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

Johanna Weber¹, ²

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

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 ≤ 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
There are several tests to diagnose handedness, one being the determination of the preferred hand while observing the preference during several tasks (Hermsdorff, 2009). If neither hand is preferred, ambidexterity can be assumed. No preference is related to benefits in both-handed tasks (Kourtis, De Saedeleer & 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, Hedvánová, 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.

One way 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 \( \eta^2 \) (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).*

<table>
<thead>
<tr>
<th>Differences</th>
<th>N</th>
<th>$X \pm SD$</th>
<th>$p$</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fear of failure</td>
<td>44</td>
<td>10.48 ± 7.97</td>
<td>0.045</td>
<td>0.141</td>
</tr>
<tr>
<td>Overall performance motive</td>
<td>44</td>
<td>44.77 ± 9.44</td>
<td>0.020</td>
<td>0.173</td>
</tr>
</tbody>
</table>

- Fear of failure
  - Right-handed vs. ambidextrous: 36 vs. 6
    - $10.19 \pm 7.40 \text{ vs. } 7.83 \pm 9.00$
    - $0.065$ -
  - Left-handed vs. ambidextrous: 2 vs. 6
    - $23.50 \pm 4.95 \text{ vs. } 10.48 \pm 7.67$
    - $0.050$ -

- Overall performance motive
  - Right-handed vs. ambidextrous: 36 vs. 6
    - $44.08 \pm 8.52 \text{ vs. } 43.00 \pm 11.18$
    - $0.023$ -
  - Left-handed vs. ambidextrous: 2 vs. 6
    - $62.5 \pm 2.12 \text{ vs. } 43.00 \pm 11.18$
    - $0.034$ -

Table 2

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

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

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.*

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Overall merit</th>
<th>Difficulty value</th>
<th>Execution value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-handed</td>
<td>$r$ -0.918</td>
<td>-0.827</td>
<td>0.783</td>
</tr>
<tr>
<td></td>
<td>$p$ 0.028</td>
<td>0.084</td>
<td>0.118</td>
</tr>
<tr>
<td></td>
<td>$N$ 5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

| Left-handed  | $r$ 0.855     | 0.949            | -0.832          |
|              | $p$ 0.065     | 0.014            | 0.080           |
|              | $N$ 5          | 5                | 5               |

*Not significant*
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


**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

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