ARE THERE CONNECTIONS BETWEEN HANDEDNESS, COMPETITIVE RESULTS AND MOTIVATION IN WHEEL GYMNASTS?

Johanna Weber[1, 2]

[1] Neurocognition and Action – Biomechanics, Bielefeld University, Germany
[2] Institute for sports science, Christian-Albrechts-University of Kiel, Germany
Germany

Original article *DOI:10.52165/sgj.14.1.107-117*

Abstract
Handedness is a performance-influencing factor in many competitive sports. In female team handball, psychological factors such as motivation have been connected to handedness. It should be researched whether this is also the case in wheel gymnastics and whether motivation is related to performance or handedness. For this purpose, 203 German wheel gymnasts were studied. There are significant differences in motivational aspects between gymnasts of different handedness within the straight line discipline. No differences were found in the all-around. There were not enough cases of gymnasts competing in spiral or vault only. When comparing the prevalence of different types of handedness in the general population to those among wheel gymnasts, no specific evaluation could be conducted for male gymnasts due to too few cases, although it should be noted that all 13 male participants were right-handed. When comparing the percentages of the left-handed and ambidextrous among female gymnasts to those in the general female population, it is evident that there is a higher percentage of ambidexters and left-handers among wheel gymnasts than in the general female population. There are differences in the percentages of female gymnasts of different handedness competing in straight line and all-around. There are correlations between percentage of handedness and competitive results when considering quintiles of competitive results (e. g. $r = 0.949$ and $p \leq 0.014$ for technical difficulty in left-handed athletes). Our results suggest that it might be necessary to consider handedness when it comes to individual coaching and selection.

Keywords: Handedness, Competitive results, Motivation, Disciplines, Performance.

INTRODUCTION

Wheel gymnastics originated in Germany in 1925 when Otto Feick built a two-rimmed wheel in which a person can stand while the wheel itself is moving (Sebesta, 2002). In current wheel gymnastics, there are four different disciplines: vault, straight line with/ without music, spiral and, more recently, cyr (Kauther, Rummel, Hussmann, Lendemans, Wedemeyer & Jaeger, 2015). In wheel gymnastics, points are awarded to the athlete for technical difficulty and

composition of a routine but deducted from the execution value if the athlete performs the movement technically correctly but inaccurately (Deutscher Turner-Bund (DTB), 2008). According to literature, the disciplines demand strength, endurance, and flexibility as well as core, explosive and jumping strength, coordination of movement, concentration, emotional control, perception, stress resistance and self-esteem as well as aesthetic expression (Hundrieser, 2012; Weyermann, 2016).

Sports performance is limited by physical aspects and psychological factors such as motivation: performance demands and psychological factors have been found to be related, for example, in netball (Grobbelaar & Eloff, 2011) and soccer (Hughes, Caudrelier, James, Redwood-Brown, Donnelly, Kirkbride et al., 2012). It should be researched whether motivation is also performance-relevant in wheel gymnastics. It is known that self-regulation practice enhances gymnastic skills (Wolko, Hrycaiko & Martin, 1993). Hume, Hopkins, Robinson, Robinson & Hollings (1993) found that motivation correlates with attainment in gymnastics, while D'Arripe-Longueville, Hars, Debois & Calmels (2009, p 1) showed that "*the main psychological characteristics developed by all the participants pertained to achievement motivation, performance enhancement cognitive skills (e.g., focusing, imagery), and affective and psychosomatic skills (e.g., ability to deal with anxiety; relaxation)*". Munkácsi, Kalmár, Hamar, Katona & Dancs (2012) claim that a strong motivational driving force is essential to perform high level gymnastic exercises and maintain daily practice.

In team sports, handedness can be a performance-influencing factor. In handball, right-handed players are often put on the left side of the court and left-handers on the right, since this leads to optimal angles when shooting at the goal (Oberbeck, 1989; Pohn, 2009). Amongst female German players, the percentages of handedness differed from the female population, and the percentages of handedness per position varied (Weber, 2018). In the same study, motivational differences according to handedness were found. Also, handedness has been found to be related to velocity in repeated sprints in male prepubertal youth players (Ziyagil, 2011) and reaction in female elite players (Al Awamleh, Mansi & Alkhaldi, 2013). These findings could perhaps be extended to individual sports.

Hand preference is connected to laterality (Pritzel, 2006). In the general population there are about 10% left-handed people (Pohn, 2009; Springer & Deutsch, 1998; Raymond, Pontier, Dufour & Moller, 1996). Among the female population, Coren (1993) found 90.9% right-handed, 6.8% left-handed and 2.4% ambidextrous. Among artistic gymnasts, Bessi (2016) found 84.4% to be right-handed. For different kinds of sports, the frequency of left-handedness in athletes differs from that in the general population, especially in interactive sports. In baseball, there seems to be an ideal relation regarding the staffing of positions with the right and the left-handed (Loffing & Hagemann, 2012). Human lateralities incorporate handedness, leggedness/footedness and a preferred direction of turn. Not only the executing organs but sensors and central nervous structures show lateral differences (Hermsdorf, 2009) while brain functions are also partially lateralized (for example logic/analysis, perception, kinaesthetic ability, visual and linguistic aspects; Bogen, 1969). Handedness as a lateral phenomenon is the disposition to perform fine coordinative movements faster and more precisely with the preferred hand (Stier, 1911). It is still unclear whether handedness is genetically determined or developed later (Hermsdorf, 2009; Springer & Deutsch, 1998), although it should be assumed that handedness can be shifted to a certain degree via training (Maeda, Souza & Teixeira, 2014). There

are several tests to diagnose handedness, one being the determination of the preferred hand while observing the preference during several tasks (Hermsdorf, 2009). If neither hand is preferred, ambidexterity can be assumed. No preference is related to benefits in both-handed tasks (Kourtis, De Saedeler & Vingerhoets, 2014). Another method of diagnosis is based on performance, where the better performing hand is identified (Oberbeck, 1989).

Left-handers are over-represented at elite-levels of interactive sports (Hagemann, 2009) and most often outperform right-handers (left-handers' advantage, Grouios, Tsorbatzoudis, Alexandris & Barkoukis, 2000; Loffing & Hagemann, 2012). The left-handers' advantage is based on shorter reaction times (Noroozian Shadloo, Shakiba & Panahi, 2012) as well as tactical advantages (Sattler, 2007) since opponents are not used to left-handers (Wood & Aggleton, 1989). In ice-hockey, ambidextrous players perform better (Porac & Coren, 1981). In handball, players are used to right-handed opponents and are thus unable to anticipate the left-handers' actions as well as those of the right-handed players (Schorer, Loffing, Hagemann & Baker, 2012). According to Sattler (2007), the left-handed do have tactical advantages due to the dominance of the right hemisphere of the brain.

When observing lateral phenomena occurring in gymnastics, there are differences regarding injuries on the balance beam in relation to the preferred leg used on take-off (Pajek, Hedbávný, Kalichová & Čuk, 2016). Handedness, footedness and probably brain hemisphere lateralisation are predictors of the twist direction regarding both global and local movements (Stochl & Croudace, 2013). Also, the twist direction might be related to lateral preference (Heinen, Vinken & Velentzas, 2010) as well as the hand put down first in round-offs and cartwheels, which implies a connection to handedness (Sands, 2000). There are differences in the twist direction according to the performance level and the performed element: lateral preference is linked to rotational preference in non-elite gymnasts, and vestibulospinal asymmetry is connected to rotational preference in elite gymnasts (Heinen, Jeraj, Vinken & Velentzas, 2012).

Despite the claimed relevance of laterality for motoric and sensor aspects, there are only few sports-related studies on this theme (Fischer, 1988). Certain psychological and cognitive abilities are said to occur together with left-handedness (Grouios et al., 2000; Holtzen, 2000; Noroozian et al., 2012) and could thus influence sports performance in wheel gymnastics. Cognitive advantages for left-handers in sports are also mentioned (Raymondet al., 1996), as well as characteristics concerning visuospatial and attentional factors (Springer & Deutsch, 1998; Bisiacchi, Ripoll, Stein, Simonet & Azémar, 1995) and hemispheric/visuomotoric factors (Annett, 1985; Azémar, Ripoll, Simonet & Stein, 1983; Gorynia & Egenter, 2000; Gursoy, 2009; Holtzen, 2000; McLean & Ciurczak, 1982). Goulet, Bard & Fleury (1989) mention visual perception (also: Hagemann, 2009; Loffing, Schorer, Hagemann & Baker, 2012; McMorris & Colenso, 1996; Schorer et al., 2012). Neuropsychological disposition is also mentioned (Boulinguez, 1999), next to differences regarding volition, motivation, and disposition for action (Weber, 2018).

The main question is if and how handedness influences performance in wheel gymnastics. To address this topic, the study aims to answer the following detailed questions:

1. Are there significant differences in motivational aspects between gymnasts of different handedness within the different disciplines?
2. Do gymnasts differ from the overall population regarding percentage of right-handers, left-handers and ambidexters?

3. Are gymnasts of different handedness competing in different gym wheel disciplines (vault, spiral, straight line, all-around)?
4. Are there correlations between percentage of handedness and competitive results when considering certain groups of gymnasts?

METHODS

Measurements included 203 voluntary participants of the German Gymnastics Federation (Deutscher Turner-Bund/ DTB) in the gym wheel section. Informed consent was obtained from all participants (female: N = 183, age average = 21.17 ± 11.91; male: N = 20, age average = 16.84 ± 4.90). The age ranged from 6 to 58 for female and from 7 to 27 for male gymnasts.

Skinfolds were recorded using a calliper. Competitive results, performance during training, evaluation of the current competition, gender, age, and competitive level were obtained using a specially developed questionnaire. All values were recorded at major national competitions in 2018.

Motivation was measured using the Achievement Motives Scale (AMS) by Elbe & Wenhold (2005), which includes the following categories: hope of success, fear of failure, net hope (hope of success minus fear of failure), and total achievement motive (sum of hope of success and fear of failure). The questionnaire is in use in German talent selection in team sports up to the national level (Beckmann & Linz, 2009) and is suitable for talent selection in several sports (Wenhold, Meier, Beckmann, Elbe & Ehrlenspiel, 2007). The scale consists of 30 questions with 0 to 3 points per question, 15 questions for hope of success (0 to 45 points) and 15 for fear of failure (0 to 45 points), out of which net hope is calculated as net hope = hope of success – fear of failure (-45 to 45 points) and the total achievement motive as total achievement motive = hope of success + fear of failure.

An additional questionnaire asked for age, gender and straight line difficulty (technical merit) achieved at the current competition. The difficulty difference was calculated as the difference between the technical difficulty achieved during training minus the technical difficulty achieved during competition in the straight line discipline. In German competitive wheel gymnastics, athletes are required to hand in a difficulty chart before competition, stating what difficulty they were able to perform during training and are therefore intending to perform in competition.

Oneway ANOVA was performed amongst gymnasts at both performance levels (Bundesklasse/ Landesklasse) and within two disciplines (Straight line/ All-around), once for all gymnasts and once for female gymnasts only as there was an insufficient number of male participants. The criterion level for significance was set at $p<0.05$ and the trend significance at $p<0.10$. The effect size was evaluated with η^2 (Eta partial squared), where $0.01<\eta^2<0.06$ constitutes a small effect, $0.06<\eta^2<0.14$ constitutes a medium effect and $\eta^2>0.14$ constitutes a large effect (Cohen, 1988). Correlations between performance and motivation were calculated via Pearson and Spearman`s Rho with correlation levels >0.1 (weak), >0.3 (moderate) and >0.5 (strong) for Pearson`s correlation coefficient. Statistical analysis was performed in SPSS, version 26 (SPSS, Inc., Chicago, IL).

RESULTS

There are significant differences in motivational aspects between gymnasts of different handedness within the straight line discipline. No differences were found in the all-around. There were not enough cases of gymnasts competing in spiral or vault only.

Table 1
Differences according to handedness between female gymnasts competing in straight line (Oneway ANOVA and Scheffé post hoc test).

Differences	N	$X \pm SD$	p	η^2
Fear of failure	44	10.48 ± 7.97	0.045	0.141
Overall performance motive	44	44.77 ± 9.44	0.020	0.173
Fear of failure				
Right-handed vs. ambidextrous	36 vs. 6	10.19 ± 7.40 vs. 7.83 ± 9.00	0.065	-
Left-handed vs. ambidextrous	2 vs. 6	23.50 ± 4.95 vs. 10.48 ± 7.67	0.050	-
Overall performance motive				
Right-handed vs. ambidextrous	36 vs. 6	44.08 ± 8.52 vs. 43.00 ± 11.18	0.023	-
Left-handed vs. ambidextrous	2 vs. 6	62.5 ± 2.12 vs. 43.00 ± 11.18	0.034	-

Table 2
Percentages of handedness within disciplines and at competitive levels (female athletes).

Discipline/ competitive level	Right-handed [%]	Left-handed [%]	Ambidextrous [%]
Straight line: N = 49	79,6	8,2	12,2
All-around: N = 29	89,7	10,3	0
Bundesklasse: N = 24	95,8	4,2	0
Landesklasse: N = 36	72,2	11,1	6,7

Estimated failure at confidence interval 0.95 = 5.2 %.

Table 3
Correlations between percentages of handedness within performance quintiles and arithmetic mean of performance related parameters.

Correlations		Overall merit	Difficulty value	Execution value
Right-handed	r	-,918	-,827	*,783*
	p	,028	,084	*,118*
	N	5	5	*5*
Left-handed	r	,855	,949	-,832
	p	,065	,014	,080
	N	5	5	5

Not significant

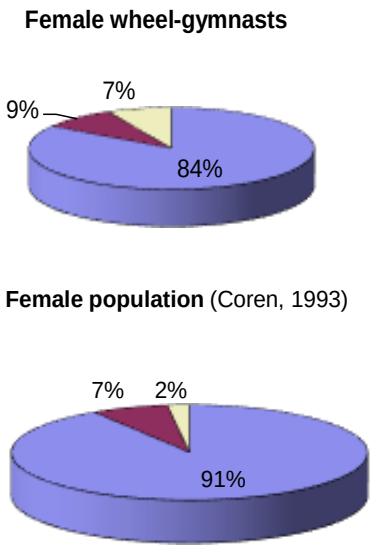

Figure 1. Percentages of handedness among female wheel gymnasts and the female population; blue = right-handed, magenta = left-handed, yellow = ambidextrous; estimated failure = 5.2% for confidence interval 0.95.

When comparing the prevalences of different types of handedness in the general population to those among wheel gymnasts, no dedicated evaluation could be conducted for male gymnasts as there were too few cases, although it should be noted that all 13 male participants were right-handed. When comparing the percentages of left-handedness and ambidexterity among female gymnasts to those in the general female population, it is evident that there is a higher percentage of ambidexters and the left-handed among wheel gymnasts than in the general female population.

There are differences in the percentages of female gymnasts of different handedness competing in straight line and all-around. Spiral and vault could not be evaluated due to too few cases. Interestingly, no ambidexters are competing at the Bundesklasse level and the percentage of the left-handed is very low.

When testing for different types of handedness among wheel gymnasts, statistics could not be evaluated in subgroups for male gymnasts as there were not enough cases.

There are correlations between the percentage of handedness and competitive results when considering quintiles of competitive results in the straight line discipline. The percentage of the left-handed in quintiles correlated positively with the arithmetic mean of the overall merit and difficulty value within quintiles, while for the right-handed the correlations were negative. The more left-handed in a quintile, the better the arithmetic mean for overall merit and difficulty, while the more right-handed correlated with a lower arithmetic mean for overall merit and difficulty. When considering the execution merit, there was a negative correlation between the percentage of the left-handed and the execution merit. The higher the percentage of the left-handed, the lower was the arithmetic mean of the execution value in that quintile. No significant correlations were found regarding ambidexters.

DISCUSSION

There are significant differences in motivational aspects between gymnasts of different handedness within the straight line discipline. The left-handed displayed a significantly higher fear of failure compared to the right-handed and the ambidexters, while the latter had a higher fear of failure compared to the right-handed. It should be noted that all ambidexters were 33 years old or older and competing at the Landesklasse level. This could mean that they were expecting to fail because of their already decreased performance quality, which could have negatively affected their fear of failure. The left-handers' higher fear of failure will be discussed below. The overall performance motivation was the highest in the left-handed followed by the ambidexters and the right-handed. This could be due to the left-handers` increased fear of failure.

When comparing the percentages of the left-handed and ambidexters among female gymnasts to those in the general female population, it is evident that there is a higher percentage of left-handers (9%) and ambidexters (7%) among wheel gymnasts than in the general female population (7 and 2%). Even when calculating estimated failure of 5.2%, the percentage of ambidexters is much higher. At the same time, the results match those of Bessi (2016), who found 84.4% right-handers in artistic gymnasts of both genders. This suggests a coordinational advantage (probably similar to the left-handers' advantage in interactive sports as discussed in the introduction) for gymnastics, which could be linked to the findings of Kourtis et al. (2014). Ambidexters might benefit from a better coordination regarding both-handed movements and the ability to flexibly choose rotation directions (which might be linked to handedness as discussed in the introduction) for different elements.

There are differences in the percentages of female gymnasts of different handedness competing in straight line and all-around. This suggests that there might be a connection to the observed difference in twist direction between gymnasts at the elite and the lower level (Heinen et al., 2012). Interestingly, no ambidexters are competing at the Bundesklasse level and the percentage of the left-handed is very low. The higher age of the ambidexters explains their high prevalence of 12.2% in the lower class; all-around has not been introduced until some years ago in Landesklasse and therefore none of the older ambidexters are performing well enough to compete in this discipline. Still, it is notable that there are no ambidexters and fewer left-handed gymnasts at the Bundesklasse level. When considering the results of Bessi (2016), none of the groups of the current study matches Bessi's (2016) percentages. However, in regard to the connection between turning direction and handedness in artistic gymnastics (Heinen et al., 2012; Bessi, 2016), it is probable that the direction of turn in the spiral discipline might influence the performance and learning curve of the left-handed and/ or ambidexters in that discipline. The direction of turn in German clubs is mostly predetermined according to the preference of the coaches in the clubs. This might put gymnasts with different types of handedness in different positions regarding motor learning and competitive results.

There are correlations between the percentage of handedness and competitive results when considering quintiles of competitive results in the straight line discipline. The percentage of the left-handed in quintiles correlated positively with the arithmetic mean of the overall merit and difficulty value within quintiles, while the correlations for the right-handed were negative. The more left-handed in a quintile, the better the arithmetic mean for overall merit and difficulty, whereas the more right-handed correlated with a lower

arithmetic mean for overall merit and difficulty. When considering the execution merit, there was a negative correlation between the percentage of the left-handed and the execution merit. The higher the percentage of the left-handed, the lower the arithmetic mean of the execution value in that quintile was. This could mean that the left-handed perform well at difficulty while right-handers are able to display good execution. Perhaps repeating a task accurately is not as motivating for the left-handed, as they have a higher activity in the right ("creative") hemisphere (e. g. Gorynia & Egenter, 2000).

CONCLUSION

It is evident that the topic needs further consideration, especially when regarding coordinational differences and differences in task motivation between gymnasts of different handedness and rotation direction in the spiral discipline. It is yet to be determined which handedness-related factors influence performance in wheel gymnastics, probably at a neural or vestibulospinal level. However, it can be concluded that gymnasts of different handedness need coaching according to their individual needs. A special coaching or selection for left-handers and ambidexters, especially in the spiral discipline, could be indicated.

REFERENCES

Al Awamleh, A. A., Mansi, T., & Alkhaldi, H. (2013). Handedness differences in eye-hand coordination and, Choices, simple reaction time of international handball players. *Journal of Physical Education and Sport*, *13*(1), 78.

Annett, M. (1985). *Left, right, hand and brain: The right shift theory*. London : Erlbaum.

Azémar, G., Ripoll, H., Simonet, P. & Stein, J. F. (1983). Étude neuro-psychologique du comportement des gauchers en escrime. *Cinésiologie,* 22, 7 - 18.

Beckmann, J & Linz, L. (2009). Psychologische Talentdiagnostik und –entwicklung der Nachwuchsnationalmannschaften des Deutschen Hockey Bundes (DHB) [Psychological diagnostic and development of national youth teams of the German Hockey Federation (DHB)], BISP-Jahrbuch Forschungsförderung 2008/ 2009.

Bessi, F. (2016). Laterality in artistic gymnastics. *Revista Brasileira de Educação Física e Esporte*, *30*(1), 19-27.

Bisiacchi, P. S., Ripoll, H., Stein, J. F., Simonet, P. & Azémar, G. (1995). Left-handedness in fencers: an attentional advantage? *Perceptual and Motor Skills*, 61 (2), 507 - 513.

Bogen, J. E. (1969). The other side of the brain II : an appositional mind. *Bulletin of the Los Angeles Neurological Society*, 34 (1969), 135- 162.

Boulinguez, P. (1999). Les avantages liés à la latéralité manuelle en escrimes sont-ils l'expression d'asymétries cérébrales fonctionelles? [Are the advantages related to manual laterality in fencing the expression of functional cerebral asymmetries?] *Schweizerische Zeitschrift für Sportmedizin und Sporttraumatologie*, 47 (2), 63 - 67.

Coren, S. (1993). *The Left-handed Syndrome.* New York : Vintage Books.

Calmels, C., d'Arripe-Longueville, F., Hars, M., & Debois, N. (2009). Perceived development of psychological characteristics in male and female elite gymnasts. *International Journal of Sport Psychology*, 40 (3), 424 – 455.

Deutscher Turnerbund (2008). Technisches Komitee Rhönradturnen im DTB in Zusammenarbeit mit dem IRV Wertungsbestimmungen 1997, Überarbeitete Ausgabe 2008 mit Einarbeitung aller aktuellen Änderungen (Band 1: Allgemeiner Teil). [Technical committee wheel-gymnastics in the German Gymnastics Federation together

with the code of points of the International Wheel-gymnastics Federation 1997, corrected version of 2008 with current changes (volume 1: general rules).] *Protocol of the proceedings of the technical committee of wheel-gymnastics in the German Gymnastics Federation in 2007/ 2008*.

Elbe, A.-M., & Wenhold, F. (2005). Cross-Cultural Test Control Criteria for the AMS-Sport. *International Journal of Sport and Exercise Psychology*, 3 (2), 163-178.

Fischer, K. (1988). Rechts-Links-Probleme in Sport und Training. In F. Schilling, E. J. Kiphard & H.-J. Müller: *Reihe Motorik* (6). Schorndorf : Hofmann.

Gorynia, I. & Egenter, D. (2000). Intermanual coordination in relation to handedness, familial sinistrality and lateral preferences. *Cortex*, 36 (1), 1 - 18.

Goulet, C., Bard, C. & Fleury, M. (1989). Expertise differences in preparing to return a tennis serve : a visual information processing approach. *Journal of sport & exercise psychology*, 11 (4), 382 - 398.

Grobbelaar, H. W. & Eloff, Maryke (2011). Psychological Skills of Provincial Netball Players in Different Playing Positions. *South African Journal for Research in Sport, Physical Education and Recreation*, 33 (2), 45 - 58.

Grouios, G., Tsorbatzoudis, H., Alexandris, K., Barkoukis, V. (2000). Do Left-Handed Competitors Have an Innate Superiority in Sports?. *Perceptual and Motor Skills*, 90 (3_suppl), 1273 - 1282.

Gursoy, R. (2009). Effects of left- or right-hand preferences on success of boxers in Turkey. *British Journal of Sports Medicine*, 43 (2), 142 - 144.

Hagemann, N. (2009). The advantage of being left-handed in interactive sports. *Attention, Perception & Psychophysics*, 71 (7), 1641 - 1648.

Heinen, T., Vinken, P., & Velentzas, K. (2010). Does laterality predict twist direction in gymnastics?. *Science of Gymnastics Journal*, *2* (1), 5 - 14.

Heinen, T., Jeraj, D., Vinken, P. M., & Velentzas, K. (2012). Rotational preference in gymnastics. *Journal of human kinetics*, *33 (2012)*, 33 - 43.

Hermsdorf, M. (2009) *Lateralität bei Leistungsschwimmern : experimentelle Studie zur Verringerung von Seitigkeitsunterschieden.[Laterality in elite swimmers : experimental study on reducing laterality differences]*. Doctoral dissertation, Humboldt-University of Berlin, 2009.

Holtzen, D. W. (2000). Handedness and professional tennis. *International Journal of neuroscience*, 105 (1 - 4), 101 - 119.

Hughes, M., Caudrelier, T., James, N., Redwood-Brown, A., Donnelly, I., Kirkbride, A., Duchesne, C. (2012). Moneyball and soccer - an analysis of the key performance indicators of elite male soccer player by position. *Journal of* Human *Sport and Exercise*, 7 (2), 402 - 412.

Hume, P. A., Hopkins, W. G., Robinson, D. M., Robinson, S. M. & Hollings, S. C. (1993). Predictors of attainment in rhythmic sportive gymnastics..*The Journal of Sports Medicine and Physical Fitness*, 33 (4), 367 – 377.

Kauther, M. D., Rummel, S., Hussmann, B., Lendemans, S., Wedemeyer, C., & Jaeger, M. (2015). Wheel-gymnastic-related injuries and overuse syndromes of amateurs and professionals. *Knee Surgery, Sports Traumatology, Arthroscopy*, *23* (8), 2440 - 2448.

Kourtis, D., De Saedeleer, L., & Vingerhoets, G. (2014). Handedness consistency influences bimanual coordination: a behavioural and electrophysiological investigation. *Neuropsychologia*, *58*, 81-87.

Loffing, F., Schorer, J., Hagemann, N. & Baker, J. (2012). On the advantage of being left-handed in volleyball : further evidence of the specificity of skilled visual

perception. *Attention, Perception & Psychophysics*, 74, 446 - 453.

Maeda, R. S., Souza, R. M., & Teixeira, L. A. (2014). From specific training to global shift of manual preference in Kung Fu experts. *Perceptual and motor skills*, *118*(1), 73-85.

McLean, J. M. & Ciurczak, F. M. (1982). Bimanual dexterity in major league baseball players : a statistical study. *The New England Journal of Medicine,* 307 (20), 1278 - 1279.

McMorris, T. & Colenso, S. (1996). Anticipation of professional soccer goalkeepers when facing right- and left-footed penalty kicks. *Perceptual and Motor Skills,* 82 (3), 931 - 934.

Munkácsi, I., Kalmár, Z., Hamar, P., Katona, Z. & Dancs, H. (2012). Role of motivation in artistic gymnastics by results of a questionnaire based international survey. *Journal of Human Sport and Exercise*, 7 (1), 91 – 102.

Noroozian, M., Shadloo, B., Shakiba, A. & Panahi, P. (2012). Educational Achievement and other controversial issues in left-handedness: a neuropsychological and psychiatric view. In T. Dutta, M. K. Mandal & S. Kumar: *Bias in Human Behavior* (p. 41 - 82), Nova Science Publ. Inc, NY.

Oberbeck, H. (1989). *Seitigkeitsphänomene und Seitigkeitstypologie im Sport. [Laterality and lateral typology in sports]*. Schorndorf : Hofmann.

Pajek, M. B., Hedbávný, P., Kalichová, M., & Čuk, I. (2016). The asymmetry of lower limb load in balance beam routines. *Science of gymnastics journal*, *8* (1) 5 – 13.

Pohn, S. (2009). *Linkshändigkeit aus anthropologischer Sicht. [Left-handedness from an anthropological point of view]*. Unpublished exame-paper, University of Vienna.

Porac, C. & Coren, S. (1981). *Lateral preferences and human behavior*. New York : Springer.

Pritzel, M. (2006). Händigkeit. In H.-O. Karnath & P. Thier (Ed.), *Neuropsychologie* (2nd, revised ed., p. 605 - 609). Heidelberg: Springer.

Raymond, M., Pontier, D., Dufour, A. B. & Moller, A. P. (1996). Frequency-dependent maintenance of left-handedness in humans. *Proceedings of biological science*, 263 (1377), 1627 - 1633.

Sands, W. A. Twist direction. *Technique*, 20 (2), 5-7.

Sattler, J.B. (2007): Sport. Published online: http://www.linkshaender-beratung.de/deutsch/Sport.htm

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 (5), 507 - 513.

Sebesta, I. (2002). *Rhönrad- Report.* Köln: Sport & Buch Strauß.

Stochl, J., & Croudace, T. (2013). Predictors of human rotation. *Laterality: Asymmetries of Body, Brain and Cognition*, *18*(3), 265-281.

Weber, J. & Wegner, M. (2018). Handedness in female team handball. Talent development and excellence (in press).

Wenhold, F., Meier, C., Beckmann, J., Elbe, A. M., & Ehrlenspiel, F. (2007). Sportpsychologische Eingangsdiagnostik–sportbezogene Motivation. [Sports psychological initial diagnostics – sports-related motivation] *Bundesinstitut für Sportwissenschaft: BISp-Jahrbuch Sportförderung*, *2008*, 219 - 222.

Weyermann, C. (2016). *Zusammenhang zwischen der Rumpfkraft und der Wettkampfleistung in der Senior- sowie Jugendkategorie im Rhönradturnen bezüglich der verschiedenen Disziplinen*. [Connection between core power and competitive performance in senior and youth wheel-gymnasts per discipline]. Master Thesis Sports Physiotherapy, University of Salzburg.

Wood, C. J. & Aggleton, P. (1989). Handedness in 'fast ball' sports : do left-handers have an innate advantage? British Journal of Psychology, 80 (2), 227 - 240.

Wolko, K. L., Hrycaiko, D. W., & Martin, C. L. (1993). A comparison of two self-management packages to standard coaching for improving practice performance of gymnasts. *Behavior Modification*, *17*(2), 209 - 223.

Ziyagil, M. A. (2011). Handedness and footedness: relations to differences in sprinting speed and multiple sprints performance in prepubertal boys. *Perceptual and motor skills*, *112*(2), 440-450.

Corresponding author:

Johanna Weber
Neurocognition and Action – Biomechanics
Bielefeld University
Universitätsstraße 25
33615 Bielefeld
Germany
Tel: +49 170 41 000 10

Email: j.weber_@hotmail.de

Article received: 11.2.2021
Article accepted: 19.10.2021