# DEMANDS PROFILE IN WHEEL GYMNASTICS: DIFFERENCES BETWEEN ATHLETES AT DIFFERENT PERFORMANCE LEVELS, BETWEEN GENDERS AND IN DIFFERENT DISCIPLINES

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*Abstract*

*Performance in many competitive sports is limited by motivation as well as constitutional factors. In this paper the question is addressed whether motivation is related to performance in wheel gymnastics and whether the manifestation of motivation is related to gender, performance level or competitive discipline. To this end, 203 German wheel gymnasts of varying performance level were studied. Different levels of motivation, competitive results and percentages of body fat were found in different groups of gymnasts: gymnasts performing in all-around/ straight line male and female athletes and in gymnasts competing at different performance levels. Also, female and male gymnasts differed significantly in body fat percentage, age and overall merit. Differences between performance levels underline the importance of individual coaching regarding, e. g., hope for success ($p \leq 0.003$, $\eta^2 = 0.108$) and other performance limiting factors. Further, individual coaching for athletes competing in different disciplines seems necessary, as shown by differences in the overall performance motive ($p \leq 0.033$, $\eta^2 = 0.042$). Therefore, each group of athletes should receive coaching tailored to their needs during training and performance that considers their individual background and circumstances, in order to optimize performance.*

*Keywords: Body fat percentage, Disciplines, Performance, Gender, Motivation.*

## 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 for the overall merit are given to the athlete as a sum of points for composition, technical difficulty and execution. The values earned for technical difficulty and composition of a routine are added to the remainder of the execution value. Deductions regarding the execution value are made if the athlete performs a movement technically correctly but inaccurately (Deutscher Turner-Bund (DTB), 2008). According to literature, the disciplines demand strength, endurance, flexibility as well as core, explosive and jumping strength, coordination of

movement, concentration, emotional control, perception, stress resistance and self-esteem, along with 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 gymnastics skill (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 424) 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.

When selecting athletes for wheel gymnastics, the current discussion on talent selection must be kept in mind. While Samuelsen (2003) claims that anthropometric factors are irrelevant for performance in wheel gymnastics because the wheels come in different sizes, Rummel (2016) names BMI as relevant and claims that in this respect wheel gymnastics is comparable to ski-jumping (Muller, Groschl, Muller & Sudi, 2006). Female gymnasts show a lower BMI than males and female wheel gymnasts lie in the lowest percentile within the German population (Kromeyer-Hauschild,

Wabitsch, Kunze, Geller, Geiß, Hesse et al., 2001). Some gymnasts are below the z-scores recommended by the World Health Organization (Onis, Onyango, Borghi, Syiam, Nishida & Siekmann, 2007). Low BMI is mostly prevalent in amateur wheel gymnasts according to Rummel (2016).

Atiković, Kalinski & Čuk (2017) found that due to static strength, e. g.,which can only be developed over time, differences in the age of gymnasts in different disciplines is performance relevant on the rings. This is the reason why the average age is higher on this apparatus, while gymnasts competing on the floor have a higher training load and are usually younger. The floor exercise, while being very complex, is linked to strength, flexibility, muscular anaerobic endurance (Nunomura, 2002) and reactive force at take-offs and landings (Karacsony, Čuk, Tihanyi, Fink, Jošt & Čoh, 2005).

Conditional and constitutional factors are viewed as controversial in talent selection (Gonçalves, Rama & Figueiredo, 2012), so mental skills might be of better use (Baron-Thiene & Alfermann, 2015). According to Moesch, Hauge, Wikman & Elbe (2013). Skills such as volition and probably motivation might be a better predictor than other performance factors in selecting for team sports. Wagner, Finkenzeller, Würth and v. Duvillard (2014) state that mental skills are highly relevant for success in handball. This might also be true for individual sports and thus wheel gymnastics, perhaps even with differences regarding gender or different disciplines. However, so far, only a few studies have researched the gender- or discipline-specific demand profiles in wheel gymnastics. Koumpoula, Tsopani, Flessas and Chairopoulou (2011) found high motivation as relevant in rhythmic gymnasts. Also, motivation and training time can be seen as predictors of attainment in gymnastics (Hume, Hopkins, Robinson, Robinson & Hollings, 1993), and motivation is related to gymnastics performance (Munkácsi, Kalmár, Hamar,

Katona & Dancs, 2012). It should be clarified whether motivation is performance relevant for wheel gymnasts of different gender and/or in different disciplines.

Without a corresponding study, Mies (1994) states that wheel gymnastics can be counted among the aesthetic sports, where, according to Potter, Lavery and Bell (1996), athletes are required to look slim. In aesthetic sports such as artistic and rhythmic gymnastics, performance is related to slenderness in terms of body proportions, BMI or body fat percentage. Various examples can be found in literature (e. g. Claessens, Lefevre, Beunen & Malina, 1999; Bacciotti, Baxter-Jones, Gaya & Maia, 2017) for female athletes, and low percentages of body fat can be found in male athletes as well (Gurd & Klentrou, 2003). Compared to other aesthetic sports, wheel gymnasts display a rather low body fat percentage and earn lower scores from the judges for their performance if they don't meet this requirement (Weber, 2020). It should be clarified whether there are specifics demands regarding body fat percentage at different competitive levels and within different disciplines.

To facilitate individualized training for different groups of gymnasts, the study aims to answer the following questions:
1. Are there differences in percentages of body fat, competitive results or psychological performance factors in female gymnasts performing in different disciplines or at different performance levels that can be shown via a) ANOVA or b) specific demands regarding the aforementioned factors that can be shown via testing for correlations?
2. Are there differences between male and female athletes for the different variables?

**METHODS**

The project is part of a broader study. Measurements included 203 voluntary participants of the German Gymnastics Federation (Deutscher Turner-Bund/ DTB), the gym wheel section. Informed consent was obtained from all participants. The age ranged from 6 to 58 for female (N = 178, age average = 21.17 ± 11.91) and from 7 to 27 for male (N = 20, age average = 16.84 ± 4.90) 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.

Body fat percentage was calculated using the Siri method (1956) for calculating body fat using three skinfolds for female gymnasts (Jackson, Pollock & Ward, 1980). For male gymnasts, Siri (1956) and Jackson & Pollock (1978) methods were used to calculate percentage of body fat using three skinfolds and two circumferences. Due to different compositions of body tissue, female and male athletes require individual calculation methods (Jackson & Pollock, 1978; Jackson et al., 1980).

Percentage of body fat was calculated with %_Bodyfat = (4.95 / Body density) - 4.5 (Siri, 1956). Body density was calculated with *Body density = 1.096095 – 0.0006952 * sf_tri + sf_abd + sf_sup + sf_thigh) + 0.0000011 * (sf_tri + sf_abd + sf_sup + sf_thigh)² – 0.0000714 * age* for female gymnasts (Jackson, Pollock & Ward, 1980), using age in years and four skinfolds, where sf = skinfold, tri = triceps, abd = abdominal, sup = suprailiacal and thigh = directly above the knee. Body density for male gymnasts was calculated with *Body density = 1.15737 – 0.02288 * ln(sf_pect + sf_abd + sf_thigh) – 0.00019 * age – 0.0075 * c_nav + 0.223 * c_arm* (Jackson & Pollock, 1978), using age in years, two skinfolds and two circumferences, where sf = skinfold, pect = pectoralis, abd = abdominal, c_nav = circumference at navel height and c_ arm = highest circumference of the lower arm.

Motivation was measured using the Achievement Motives Scale (AMS) by Elbe & Wenhold (2005) which consists of the following dimensions: 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 can be used 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, straight line difficulty (technical merit) achieved during training, straight line difficulty achieved at the current competition, self-rating of own performance at the current competition, and rating of the judges` performance judging the athlete. The difficulty difference or planned difficulty 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 card before competition, stating what difficulty they were able to perform during training and are therefore intending to perform in competition. Usually, gymnasts hand in cards that show which difficulty was safely performed during training. Cards are prepared in cooperation with the coaches and it is common practice to compose the card realistically. For the current study, values from those difficulty cards were used to calculate the difference between the difficulty safely performed during training and the difficulty earned during competition.

To assess differences regarding motivational factors and body fat percentages between disciplines and performance levels, Oneway ANOVA was performed in each of the following subgroups: female gymnasts at both performance levels (Bundesklasse/ Landesklasse) and in two disciplines (Straight line/ All-around) as there was an insufficient number of male participants. Also, Oneway ANOVA was performed to test for differences between genders. 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). To test for specific demands, correlations were calculated via Pearson and Spearman`s Rho with correlation levels $>0.1$ (weak), $>0.3$ (moderate) and $>0.5$ (strong). Different types of correlation coefficients were used due to varying sample sizes as well as outliers and lack of homogeneity within subgroups (David 1938; Mukaka, 2012). Statistical analysis was performed in SPSS, version 25 (SPSS, Inc., Chicago, IL).

**RESULTS**

There are different body fat percentages, competitive results in straight line and psychological performance factors in female gymnasts performing in all-around/ straight line and in gymnasts competing at different performance levels (Tab. 1).

There seem to be specific demands for female athletes competing in different disciplines or at different performance levels (Tab. 3). Athletes at the Bundesklasse level could not be evaluated according to discipline as there were too few cases.

Table 1

*Differences between female gymnasts competing in different disciplines and at different performance levels.*

| Differences | N | $\bar{X} \pm SD$ | $p$ | $\eta^2$ |
|---|---|---|---|---|
| **Straight line vs. all-around (all performance levels)** | | | | |
| Overall merit* | 74 vs. 26 | 5.50 ± 1.45 vs. 7.80 ± 1.83 | 0.000 | 0.302 |
| Difficulty in competition | 69 vs. 26 | 2.50 ± 1.12 vs. 4.50 ± 1.29 | 0.000 | 0.639 |
| Difficulty in training | 53 vs. 25 | 2.75 ± 1.30 vs. 4.45 ± 1.23 | 0.000 | 0.284 |
| Age | 78 vs. 36 | 23.92 ± 14.83 vs. 19.53 ± 6.70 | 0.092 | 0.025 |
| Composition in competition | 57 vs. 26 | 0.83 ± 0.31 vs. 1.00 ± 0.00 | 0.007 | 0.085 |
| Hope for success | 73 vs. 35 | 33.56 ± 7.66 vs. 36.91 ± 5.26 | 0.021 | 0.049 |
| Overall performance motive | 72 vs. 35 | 43.56 ± 9.03 vs. 47.63 ± 9.42 | 0.033 | 0.042 |
| **Straight Line vs. all-around (Landesklasse**)** | | | | |
| Overall merit | 42 vs. 6 | 5.45 ± 1.53 vs. 6.85 ± 1.20 | 0.038 | 0.090 |
| Difficulty in competition | 39 vs. 6 | 2.42 ± 1.11 vs. 3.73 ± 1.11 | 0.010 | 0.144 |
| Net hope | 41 vs. 6 | 22.76 ± 11.54 vs. 31.67 ± 11.81 | 0.085 | 0.065 |
| **Bundesklasse vs. Landesklasse** | | | | |
| Age | 33 vs. 49 | 15.88 ± 5.74 vs. 28.96 ± 15.05 | 0.000 | 0.221 |
| Body fat percentage | 33 vs. 48 | 12.67 ± 2.64 vs. 15.74 ± 3.83 | 0.000 | 0.168 |
| Hope for success | 31 vs. 48 | 37.90 ± 5.30 vs. 33.29 ± 7.25 | 0.003 | 0.108 |
| Overall performance motive | 31 vs. 47 | 48.35 ± 8.83 vs. 43.00 ± 9.68 | 0.016 | 0.074 |

*All values for straight line.  **Dividing into disciplines in Bundesklasse was not possible due to too few cases.

Table 2
*Performance relevance of certain factors measured as correlations between performance variables within subgroups for female gymnasts.*

| Subgroup | Correlations | Pearson's r | p | N |
|---|---|---|---|---|
| Landesklasse | Age vs. Difficulty | - 0.263 | 0.085 | 38 |
|  | vs. Execution | 0.448 | 0.005 | 38 |
| Bundesklasse | Age vs. Difficulty | 0.412 | 0.051 | 23 |
|  | vs. Composition | 0.438 | 0.032 | 24 |
|  | vs. Deduction off planned difficulty | 0.406 | 0.061 | 22 |
|  | vs. Hope for Success | - 0.401 | 0.025 | 31 |
|  | vs. Fear of Failure | 0.491 | 0.005 | 31 |
|  | vs. Net hope | - 0.545 | 0.002 | 31 |
|  | Fear of Failure vs. Execution | - 0.579 | 0.004 | 23 |
|  | vs. Deduction off planned difficulty | 0.592 | 0.005 | 21 |
|  | Net Hope vs. Execution | 0.470 | 0.024 | 23 |
|  | vs. Deduction off planned difficulty | - 0.457 | 0.037 | 21 |
|  | OPM** vs. Execution | - 0.577 | 0.004 | 23 |
|  | vs. Deduction off planned difficulty | 0.639 | 0.002 | 21 |
| Straight Line | Age vs. OPM | - 0.263 | 0.027 | 71 |
|  | vs. Execution | 0.321 | 0.014 | 58 |
|  | vs. Body fat percentage | 0.334 | 0.003 | 76 |
|  | Fear of Failure vs. Difficulty | 0.369 | 0.003 | 65 |
|  | vs. Composition | 0.303 | 0.026 | 54 |
|  | vs. Overall merit | 0.295 | 0.014 | 68 |
|  | Net Hope vs. Difficulty | - 0.260 | 0.037 | 65 |
|  | vs. Composition | - 0.234 | 0.089 | 54 |
|  | vs. Overall merit | - 0.229 | 0.060 | 68 |
|  | OPM vs. Difficulty | 0.261 | 0.036 | 65 |
| All Around | Age vs. Body fat percentage | 0.482 | 0.003 | 36 |
|  | vs. Difficulty** | - 0.499 | 0.009 | 26 |
|  | Fear of Failure vs. Execution | - 0.382 | 0.059 | 25 |
|  | Net Hope vs. Execution | 0.414 | 0.040 | 25 |
|  | OPM vs. Deduction off planned difficulty | 0.353 | 0.098 | 23 |
| Landesklasse Straight Line | Age vs. Execution | 0.446 | 0.010 | 32 |
|  | vs. Body fat percentage | 0.363 | 0.020 | 41 |
|  | Fear of Failure vs. Difficulty | 0.351 | 0.033 | 37 |
|  | vs. Overall merit | 0.293 | 0.066 | 40 |
| Landesklasse All Around | Age vs. Difficulty* | - 0.905 | 0.013 | 6 |

*Overall performance motive  **Difficulty value in the straight line discipline

Table 3
*Differences between gymnasts of different gender.*

| Differences (female vs. male) | N | $\bar{X} \pm SD$ | p | $\eta^2$ |
|---|---|---|---|---|
| Body fat percentage | 113 vs. 16 | $14.62 \pm 3.75$ vs. $8.32 \pm 3.51$ | 0.000 | 0.259 |
| Age | 114 vs. 15 | $22.54 \pm 5.11$ vs. $16.07 \pm 12.98$ | 0.059 | 0.028 |
| Overall merit | 100 vs. 15 | $6.10 \pm 1.84$ vs. $6.97 \pm 1.97$ | 0.092 | 0.025 |

Further, there are differences between male and female athletes in percentages of body fat, age and overall merit (tab. 2). No gender-related differences were found when considering other performance measures or motivational aspects.

**DISCUSSION**

For athletes competing in different disciplines, it is evident that gymnasts in the all-around had higher values in all competitive values compared to athletes competing only in straight line. This could be due to better coordination, a higher level of training, and more weekly training time as this might help them develop their skills more thoroughly. Also, gymnasts competing in straight line only were significantly older than gymnasts competing in the all-around while displaying lower values in the composition of their routines. This might be caused by more training time for younger competitors due to fewer demands in their daily lives. Gymnasts competing in the all-around had a higher hope of success and overall performance motive.

When considering results for gymnasts at the Landesklasse level, athletes competing in the all-around had a higher overall merit and difficulty, also higher net hope, probably due to having had success in the past, or, again, due to more time spent training.

This matches results for motivational factors at the Bundesklasse level, where hope of success and overall performance motive are significantly higher than at Landesklasse. This might be caused by

higher self-esteem. Additionally, athletes at the Bundesklasse level were significantly younger than at the Landesklasse level, this is probably due to a mixture of more training time and also better constitution and physical fitness at a younger age. This matches the results of Atiković et al. (2017) who found age-related differences between gymnasts competing on different kinds of apparatus. It is evident that the body fat percentage of the older gymnasts at the Landesklasse level is significantly higher than that at Bundesklasse, which is not in accordance with findings by Rummel (2016), but matches the results of a literature research conducted by Weber (2020). The body fat percentage seems to be a performance limiting factor, although it might also be that the aesthetic aspect might have influenced the judging (Weber, 2020).

When comparing male and female wheel gymnasts, it appears that males display a lower body fat percentage, as indicated in the abovementioned literature research regarding previous studies on gymnasts from various disciplines (Weber, 2020). Also, male wheel gymnasts displayed a significantly lower age than females, probably due to early drop-out due to social pressure from peers during puberty. Males had a higher overall merit than females. Due to the low number of male participants, it was not possible to attribute the higher overall merit to any cause, e. g., higher difficulty, execution, or composition values.

When comparing gymnasts from Bundesklasse and Landesklasse, correlations occur at the Landesklasse

level between age and difficulty (negative correlation) as well as execution (positive correlation), while at the Bundesklasse level, positive correlations are present between age and difficulty, age and composition, age and deductions off planned difficulty, age and fear of failure as well as fear of failure and deduction off planned difficulty, net hope and execution and overall performance motive and deduction off planned difficulty. Negative correlations can be found between age and hope of success, age and net hope, fear of failure and execution, net hope and deduction off planned difficulty, and overall performance motive and execution. This could mean that a high difficulty routine cannot be performed at a higher age and/ or with less training time. Also, the execution seems to improve with age despite training time per week, but rather concurrent with time spent in training over a lifetime. BK athletes seem to have a higher composition with rising age, but also a lower difficulty. Their motivation decreases, perhaps due to growing more nervous over time or having less success in line with a decrease in physical fitness. Fear of failure seems to have a negative effect on execution, probably due to being nervous in competition and making more minor mistakes.

A comparison of straight line versus all-around shows that the overall performance motive decreases with increasing age, perhaps due to less success or disappointments accumulated over time. It must be mentioned that there is a higher number of Landesklasse athletes performing in straight line, probably due to not having enough time to train more than one discipline. The concept of competing in the all-around was only introduced for Landesklasse gymnasts a few years ago. Execution value and body fat percentage increase with age in gymnast competing in straight line, just as the execution value did in gymnasts competing at the Landesklasse level. For straight line competitors, fear of failure is linked positively to difficulty

value, composition value and overall merit, probably due to athletes being motivated to take a higher risk to win. This also shows in net hope as it is negatively linked to the three aforementioned factors and the overall performance motive is positively linked to the difficulty value in straight line. In the all-around, age correlates positively with body fat percentage and negatively with difficulty in the straight line routine. Interestingly, fear of failure correlates negatively with execution, which has not been the case in straight line. Net hope is linked positively to the execution value, underlining the positive effect of hope of success in the accuracy of movements. For all-around competitors, the overall performance motive is connected to deduction off planned difficulty which might be caused by increased pressure during competition.

Considering differences between competitors in straight line and all-around for Landesklasse athletes only, execution and body fat percentage are connected positively with age in the straight line discipline. This underlines the hypothesis that accuracy in the execution of movement improves over the lifespan. Also, fear of failure correlates positively with difficulty and overall merit, probably due to a high level of ambition and thus high pressure to compose routines with a high difficulty. For Landesklasse gymnasts competing in the all-around, there is a high negative correlation between age and difficulty, probably also showing a decline in physical ability for the older gymnasts who are predominantly competing at the Landesklasse level.

**CONCLUSION**

Athletes at different performance levels need to be coached individually, as are athletes competing in different disciplines. Gender, on the other hand, does not have a strong effect when it comes to differences between gymnasts. Also, a strong aging effect is measurable.

More attention should be paid by coaches to the triad of physical decline - age - training time. It seems that older athletes mostly do not have the possibility to train properly despite needing more training to keep fit and achieve good results due to demands placed on them by daily life. This might affect hope of success and thus self-esteem, resulting in poor performance. Also, aspects of mental health must be taken into account. There might be connections between success and dropout rates for older athletes, even though they could still be competing at the Landesklasse level for some time: instead, there is a loss of role models, possibilities to learn from experiences and rivalry for the younger athletes as well as costs to the health care system. Especially ageing athletes should be encouraged to keep fit.

In summary, psychological factors seem to be performance relevant in wheel gymnastics as also shown in studies of other gymnastics disciplines (Calmels et al., 2009; D'Arripe-Longueville et al., 2009; Hume et al., 1993; Munkácsi et al., 2012; Wolko et al., 1993). Some factors can be considered performance relevant in general and within the different disciplines, including hope of success, fear of failure, net hope, overall performance motive and, to a certain degree, body fat percentage. While fear of failure may pose a hindrance to some gymnasts, others need it to drive their performance. These findings should be considered and gymnasts should be coached accordingly.

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