



Are they all born to score? The relationship between throwing arm and scoring from the 7-meter line in semi-professional handball

Aron Laxdal, Sveinn Þorgeirsson, Jose M. Saavedra, Ólafur Sigurgeirsson & Andreas Ivarsson

To cite this article: Aron Laxdal, Sveinn Þorgeirsson, Jose M. Saavedra, Ólafur Sigurgeirsson & Andreas Ivarsson (2023): Are they all born to score? The relationship between throwing arm and scoring from the 7-meter line in semi-professional handball, *Laterality*, DOI: [10.1080/1357650X.2023.2234636](https://doi.org/10.1080/1357650X.2023.2234636)

To link to this article: <https://doi.org/10.1080/1357650X.2023.2234636>



© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 31 Jul 2023.



Submit your article to this journal [↗](#)



Article views: 91



View related articles [↗](#)



View Crossmark data [↗](#)

Are they all born to score? The relationship between throwing arm and scoring from the 7-meter line in semi-professional handball

Aron Laxdal ^a, Sveinn Þorgeirsson ^{b,c}, Jose M. Saavedra^b, Ólafur Sigurgeirsson^d and Andreas Ivarsson ^{a,e}

^aDepartment of Sport Science and Physical Education, University of Agder, Kristiansand, Norway; ^bPhysical Activity, Physical Education, Sport and Health Research Centre, Reykjavik University, Reykjavik, Iceland; ^cFaculty of Kinesiology, University of Split, Split, Croatia; ^dHB Statz, Seltjarnarnes, Iceland; ^eCenter of Research on Welfare, Health and Sport, Halmstad University, Halmstad, Sweden

ABSTRACT

Indications of lateral biases favouring left-handers have been found in various sports; especially interactive sports where the athletes have limited time to react to incoming objects. The aim of this study was therefore to explore whether any lateral biases exist in handball by examining 7-meter shots. A total of 6846 7-meter throws from 240 7-meter shooters across four seasons in the semi-professional Icelandic elite handball division (male and female) were analyzed. Out of the 240 7-meter shooters, of which 151 were male and 89 were female, 22% were left-handed (22% of the males and 20% of the females). The left-handed 7-meter shooters took a disproportionate number of the 7-meter shots, with left-handed shooters performing 29% of the 7-meter shots (27% in the male league and 33% in the female league). The results of a Bayesian two-level analysis indicated that left-handedness is not associated with greater success from the 7-meter line at the semi-professional level.

ARTICLE HISTORY Received 9 November 2022; Accepted 4 July 2023

KEYWORDS 7-meter throw; handedness; left-handed; negative frequency-dependent advantage; penalty throw

Introduction

Being left-handed has been found to be surprisingly advantageous in interactive sports (Loffing & Hagemann, 2016; Richardson & Gilman, 2019). While the explanation for the advantage is somewhat unclear, two

CONTACT Aron Laxdal  aron.laxdal@uia.no  Department of Sport Science and Physical Education, University of Agder, Kristiansand, Norway

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

hypotheses have generally been proposed: the innate superiority hypothesis and the negative frequency-dependent advantage hypothesis (Loffing & Hagemann, 2016).

The innate superiority hypothesis supposes that left-handers are innately predisposed to sporting success due to right-hemisphere specialization, less lateralization, and a more optimal hormonal configuration (Groothuis et al., 2013; Loffing & Hagemann, 2016). These advantages are assumed to result in improved visuospatial and spatiotemporal skills, more efficient neural processing, better bimanual coordination, and higher aggression (Dane & Erzurumluoglu, 2003; Loffing & Hagemann, 2016).

The negative frequency-dependent advantage hypothesis associates the advantages of being left-handed with the relative infrequency of left-handers in society (Raymond et al., 1996). In other words, with most of the world population being right-handed, right-handedness and the movement patterns associated with right-handedness are the expected norm. When presented with a left-handed opponent, the processing of kinematic information appears to be affected due to difficulties adequately responding to less frequently observed movement patterns (Hagemann, 2009; Loffing et al., 2015; Loffing & Hagemann, 2020).

Due to left-handedness appearing to be more advantageous in interactive sports than in non-interactive sports, the negative frequency-dependent advantage hypothesis is believed to have more explanatory power than the innate superiority hypothesis (Loffing & Hagemann, 2016). However, there are some indications that both may play a part simultaneously (Loffing & Hagemann, 2015; Pollet et al., 2013; Witkowski et al., 2019).

While studying the potential superiority of left-handed athletes is an interesting and relatively popular pursuit, studying left-handed handball players is particularly interesting and should arguably be more prevalent. Due to having a tactical advantage on the right side of the court, teams traditionally strive to have two left-handers on the field at any time and four on the team in total. That leads to an overrepresentation of left-handers in handball compared to the general population (29% of handball players are expected to be left-handed compared to 12% of the male population and 9% of the female population [Papadatou-Pastou et al., 2020]). The mismatch between the desired number of left-handed players and the available left-handed candidates tends to result in left-handers being favoured during various selection processes (Baker et al., 2013; Karcher & Buchheit, 2017).

However, there is one situation where there is supposedly no tactical reason for left-handers to be overrepresented; namely the 7-meter shot. This shot is always taken 7 metres from the goal at a perpendicular angle. Seeing as there are no angular advantages to being either left- or right-handed when performing a 7-meter shot, one would expect the handedness of the shooter to be inconsequential when 7-meter shooters are selected. An argument can even be made

that left-handers should be underrepresented in that particular role seeing as they have been subjected to positive discrimination throughout their career (Baker et al., 2013; Karcher & Buchheit, 2017). More skill would therefore be required to claim a spot on the team as a right-hander, and in a winner-takes-all situation like the 7-meter shot, the right-handed shooters would be expected to come out on top (Gallup & Sleicher, 2021).

Nevertheless, a recent study on the relationship between handedness and success from the 7-meter line found that left-handed 7-meter shooters were overrepresented at the 2016–2022 men's European championships; not just compared to society at large, but to the number of left-handers at the tournaments as well (Laxdal et al., 2022). However, Laxdal et al. (2022) did not find handedness to be associated with increased success from the 7-meter line. Their findings were therefore incongruent with the results of Lobinger et al. (2014), who found left-handed 7-meter shooters to have a better scoring record at the 2010 men's European championship.

Lateral biases have also been found in other highly controlled sporting situations where balls travel at high velocities, namely penalty kicks in soccer and batting in cricket. However, the results are somewhat mixed. While Baumann et al. (2011) found that left-footed penalty takers were both overrepresented and more likely to score than right footed penalty takers in the German Bundesliga, the same was not true in the French or the Italian top divisions (Coloma, 2007). Furthermore, Schorer et al. (2015) found that even though left- and right-footers performed equally from penalties at the World Cup group stages, lefties did worse in the playoffs. The authors interpreted this as left-footers being more likely to choke in high stress situations, in stark contrast to the findings of Mesagno et al. (2019), whose quasi-experimental study found left-handers to be less likely to choke under pressure. Interestingly, Brooks et al. (2004), found left-handed batters in cricket to have a higher batting average than their right-handed counterparts. However, the batters stand on the other side of the throw, and may have more of a strategic advantage, rather than one related to negative frequency-dependency.

In light of the inconsistent findings from previous studies within the literature, this study aimed to expand on the work of Laxdal et al. (2022) by (1) testing a larger sample, (2) including females in the sample, and (3) studying a different population (i.e., semi-professional instead of world-class handball players). The last two are especially significant contributions to the literature, as previous studies have indicated that females are less likely to be left-handed than males (Papadatou-Pastou et al., 2020), lateral biases appear to be less pronounced among females (Connor et al., 2020; Loffing et al., 2012), and negative frequency-dependent effects seem to vary across skill levels (Dochtermann et al., 2014; Holtzen, 2000). This study therefore set out to (1) examine whether left-handers are overrepresented at the 7-meter line at the semi-professional level, (2) investigate the relationship between left-

handedness and the outcome of 7-meter shots at the semi-professional level, and (3) explore whether any sex differences exist when it comes to lateral biases from 7-meter shots at the semi-professional level. Based on previous research, left-handers were expected to be overrepresented and they were believed to be more likely to score from 7-meter shots than right-handers. However, it was uncertain whether the proposed lateral biases only applied to the males or if they were present among the females as well.

Methods

Data and procedure

The outcome of all 7-meter shots in the Icelandic elite handball division (male and female) during the four seasons from 2018–2022 was registered into the HBStatz system (a handball-specific statistical platform; www.hbstatz.is); a total of 6846 7-meter shots by 240 different shooters (151 males and 89 females). The number of male and female shooters is uneven because the male and female elite handball divisions in Iceland vary in size. While the male league includes a twelve-team league and a playoff series between eight teams, the female league only includes eight teams and a four-team playoff series. The leagues are semi-professional and rank 27th (male league) and 25th (female league) on the European Handball Federation's coefficient (European Handball Federation, 2021).

The registration was done in situ by representatives from the home teams who were familiar with the platform and had received training prior to the data collection. In an effort to reduce discrepancies and increase the reliability of the collected data, the HBStatz reports are cross-referenced with the official game reports. Logical tests are also performed on all games to ensure that the reports balance out (e.g., number of 7-meter throws given = goals from 7-meter throws + missed 7-meter throws). Reports that do not pass the quality control process are reviewed and the games reanalyzed if needed. Additional quality controls are done at random in real-time by representatives from HBStatz. As the data is publicly available, no ethical approval was needed and informed consent was not collected from the players.

The variables of interest were the outcome of the 7-meter shots (categorized dichotomously depending on whether they resulted in a goal or a miss), the players' dominant throwing hand (categorized dichotomously depending on whether they prefer to throw with their right- or their left hand), the handedness of the goalkeeper (categorized in the same way as the shooters' handedness), and the sex of the shooter (whether the shooter played in the male or female league). The researchers registered the dominant throwing hand of the players by using information that was openly available online (e.g., video and photographs of the players throwing a ball). The information was

validated independently by players and coaches from the leagues in question. No anomalies were discovered. Twenty 7-meter shots in the database were missing a shooter ID and 42 7-meter shots were missing a goalkeeper ID, meaning that handedness could not be categorized. Additionally, no information was found on the handedness of 10 out of the 122 goalkeepers (a total of 29 7-meter shots). Those 7-meter shots were therefore excluded from further analysis (1% of 7-meter shots in the sample).

Statistical analyses

Binomial tests of proportions were performed in SPSS (version 28.0; IBM Corp., Armonk, NY) to determine whether left-handers were overrepresented within the sample, and whether left-handers took a disproportionate amount of 7-meter shots. In line with Laxdal et al. (2022), the number of left-handers in the sample was compared to the prevalence of left-handers on the teams in question; with the proportion of left-handers during the 2021/2022 season used as a proxy for all four seasons. As the proportions in the male and female leagues differed (23% left-handers in the male league and 13% left-handers in the female league), separate analyses were performed for each sex. The proportion of left-handed 7-meter shooters in the sample was then compared to the proportion of 7-meter shots performed by left-handers.

To determine whether left-handed players were more likely to score from any individual 7-meter shot than right-handers, a Bayesian two-level analysis was performed in Mplus (version 8.4; Muthén & Muthén, Los Angeles, CA). To account for dependency within the data, the 7-meter shot outcomes (level one) were nested within the shooters (level two), with the shooters' handedness and the shooters' sex included as covariates on level two. The goalkeepers' handedness was included as a covariate on level one.

A Bayesian estimator was used for the two-level analysis (see Wagenmakers et al., 2018 for a comparison between the Bayesian estimator and the more traditional frequentist approach). Markov Chain Monte Carlo simulation procedures with a Gibbs sampler with 200 000 iterations were performed. A potential scale reduction factor of around one was used to indicate adequate convergence. Model fit was assessed using the posterior predictive p (PP p) value and its accompanying 95% confidence interval (Muthén & Asparouhov, 2012). Credibility intervals (CI) were estimated for all parameters within the models, and the null hypothesis was rejected if the 95% CI did not include zero (Zyphur & Oswald, 2015).

Results

Of the 6848 7-meter shots, 5229 resulted in goals (76%), and 1617 resulted in misses (24%). The binomial tests of proportions indicated mixed results, with

left-handed 7-meter shooters in the female league being overrepresented compared to the number of left-handed players in the league (20% vs. 13%, $p < .001$). However, no overrepresentation was found in the male league (22% vs. 23%, $p = .489$). Nevertheless, the left-handed shooters in both leagues performed a disproportionate amount of 7-meter shots compared to the proportion they would be expected to take (i.e., the proportion of left-handed 7-meter shooters during the studied period; 33% vs. 20%, $p < .001$ in the female league and 27% vs. 22%, $p < .001$ the male league).

The two-level model showed good fit to data ($PPp = .46$, 95% Confidence Interval = [-9.83, 10.53]). There was no relationship between handedness and the outcome of 7-meter shots ($\beta = -.12$, 95% CI = [-.44, .19]). Sex had a credible association with the outcome ($\beta = -.45$, 95% CI = [-.78, -.11]), indicating that females have a higher success rate from 7-meter shots. No relationship was found between the goalkeepers' handedness and the outcome of 7-meter shots ($\beta = -.02$, 95% CI = [-.05, .01]).

Discussion

This study tested whether left-handers were overrepresented at the 7-meter line at the semi-professional level. Left-handed females were found to be overrepresented in the current sample compared to the prevalence of left-handed females in the league, which corresponds with the results of Laxdal et al. (2022), who found the same trend for males at the world-class level. However, the same trend was not found for the left-handed males in this sample, who were not found to be overrepresented at the 7-meter line. This discrepancy does not only indicate differences between males and females at this level but also between semi-professional- and world-class male 7-meter shooters (a binomial test of proportions indicated that there was no statistical difference between the proportion of left-handed players at the two levels of proficiency; 25% vs. 23%, $p = .092$). While left-handed males were not overrepresented as a proportion of shooters, they did nevertheless perform a disproportionate amount of the 7-meter shots; and the same was true for the females. In other words, the left-handed 7-meter shooters took a larger proportion of the 7-meter shots than one would expect them to, based on their representation as 7-meter shooters. These results also align with the findings of Laxdal et al. (2022) and indicate that the coaches are relatively more likely to let left-handed take 7-meter shots than right-handed 7-meter shooters.

While finding sex differences in the current sample was not particularly surprising, the fact that the lateral biases were more prominent among the females than the males was somewhat surprising. Several previous studies on lateral biases in sports have namely found the opposite to be true in other sporting contexts (Breznik, 2013; Connor et al., 2020; Loffing, 2017;

Loffing et al., 2012; Lucafò et al., 2021). While there is no clear biological reason why females would benefit more from being left-handed when taking 7-meter shots than males, there is a possible tactical reason. Seeing as there are so few left-handed females playing in the league in question (13% of players in matchday squads), their offensive value becomes even more substantial. With left-handedness adding no value on the defensive end, some left-handers are rested when the rest of the teams defend to ensure that they can partake in every offensive action. If that is the case in the Icelandic elite division, that could explain the disparity between males and females.

However, with left-handed females being so underrepresented in the league in question, compared to the preferred frequency of left-handers on any given handball team (i.e., $4/14 = 29\%$), the left-handed players would be expected to be less skilled than their right-handed counterparts. When left-handedness is such a scarce commodity, progression through the ranks is likely expedited, meaning that players without the skills usually associated with playing at that level are given the opportunity out of tactical necessity (Baker et al., 2013; Karcher & Buchheit, 2017). If no lateral biases were present, right-handed players would be expected to possess greater skills and be better suited as 7-meter shooters (Gallup & Sleicher, 2021). The expected heterogeneity in skill-levels at the semi-professional level may also explain the discrepant results between the current study and the study of Laxdal et al. (2022) with regards to the male shooters. In a more homogeneous environment (i.e., the world-class level), where the best players compete on a more level playing field and the best possible players have been chosen for every single position, lateral biases may become more prominent.

The incongruity between the semi-professional- and the world class level could also be explained by the mechanisms behind shooter selection and the pool of available players at the various levels. While national team coaches usually have a myriad of proficient 7-meter specialists to choose from, players who have specialized in the shot type for years, club coaches may be forced to choose from players who are only moderately proficient from the 7-meter line. With most coaches opting to change shooters when the first-choice shooter misses, a significant number of 7-meter shots at the semi-professional- and amateur level may be taken by players with relatively modest experience with the shot type. In other words, the selection process might be too inefficient to identify the best shooters, or to consistently let the best shooters take the 7-meter shots that materialize. Since the processes behind shooter choice do not appear to have been studied yet, there are no empirical data to discuss.

No relationship was found between handedness and success from the 7-meter line. These findings align with the results of Laxdal et al. (2022), who found the same null effect at the 2016–2022 European championships

(calculating the difference between the two slopes from the current study and Laxdal et al. (2022) showed no statistically significant difference between the two estimates). However, the results were at odds with those of Lobinger et al. (2014), who found that left-handers had a better scoring percentage than their right-handed counterparts at the 2010 men's European championship. Seeing as Loffing (2017) found increased time pressure to be associated with lateral biases, one would expect greater left-hander advantage when executing 7-meter throws. Yet, if the overrepresentation of left-handed females, and disproportionate shot-taking by left-handed males and females is viewed as a form of lateral bias, that may indeed be an indication that the selection process for who takes 7-meter shots works. In other words, the lateral biases have already materialized before the shot is taken, when the best 7-meter shooters are selected to take 7-meter shots.

It is unclear whether the results of the current study are at odds with the negative frequency-dependent advantage hypothesis or not. The results appear to be in line with the general trends within the handedness literature, where left-handers have been found to be overrepresented in various sports (Loffing, 2017; Loffing & Hagemann, 2016), but signs of left-handers performing better than right-handers on individual trials fail to materialize (e.g., Baker & Schorer, 2013; Laxdal et al., 2022; Pollet et al., 2013). Perhaps the advantage does not materialize in any single event, but rather across time, meaning that the chosen methodology may be limited. Seeing as Richardson and Gilman (2019) found such a performance advantage studying the fighting records of thousands of boxers and MMA-fighters, one could argue that it would be more pertinent to study the 7-meter records of a multitude of shooters over a long period if the question of whether left-handedness is associated with greater success from the 7-meter line is going to be answered. But then again, as Groothuis et al. (2013) pointed out, although lateral biases in sports are somewhat common, they are immensely difficult to explain, and may be caused by innate- or tactical factors and not negative-frequency dependent factors.

Other limitations to the study should also be considered when interpreting the results. For various reasons, 7-meter shooters at the semi-professional level are not always specialists at the shot type. In uneven games, young, inexperienced, or sometimes players needing a confidence boost are offered the opportunity to score a relatively easy goal. With most handball players being right-handed, these shooters likely inflated the number of right-handed shooters in the sample. In fact, 86% of the players who only performed a single 7-meter shot during the four year period were right-handed (79% in the male league and 95% in the female league). Seeing as the inclusion of those shooters could conceivably have biased the results, additional analyses were done where the players who performed only one 7-meter shot and the players who performed less than five 7-meter shots were excluded, respectively. The results from these analyses did not

change the conclusion (See β -values for handedness: $\beta = -.12$, 95% CI = [-.49, .24]; $\beta = -.09$, 95% CI = [-.49, .30]).

Future research should explore whether different methodologies can shed more light on the relationship between 7-meter shots and throwing arm. Qualitative interviews with goalkeepers and coaches where various processes related to 7-meter shots (i.e., selection, preparation, execution, evaluation, etc.) are delineated could introduce new insights and add nuance to the discussion.

Conclusion

No relationship was found between handedness and success from 7-meter shots in semi-professional handball. However, females were overrepresented as 7-meter shooters and both males and females took a disproportionate amount of the 7-meter shots. These findings both support and add to the existing literature on lateral biases in sports and pave the way for more research into this complex phenomenon.

Author statements

Data is openly available at doi.org/10.6084/m9.figshare.21026680.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Aron Laxdal  <http://orcid.org/0000-0002-2239-427X>

Sveinn Þorgeirsson  <http://orcid.org/0000-0001-5047-7147>

Andreas Ivarsson  <http://orcid.org/0000-0002-8987-5975>

References

- Baker, J., Kungl, A.-M., Pabst, J., Strauss, B., Buesch, D., & Schorer, J. (2013). Your fate is in your hands? Handedness, digit ratio (2D: 4D), and selection to a national talent development system. *Laterality: Asymmetries of Body, Brain and Cognition*, 18(6), 710–718. <https://doi.org/10.1080/1357650X.2012.755992>
- Baker, J., & Schorer, J. (2013). The Southpaw advantage?—lateral preference in mixed martial arts. *PLoS ONE*, 8(11), e79793. <https://doi.org/10.1371/journal.pone.0079793>

- Baumann, F., Friehe, T., & Wedow, M. (2011). General ability and specialization: Evidence from penalty kicks in soccer. *Journal of Sports Economics*, 12(1), 81–105. <https://doi.org/10.1177/1527002510371194>
- Breznik, K. (2013). On the gender effects of handedness in professional tennis. *Journal of Sports Science & Medicine*, 12(2), 346. PMID: 24149815.
- Brooks, R., Bussiere, L. F., Jennions, M. D., & Hunt, J. (2004). Sinister strategies succeed at the cricket world Cup. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 271(3), 64–66. <https://doi.org/10.1098/rsbl.2003.0100>
- Coloma, G. (2007). Penalty kicks in soccer: An alternative methodology for testing mixed-strategy equilibria. *Journal of Sports Economics*, 8(5), 530–545. <https://doi.org/10.1177/1527002506289648>
- Connor, J. D., Mann, D. L., Gomez, M.-A., Leicht, A. S., & Doma, K. (2020). Performance advantages of left-handed cricket batting talent. *Frontiers in Psychology*, 11, 1654. <https://doi.org/10.3389/fpsyg.2020.01654>
- Dane, S., & Erzurumluoglu, A. (2003). Sex and handedness differences in eye-hand visual reaction times in handball players. *International Journal of Neuroscience*, 113(7), 923–929. <https://doi.org/10.1080/00207450390220367>
- Dochtermann, N. A., Gienger, C., & Zappettini, S. (2014). Born to win? Maybe, but perhaps only against inferior competition. *Animal Behaviour*, 96(0), e1–e3. <https://doi.org/10.1016/j.anbehav.2014.07.024>
- European Handball Federation. (2021, October 22). EHF announces place distribution for 2022-23 European club competitions. <https://www.eurohandball.com/en/news/en/ehf-announces-place-distribution-for-2022-23-european-club-competitions/>.
- Gallup, A. C., & Sleicher, E. (2021). Left-hand advantage and the right-sided selection hypothesis. *Evolutionary Behavioral Sciences*, 15(2), 184–190. <https://doi.org/10.1037/ebs0000245>
- Groothuis, T. G., McManus, I., Schaafsma, S. M., & Geuze, R. H. (2013). The fighting hypothesis in combat: how well does the fighting hypothesis explain human left-handed minorities? *Annals of the New York Academy of Sciences*, 1288(1), 100–109. <https://doi.org/10.1111/nyas.12164>
- Hagemann, N. (2009). The advantage of being left-handed in interactive sports. *Attention, Perception, & Psychophysics*, 71(7), 1641–1648. <https://doi.org/10.3758/APP.71.7.1641>
- Holtzen, D. W. (2000). Handedness and professional tennis. *International Journal of Neuroscience*, 105(1-4), 101–119. <https://doi.org/10.3109/00207450009003270>
- Karcher, C., & Buchheit, M. (2017). Anthropometric and physical performance requirements to be selected in elite handball academies: Is being left-handed an advantage. *SPSR*, 9, 1–2.
- Laxdal, A., Ivarsson, A., Thorgeirsson, S., & Haugen, T. (2022). Born to score? The relationship between left-handedness and success from the 7-meter line. *Symmetry*, 14(10), 2163. <https://doi.org/10.3390/sym14102163>
- Lobinger, B., Büsch, D., Werner, K., Pabst, J., Gail, S., & Sichelschmidt, P. (2014). Erfolgsrelevante Aktionsmuster von Torhütern beim Siebenmeterwurf im Spitzenhandball [Analysis of action patterns of goalkeepers in 7-meter-throws in top-level handball]. *Zeitschrift für Sportpsychologie*, 21(2), 74–85. <https://doi.org/10.1026/1612-5010/a000116>
- Loffing, F. (2017). Left-handedness and time pressure in elite interactive ball games. *Biology Letters*, 13(11), 20170446. <https://doi.org/10.1098/rsbl.2017.0446>
- Loffing, F., & Hagemann, N. (2015). Pushing through evolution? Incidence and fight records of left-oriented fighters in professional boxing history. *Laterality*:

- Asymmetries of Body, Brain and Cognition*, 20(3), 270–286. <https://doi.org/10.1080/1357650X.2014.961471>
- Loffing, F., & Hagemann, N. (2016). Performance differences between left-and right-sided athletes in one-on-one interactive sports. In F. Loffing, N. Hagemann, B. Strauss, & C. Macmahon (Eds.), *Laterality in sports* (pp. 249–277). Elsevier. <https://doi.org/10.1016/B978-0-12-801426-4.01001-4>
- Loffing, F., & Hagemann, N. (2020). Motor competence is not enough: Handedness does not facilitate visual anticipation of same-handed action outcome. *Cortex*, 130, 94–99. <https://doi.org/10.1016/j.cortex.2020.05.008>
- Loffing, F., Hagemann, N., & Strauss, B. (2012). Left-handedness in professional and amateur tennis. *PLoS ONE*, 7(11), e49325. <https://doi.org/10.1371/journal.pone.0049325>
- Loffing, F., Sölter, F., Hagemann, N., & Strauss, B. (2015). Accuracy of outcome anticipation, but not gaze behavior, differs against left-and right-handed penalties in team-handball goalkeeping. *Frontiers in Psychology*, 6, 1820. <https://doi.org/10.3389/fpsyg.2015.01820>
- Lucafò, C., Marzoli, D., Zdybek, P., Malatesta, G., Smerilli, F., Ferrara, C., & Tommasi, L. (2021). The bias toward the right side of others is stronger for hands than for feet. *Symmetry*, 13(1), 146. <https://doi.org/10.3390/sym13010146>
- Mesagno, C., Garvey, J., Tibbert, S. J., & Gröpel, P. (2019). An investigation into handedness and choking under pressure in sport. *Research Quarterly for Exercise and Sport*, 90(2), 217–226. <https://doi.org/10.1080/02701367.2019.1588935>
- Muthén, B., & Asparouhov, T. (2012). Bayesian structural equation modeling: A more flexible representation of substantive theory. *Psychological Methods*, 17(3), 313–335. <https://doi.org/10.1037/a0026802>
- Papadatou-Pastou, M., Ntolka, E., Schmitz, J., Martin, M., Munafò, M. R., Ocklenburg, S., & Paracchini, S. (2020). Human handedness: A meta-analysis. *Psychological Bulletin*, 146(6), 481–524. <https://doi.org/10.1037/bul0000229>
- Pollet, T. V., Stulp, G., & Groothuis, T. G. (2013). Born to win? Testing the fighting hypothesis in realistic fights: Left-handedness in the ultimate fighting championship. *Animal Behaviour*, 86(4), 839–843. <https://doi.org/10.1016/j.anbehav.2013.07.026>
- Raymond, M., Pontier, D., Dufour, A.-B., & Møller, A. P. (1996). Frequency-dependent maintenance of left handedness in humans. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 263(1377), 1627–1633. <https://doi.org/10.1098/rspb.1996.0238>
- Richardson, T., & Gilman, R. T. (2019). Left-handedness is associated with greater fighting success in humans. *Scientific Reports*, 9(1), 1–6. <https://doi.org/10.1038/s41598-018-37186-2>
- Schorer, J., Rienhoff, R., Loffing, F., & Baker, J. (2015). Left kickers choke during play-offs in soccer penalties. *Talent Development & Excellence*, 7(1), 91–94.
- Wagenmakers, E.-J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Love, J., Selker, R., Gronau, Q. F., Šmíra, M., & Epskamp, S. (2018). Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychonomic Bulletin & Review*, 25(1), 35–57. <https://doi.org/10.3758/s13423-017-1343-3>
- Witkowski, M., Tomczak, M., Karpowicz, K., Solnik, S., & Przybyła, A. (2019). Effects of fencing training on motor performance and asymmetry vary with handedness. *Journal of Motor Behavior*, 52(1), 50–57. <https://doi.org/10.1080/00222895.2019.1579167>
- Zyphur, M. J., & Oswald, F. L. (2015). Bayesian estimation and inference: A user's guide. *Journal of Management*, 41(2), 390–420. <https://doi.org/10.1177/0149206313501200>