponents? *Journal of Sports Sciences*, **28**, 435–443.
- Loffing, F., Schorer, J., Hagemann, N. & Baker, J. 2012a. On the advantage of being left-handed in volleyball: further evidence of the specificity of skilled visual perception. *Attention, Perception, & Psychophysics*, **74**, 1–8.
- Loffing, F., Hagemann, N. & Strauss, B. 2012b. Left-handedness in professional and amateur tennis. *PLoS One*, **7**, e49325.
- McMorris, T. & Colenso, S. 1996. Anticipation of professional soccer goalkeepers when facing right- and left-footed penalty kicks. *Perceptual and Motor Skills*, **82**, 931–934.
- Medland, S. E., Duffy, D. L., Wright, M. J., Geffen, G. M. & Martin, N. G. 2006. Handedness in twins: joint analysis of data from 35 samples. *Twin Research and Human Genetics*, **9**, 46–53.
- MMAjunkie. 2011. UFC 141 salaries: win or lose, Brock Lesnar will be tonight's top earner: <http://mmajunkie.com/news/26754/ufc-141-salaries-win-or-lose-brock-lesnar-will-be-tonights-top-earner.mma>. Read: 20 November 2012.
- Peters, M., Reimers, S. & Manning, J. T. 2006. Hand preference for writing and associations with selected demographic and behavioral variables in 255,100 subjects: the BBC internet study. *Brain and Cognition*, **62**, 177–189.
- Raymond, M., Pontier, D., Dufour, A. B. & Moller, A. P. 1996. Frequency-dependent maintenance of left handedness in humans. *Proceedings of the Royal Society B*, **263**, 1627–1633.
- Reuters. 2007. BMA wants ultimate fighting banned. *Reuters*: <http://uk.reuters.com/article/2007/09/05/uk-britain-boxing-idUKUKO46078120070905>. Read: 20 November 2012.
- Schorer, J., Loffing, F., Hagemann, N. & Baker, J. 2012. Human handedness in interactive situations: negative perceptual frequency effects can be reversed! *Journal of Sports Sciences*, **30**, 507–513.
- Sicotte, N. L., Woods, R. P. & Mazziotta, J. C. 1999. Handedness in twins: a meta-analysis. *Laterality*, **4**, 265–286.
- Steele, J. & Uomini, N. 2005. Humans, tools and handedness. In: *Stone Knapping: the Necessary Conditions for a Uniquely Hominin Behaviour* (Ed. by B. Roux & V. Bril), pp. 217–239. Cambridge: McDonald Institute for Archaeological Research.
- Taddei, F., Viggiano, M. P. & Mecacci, L. 1991. Pattern reversal visual evoked potentials in fencers. *International Journal of Psychophysiology*, **11**, 257–260.
- Ultimate Fighting Championship. 2012a. UFC: www.ufc.com. Read: 24 July 2012.
- Ultimate Fighting Championship. 2012b. Rules and regulations: <http://uk.ufc.com/discover/sport/rules-and-regulations#15>. Read: 24 July 2012.
- Wood, C. J. & Aggleton, J. P. 1989. Handedness in 'fast ball' sports: do left-handers have an innate advantage? *British Journal of Psychology*, **80**, 227–240.
- Ziyagil, M. A., Gursoy, R., Dane, Ş. & Yuksel, R. 2010. Left-handed wrestlers are more successful. *Perceptual and Motor Skills*, **111**, 65–70.