

**Wheelchair mobility performance enhancement by changing wheelchair properties
What Is the effect of grip, seat height, and mass?**

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Title: Wheelchair Mobility Performance enhancement by changing wheelchair properties; what is the effect of grip, seat height and mass?

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Abstract

Purpose: The purpose of this study was to provide insight in the effect of wheelchair settings on wheelchair mobility performance.

Methods: Twenty elite wheelchair basketball athletes of low (n=10) and high classification (n=10), were tested in a wheelchair basketball directed field test. Athletes performed the test in their own wheelchair, which was modified for five additional conditions regarding seat height (high - low), mass (central - distributed) and grip. The previously developed, inertial sensor based wheelchair mobility performance monitor¹ was used to extract wheelchair kinematics in all conditions.

Results: Adding mass showed most effect on wheelchair mobility performance, with a reduced average acceleration across all activities. Once distributed, additional mass also reduced maximal rotational speed and rotational acceleration. Elevating seat height had effect on several performance aspects in sprinting and turning, whereas lowering seat height influenced performance minimally. Increased rim grip did not alter performance. No differences in response were evident between low and high classified athletes.

Conclusion: The wheelchair mobility performance monitor showed sensitive to detect performance differences due to the small changes in wheelchair configuration made. Distributed additional mass had the most effect on wheelchair mobility performance, whereas additional grip had the least effect of conditions tested. Performance effects appear similar for both low and high classified athletes. Athletes, coaches and wheelchair experts are provided with insight in the performance effect of key wheelchair settings, and they are offered a proven sensitive method to apply in sports practice, in their search for the best wheelchair-athlete combination.

Key words: Wheelchair mobility performance, Wheelchair properties, Paralympic sports, Classification, Wheelchair basketball

Introduction

In wheelchair sports, athlete and wheelchair form one functional unit determining individual wheelchair mobility performance.² To enhance performance, athletes could focus on physical progress, technical wheelchair improvement or optimization of the interaction between both. That athlete specific interaction is especially important in adapted sports, since the wide range of physical impairments does not enable global optimization rules that apply to all. Getting the best wheelchair setting for each individual player is usually a long and time-consuming iterative process, with incremental improvements over the years with each new custom-made wheelchair. This approach does not fit elite sports demands at all, where competition demands (near) instant improvements.

To date, the wheelchair fitting process for performance optimization is highly dependent on the experience level of athlete and wheelchair expert. At the elite level, wheelchair experts are likely to adopt scientific knowledge of research describing general effects of wheelchair settings on performance,²⁻⁴ but effects are often described in qualitative general trends, rather than in quantitative effects. More detailed insight into the relationship between key settings, such as seat height/position and performance, could support athletes and wheelchair experts in their decision making. Often, there is not a single performance target, but decisions have to be made on the trade-off; for example, between desirable high seating position for shooting and its assumed negative effect on wheelchair mobility performance. The conditions for this trade-off are highly individual, specified by the athlete's classification, skills and field position.

A prerequisite to quantify the relationship between performance and wheelchair settings, is to have accurate and objective measures. To quote a wheelchair basketball coach: "you can't improve it, if you lack information". In preceding research, a method using inertial sensors proved reliable and accurate⁵ in measuring wheelchair mobility performance and discriminated well between athletes of different classification and competition levels.^{1,6} Using this method, the effect of changes in wheelchair configuration on wheelchair mobility performance, could be tested in sport specific conditions.

To determine the effect of wheelchair settings in an ecologically valid way, this should be tested with athletes in their own sports wheelchair under sport specific conditions. However, because their sports wheelchairs are often custom made, dimensions are set and most settings fixed. Therefore, options to temporarily alter wheelchair properties are limited. Nevertheless, with creative approaches minor adjustments to the configuration of the athlete's own sports wheelchair could be made.

There are various wheelchair settings which are known to have an effect on wheelchair mobility performance. Mason et al.² described five main wheelchair settings and their effect on performance aspects: seat height, seat position, wheel camber, wheel size and gear ratio. Seat height and position are two of the key wheelchair settings, that are known to affect performance in lab based measurements. Yet, the effect of setting alterations on wheelchair mobility performance in sport specific conditions remained unknown.² Seat height can be altered in sports wheelchairs to some extent, by inserting firm foam below the cushion (elevated) or using thinner cushions (lowered), but seat position (forward-backward) is manipulated less easily in an unambiguous manner. Wheel camber, size and gear (ratio of wheel size-rim) are difficult to modify within regular sports wheelchairs, without affecting a range of other wheelchair characteristics. Wheelchair mass is a common argument towards performance and it can quite easily be altered, albeit only in one direction (adding mass). So, although ideally the effect of mass reduction on performance is tested, it is practically only feasible to test the converse. Still, a known effect of mass increase, will also provide insight in the effect of mass reduction. Finally, additional grip is expected to enhance performance.⁷⁻⁹ It is common practice to use high friction gloves in wheelchair racing and rugby, but not in wheelchair basketball. In wheelchair racing, the increased friction is used to propel the wheelchair by hitting the rim, rather than making full grip connection, whereas in wheelchair rugby the increased grip is used to compensate for loss of grip force. In wheelchair basketball, players often have normal hand functionality and wheelchair speed allow for full rim grip. Since gloves may negatively affect ball handling, the use of gloves will probably not find its way into basketball, but alternative ways for increased hand-rim friction might.

To support athletes and wheelchair experts in their search to optimize wheelchair configuration, the goal of this research was to provide *quantitative* insight in the effect of seat height, mass and grip on wheelchair mobility performance for athletes of low and high classification. The wheelchair mobility performance was measured in a standardised wheelchair basketball directed field test,¹⁰ that athletes performed with: lowered and elevated seat height; with additional mass centrally placed; with additional mass distributed over the wheelchair; with gloves for improved rim grip. Since all conditions could have dissimilar effects on differently classified athletes,¹ groups of low (1 – 1.5) and high (4 – 4.5) class athletes were included.

Given the known effect of increased seat height on the kinematics and kinetics,² it was expected that elevating the seat would decrease most wheelchair mobility performance outcomes, whereas a lowered seat might improve mobility performance. This effect was

expected to be more prominent in the low-class athletes, since they have less trunk function to compensate for changes in shoulder-rim distance. Since adding mass will increase the inertia, movements require more force, so it is expected to reduce mobility performance. If centrally placed, mass mainly affects forward acceleration whereas distributed mass also affects maximal rotational speed and rotational acceleration given the increase in rotational inertia. Maximal forward speed is expected to be less influenced in mass conditions, since the effect of additional mass is less in continuous runs of longer duration. Maximal rotational speeds are more affected by rotational acceleration, since rotations are only of short term by nature. The difference between high and low-class athletes is expected to be less prominent in these conditions, although due to the physical capacity, added weight might have slightly more effect on low-class athletes. The increased grip condition is expected to enhance performance somewhat, especially in the low-class athletes with sometimes affected hand grip functionality.

Methods

Subjects

The wheelchair mobility performance was measured in a standardised field test¹⁰ for 20 elite level wheelchair basketball athletes. Athletes played at international (n=7) or national level (Dutch competition, n=13), with a group of ten players of class 1 -1.5 and a group of ten players of 4 – 4.5 (see Table 1). Both female (n=7) and male (n=13) athletes were included.

++++ Insert Table 1 here +++++

This study was approved by the Ethics Committee of the Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands (2016-091R1). All participants signed an informed consent after being informed on the aims and procedures of the experiment.

Methodology

Athletes were familiarised with the field test and performed the ~7-minute test six times, starting with the wheelchair in its common “neutral” setting (N). After that first run, a highly-experienced wheelchair expert changed their wheelchair to one of the five test conditions. The order of the conditions was randomly assigned, to eliminate possible effects of learning or fatigue. The five test conditions were: 7.5% lowered seat height (L); 7.5% elevated seat height (H); 7.5% increased total mass centrally placed at the camber bar (MC);

7.5% increased total mass distributed at 30 cm to the front (~45% total added mass) and to the rear (~45% total added mass) of the camber bar with a custom-made clamp (~10% total added mass, MD); and finally in neutral setting but with rubberised gloves for increased grip (G). The time in-between tests varied between 15-30 minutes, to allow athlete recovery and wheelchair adjustments.

Wheelchairs settings, especially adjusted seat height, were altered while preserving other chair ratios. So, with elevating or lowering the seat, the height of the backrest and footplate was changed equally. Although a percentage (7.5%) of seat height was used for the adjustment magnitude, the actual change in seat height towards the neutral position was measured on top of the athlete's head. The magnitude of the additional mass was 7.5% of the initial total mass measured on a weight platform prior to the test.

During the field test, each wheelchair was equipped with the “wheelchair mobility performance monitor”, a three-inertial sensor based method for performance measurement, as described by van der Slikke et al.^{1,11} This method provides six Wheelchair Mobility Performance (WMP) outcomes for each field test measurement. In this method, the measurement is split in sections where the athlete moves. For forward movement a threshold >0.1 m/s was used, and for rotational movement $>10^\circ/\text{s}$.¹ The WMP outcomes are calculated on these sections, they are: average forward speed; average speed in the best two runs (speed sections); average acceleration in the first 2m from standstill; average rotational speed in a curve; average rotational speed in the best two turns (rotation sections); average absolute rotational acceleration. Since the field test consists of 15 separate test items, it is also possible to calculate item specific outcomes. Per test item, two outcomes regarding forward motion and two outcomes regarding rotation were calculated. The outcomes were: maximal forward speed, average forward acceleration, maximal rotational speed and average rotational acceleration. For rotations absolute signals were used, disregarding the direction of rotation.

The 15 test items reflect all mobility performance aspects of wheelchair basketball, like a straight sprint (12m), a 360° curve (12m), turning on the spot and combined actions. These items are performed in a regular way, but also with intervals (additional stop/start at 3m/3m/6m in a straight and curved sprint, or with additional stop/start in the turn on the spot at 90°) and while dribbling a ball (B). The curves and turns were performed in right (R) and left (L) direction. One item covering small back and forward movements was excluded from the analysis, since its execution appeared unreliable in previous research.¹²

Comparison of performance outcomes

Per field test executed, a total of 62 performance outcomes was calculated: six overall outcomes and four outcomes in 14 test items. These 62 outcomes were compared between the neutral and five test conditions (Figure 1). Furthermore, the two tests with lowered and elevated seat were compared, as well as the two conditions with added mass. Since the neutral position does not necessarily resembles the optimal seat height the comparison between both seat height extremes might reveal a more distinct difference. The comparison between both added mass conditions might reveal the specific effect of mass distribution.

++++ Insert Figure 1 here +++++

Statistical analysis

To gain insight in the difference magnitude in performance outcomes, Cohen's d effect sizes (ES) were calculated based on the t-value, the correlation and the sample number (see supplemental material).¹³ The effects were divided in small effect ($ES = 0.2 < 0.5$), moderate effect ($ES = 0.5 < 0.8$) and large effect ($ES \geq 0.8$), as described by Cohen et al.^{14,15}

The possible effect of class on performance difference between conditions is tested for the six WMP outcomes, based on a two-way mixed ANOVA with the class group as between-subject factor. The use of this statistic procedure requires a list of assumptions that must be met. Outliers in the data were checked based on a boxplot and a Kolmogorov Smirnov test was applied for testing normal distribution. Prior to the two-way ANOVA, studentized residuals were calculated and inspected. They were subsequently tested for outliers ($>\pm 3$), tested for normality (Q-Q plot), tested for equality of variances (Levene's test), tested for equality of covariances (Box's test) and sphericity of covariances (Mauchly's test).

Results

Measurements

All measurements in neutral configuration were performed successfully, but due to technical and practical setbacks, some measurements (n=8) of the other conditions were lost or not performed (L, n=1; H, n=2; MC, n=3; MD, n=1; G, n=1). Given the pairwise analysis, the effect of lost measurements on the results is minimal, but it does affect group size. In three cases, a fixed seat plateau and minimal cushion thickness made the aimed 7.5% lowering of the seat height impossible, so only about 5% was achieved.

Performance differences between conditions

Of the six WMP outcomes in seven comparisons, 12 showed effect sizes over 0.2 in comparisons between conditions. In the detailed outcomes per item in the field test 155 of the 392 (four outcomes x seven comparisons x fourteen test parts) showed effect sizes over 0.2 (Figure 2). All effect sizes and their magnitude are shown in Table 2.

++++ Insert Figure 2 here +++++

++++ Insert Table 2 here +++++

Classification effect on performance differences between conditions

The possible effect of classification on the main six WMP outcomes between conditions was determined by the two-way mixed ANOVA. For each of the six WMP outcomes, all assumptions linked to this procedure were checked, as shown in Table 3. All outliers were checked and ascertained to be genuine. Most of the assumptions were met, however, outliers distorted the distribution especially in the average forward acceleration to 2m in the high-class group.. Since data did not seem eligible for transformation correction, procedures were kept and violations noted. With due observance of the few violations, no significant interaction effect of class with any of the six WMP outcomes was found, as shown in Table 3.

++++ Insert Table 3 here +++++

Discussion

This research showed the effect of altering wheelchair configurations on wheelchair mobility performance and offers athletes and coaches a method to evaluate performance in an objective and ecologically valid way. The WMP monitor combined with the basketball directed field test could be employed as a tool to individually optimize task specific performance of athlete-wheelchair combinations.

The comparison between multiple conditions and several performance outcomes, resulted in a vast amount of values for further analysis. To gain insight in the performance differences between conditions, Cohen's d effect sizes were used. This measure allows for easy interpretation, but has its limitations given the dependence on the group composition.¹⁶

Therefore, raw data and additional statistics are presented in the supplementary material, as are the differences in WMP outcomes expressed in a factor of smallest detectable difference.⁶

Changes in performance due to the modifications in wheelchair configuration, showed in both positive and negative effect sizes, so they show increase and reduction in outcome values respectively. Which type of change is considered performance enhancement is depending on the outcome, the task executed and the aim of the athlete. Increased rotational speed in “turning” (positive ES) could generally be considered as better performance, whereas increased rotational speed in “a straight sprint” could be regarded as performance reduction, since it implies a less straight track driven. Since wheelchair mobility performance goals might differ between athletes, depending on their field position, classification or other aspects, there is no unambiguous interpretation whether a certain change is regarded as improvement or not. Therefore, the direction of performance changes due to altered wheelchair settings (Table 2) are displayed without value judgement.

Compared to the neutral position, the *lowered seat height (L)* showed small to moderate output increases and decreases, mainly in rotational aspects. Reduced rotational speed and acceleration (negative ES) in the straight sprints could be considered as better performance, since it means better maintaining a straight line. As expected, *seat elevation (H)* mainly decreased outcomes, as shown by small negative effect sizes of forward and rotational aspects in sprints (better performance) and turns (reduced performance). In the WMP outcomes both rotational speeds showed a small decrease. In the comparison between low (L) and high (H) seat height, differences per item are less prominent, but now also the WMP average forward speed outcome shows a small decrease for the elevated seat condition. These results are in line with the findings of Mason et al.,² in their review article of 2013.

In the condition with *centrally added mass (MC)*, effect sizes of rotational speed WMP outcomes were small. At test item level, forward average absolute acceleration is reduced in nearly all items, with small to moderate effect sizes. Once the same amount of *added mass is distributed (MD)*, the effect on performance is even more profound. The rotational acceleration WMP outcome shows an effect size of -0.32, and at test item level, nearly all rotation related outcomes show small to large effect sizes. Again, reduction of rotational components in straight sprints, could be considered as better performance. So, added mass has effect on acceleration, and once distributed also on rotational acceleration. Due to the short nature of rotations this is also reflected in the maximal rotational speed. In the comparison between centrally placed and distributed added mass, only the rotational

components differ.

The condition with improved *grip (G)* due to the use of rubber coated gloves, showed the least effect of all conditions. Of the overall WMP outcomes, best rotational speed in turning shows a small negative effect size. If separated per test item, only a few outcomes show small effect sizes in difference and in most cases with reduced magnitudes of outcomes. Verbal feedback from participants on the use of gloves varied widely, so maybe this condition is beneficial for some, but unprofitable for others. Furthermore, this condition seemed to have more impact on propulsion technique than any of the other conditions, possibly requiring additional learning time to optimize grip benefits.

Differences between conditions show more explicit in the analysis per test item, compared to the overall WMP outcomes. This implies that although the six WMP outcomes have been proven to discriminate well between athletes,¹ they might lack enough specificity for individual athlete-wheelchair optimisation. If the aim is to optimize an athlete-wheelchair combination for a specific task, like straight sprinting, analysis based on a task directed field test provides more specific information. By combined tasks that occur in match play, the performance increase by reduced rotational speed in straight sprinting and increased rotational speed in turning, might cancel out.

Since the WMP monitor method also allows for more detailed analysis, additional performance differences were identified at test item level. The four outcomes used were selected since they are rather easy to interpret, with the maximal (rotational) speed, and the average (rotational) acceleration reflecting movement intensity. Maximal forward speed seems to be least affected by the different conditions, whereas the other three do discriminate depending on the condition. In future analysis, the current measurement configuration can be used to detect tasks (turning, sprinting, curve, etc.), allowing for task specific display of kinematic outcomes. The WMP monitor enables research into the relationship between these outcomes and overall game performance, which could be highly beneficial for coaches and athletes.

This research showed the magnitude of effect on performance due to changes in wheelchair configuration, but it does not yet quantify the relationship between configuration and performance as expressed in a regression equation. For most settings, the possible relationship between setting and performance is expected to be non-linear, with reduced performance near the setting boundaries. This assumption implies that for each setting

multiple conditions (>3) are required to fit any regression equations. In this study, only seat height was measured in three conditions (low-neutral-high) and all others only in two conditions. Furthermore, given the heterogeneity of the group of wheelchair athletes, it is uncertain if a valid regression equation could be established, even if performance is measured in more conditions. Possibly if large volume performance data is available, it is possible to divide (by classification or impairment) the athletes in more homogenic sub-groups, to allow for regression analysis of the settings that appeared of importance.

Given the scope of this study, methodological choices had to be made that raised some limitations. All tests were performed consecutively, with limited time for the athlete to get acquainted to each new condition. Enough time in-between tests was allowed for full physical recovery, but not for full physical or coordinative adaptation. Since only minor modifications ($\sim 7.5\%$ mass and height) were made, athletes experienced no difficulty with performing the field test with adjusted wheelchair settings. Only in the “grip” (G) condition, some athletes remained unaccustomed to the gloves throughout the test.

Although it was anticipated that classification level could cause different performance effects as a result of changes in wheelchair settings, no interaction effect of classification was uncovered. This finding needs to be adopted with care, since the number of athletes included in this study was limited and there was a clear age difference between groups. Furthermore, some violations to the numerous assumptions linked to the two-way mixed ANOVA procedure occurred.

Practical Applications

The WMP monitor used, proved responsive to changes in wheelchair mobility performance due to altering wheelchair configuration. As such, it is considered a valuable tool for optimizing individual wheelchairs, reducing time and costs to get to the best athlete specific custom-made wheelchair. In this optimization process, research outcomes can guide the way in decision making regarding the different performance trade-offs. Although relationships between settings and performance have not yet been described by possible regression equations, some first quantitative insight of effect is provided. Given the range of outcomes and quantities, differences are only described in effect sizes. Evidently, in sports practice, actual outcomes could be used. For example, the difference in maximal speed in the

12m sprint between neutral (3.98 m/s) and lowered seat height (4.07 m/s) is expressed as an effect size of -0.21, which resembles a speed difference of – 0.09 m/s.

Within the measured range, lowering seat height has minimal effect, whereas elevating seat height reduces performance. Added mass reduces forward acceleration and if mass is distributed in forward-backward direction, it has considerable effect on rotation performance. Distributed mass also reduces rotation in a straight sprint, which could be considered positive in some game aspects, but it reduces manoeuvrability in most other aspects. This outcome could endorse athletes to try and reduce mass to the front and rear, in particular try to move the foot plate as far back as possible and configure wheel and seat position in such a way that the mass is most centrally placed and close to the camber bar. That solution is only applied occasionally, but seems quite beneficial regarding mobility performance. Furthermore, it is advised to align the wheelchair in such a way that the forward-backward location of the overall centre of mass is close to the rear axle, in the most frequently used body position (not necessarily upright position!).

Conclusion

It proved feasible to execute research regarding wheelchair settings with elite level athletes in their own custom made sports wheelchairs. The standard six wheelchair mobility performance outcomes do differ between some conditions, but with opposite demands across tasks, performance effects are sometimes levelled out in the used outcomes. The more detailed analysis per field test task showed of additional value, by enhancing specificity.

Seat height affected outcomes of both forward and rotational movement. Centrally added mass affected mainly forward motion outcomes, and once distributed it also affected rotational outcomes. Within the limitations of this study, the classification of an athlete does not seem to cause different effects on wheelchair mobility performance.

The WMP monitor showed to respond to minor changes in wheelchair configuration, so in future athletes, coaches and wheelchair experts can apply this cheap and easy accessible method for continuous mobility performance monitoring to evaluate optimisation interventions in training and wheelchair setting.

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Conflict of interest statement

None.

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Table 1, Subject characteristics and distribution over classification groups

	Mean	SD	Class	
			1-1.5	4-4.5
Age (y)	29.7	11.5	34.2	25.1
Height (cm)	179.6	9.1	179.4	179.8
Mass (kg)	71.1	11.8	68.9	73.2
Experience (y)	9.0	9.5	7.9	10.2
Gender (F/M)			4 / 6	3 / 7

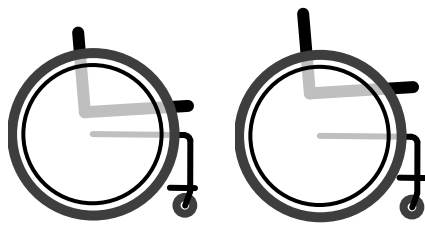
Table 2: Effect sizes (Cohen's d) of significant differences (paired T-test or Wilcoxon Rank, $p < 0.05$), with **small** ($0.2 < 0.5$), **moderate** ($0.5 < 0.8$) and **large** (≥ 0.8) marked. The sign indicates performance increase or decrease (-) towards the reference.

The table shows the comparison between conditions (indicated left) for the overall test Wheelchair Mobility Outcomes (left column of values) and for four outcomes per field test item. Outcomes are sorted by their direction (forward or rotational), their order (speed or acceleration) and their feature (Avg = average; Best 2 = best 2 actions; 2m = during first 2 meter from standstill; Abs = absolute value; Curve = rotation during driving; Turn = rotation with minimal forward speed). The test items (columns) are grouped by their features, the actual test order differs.

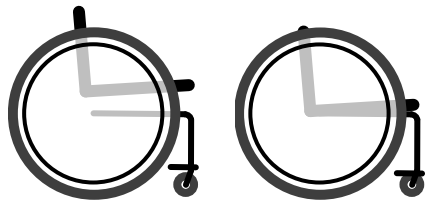
			12m straight					12m curve				Turn on the spot						Comb.
			Overall	Variable	Regular	Ball	Interval	Right	Left	R ball	L ball	R interval	L interval	Right	Left	R interval	L interval	Regular
Neutral - Low	Forward	Sp Avg	0.17															
		Best 2	-0.09	Abs max	0.21	-0.05	-0.04	-0.10	0.25	0.18	0.08	-0.02	0.14	-0.04	-0.18	-0.20	0.38	0.00
	Acc 2m Avg	0.02	Abs avg	-0.07	0.13	-0.05	-0.07	0.10	-0.07	-0.13	0.07	0.08	-0.08	0.09	-0.03	-0.29	0.01	
	Rotation	Sp Curve Avg	-0.07															
Turn best 2		0.02	Abs max	-0.43	-0.57	0.26	-0.46	-0.07	-0.20	0.05	0.10	-0.20	0.18	0.03	0.05	-0.27	0.14	
		Acc Avg	0.05	Abs avg	-0.33	-0.16	-0.13	-0.04	-0.01	-0.19	-0.14	0.10	-0.10	0.24	0.04	0.08	-0.10	0.09
Neutral - High	Forward	Sp Avg	-0.13															
		Best 2	-0.11	Abs max	0.17	-0.09	-0.26	-0.17	-0.02	-0.09	-0.04	-0.09	0.01	0.34	0.23	0.19	0.09	-0.10
	Acc 2m Avg	0.07	Abs avg	-0.25	0.26	-0.01	-0.29	0.11	-0.15	-0.14	0.07	0.07	-0.24	-0.16	-0.19	-0.34	-0.10	
	Rotation	Sp Curve Avg	-0.27															
Turn best 2		-0.30	Abs max	-0.15	-0.36	0.01	-0.22	-0.13	0.11	-0.06	-0.20	-0.17	-0.22	-0.11	-0.20	-0.48	-0.24	
		Acc Avg	-0.13	Abs avg	-0.45	-0.17	-0.13	0.03	0.14	-0.10	-0.12	0.09	-0.15	-0.22	-0.11	-0.34	-0.29	-0.03
Low - High	Forward	Sp Avg	-0.35															
		Best 2	-0.11	Abs max	-0.17	-0.03	-0.16	-0.06	-0.14	-0.27	-0.05	-0.09	-0.16	0.47	0.35	0.41	-0.27	-0.09
	Acc 2m Avg	0.00	Abs avg	-0.19	0.11	0.02	-0.25	0.03	-0.02	0.00	-0.04	0.00	-0.11	-0.15	-0.10	-0.13	-0.11	
	Rotation	Sp Curve Avg	-0.25															
Turn best 2		-0.27	Abs max	0.19	0.00	-0.12	0.20	0.00	0.06	-0.04	-0.28	0.13	-0.38	-0.14	-0.23	-0.26	-0.30	
		Acc Avg	-0.15	Abs avg	-0.05	-0.05	-0.01	0.04	0.20	0.09	0.01	0.02	-0.03	-0.39	-0.18	-0.39	-0.19	-0.12
Neutral - Weight Central	Forward	Sp Avg	0.03															
		Best 2	-0.01	Abs max	-0.04	-0.21	-0.09	-0.37	-0.22	-0.32	-0.05	0.04	-0.07	0.17	-0.36	0.14	0.30	-0.03
	Acc 2m Avg	0.02	Abs avg	-0.36	-0.13	-0.30	-0.45	-0.51	-0.42	-0.45	-0.26	-0.23	-0.49	-0.69	-0.37	-0.49	-0.45	
	Rotation	Sp Curve Avg	-0.32															
Turn best 2		-0.22	Abs max	0.02	-0.63	-0.15	-0.19	-0.11	0.09	-0.16	-0.24	-0.14	0.01	-0.13	0.00	-0.21	-0.39	
		Acc Avg	-0.05	Abs avg	-0.19	-0.14	-0.24	0.04	-0.01	-0.09	-0.06	0.03	-0.03	-0.01	-0.03	-0.10	-0.07	0.02
Neutral - Weight Distributed	Forward	Sp Avg	0.13															
		Best 2	-0.09	Abs max	0.01	-0.15	-0.05	-0.03	-0.11	-0.18	0.00	0.03	0.06	0.18	0.36	0.02	0.18	-0.20
	Acc 2m Avg	0.01	Abs avg	-0.32	-0.17	-0.28	-0.52	-0.43	-0.34	-0.41	-0.15	-0.34	-0.39	-0.37	-0.39	-0.59	-0.36	
	Rotation	Sp Curve Avg	-0.21															
Turn best 2		-0.26	Abs max	-0.54	-1.12	-0.31	-0.63	-0.75	-0.52	-0.45	-0.18	-0.48	-0.27	-0.39	-0.31	-0.41	-0.43	
		Acc Avg	-0.32	Abs avg	-0.40	-0.44	-0.38	-0.53	-0.36	-0.45	-0.43	-0.21	-0.59	-0.29	-0.31	-0.36	-0.35	-0.29
Weight Central - Weight Distributed	Forward	Sp Avg	0.17															
		Best 2	0.01	Abs max	0.09	0.05	0.05	0.36	0.19	0.18	0.03	0.06	0.14	0.21	0.51	0.02	-0.10	-0.21
	Acc 2m Avg	0.06	Abs avg	0.14	-0.01	0.04	-0.06	0.07	0.07	0.05	0.16	-0.07	0.18	0.41	-0.01	-0.24	0.07	
	Rotation	Sp Curve Avg	0.02															
Turn best 2		-0.04	Abs max	-0.69	-0.57	-0.25	-0.49	-0.49	-0.41	-0.24	0.04	-0.34	-0.26	-0.23	-0.35	-0.30	-0.11	
		Acc Avg	-0.29	Abs avg	-0.21	-0.48	-0.23	-0.48	-0.33	-0.42	-0.40	-0.25	-0.58	-0.30	-0.22	-0.27	-0.27	-0.34
Neutral - Grip	Forward	Sp Avg	-0.10															
		Best 2	-0.16	Abs max	-0.01	-0.12	-0.13	0.30	0.31	0.16	-0.20	0.07	0.18	0.12	-0.09	-0.08	0.32	0.02
	Acc 2m Avg	-0.08	Abs avg	-0.14	0.13	0.02	-0.04	0.09	-0.07	-0.17	0.07	0.11	0.04	-0.04	-0.01	-0.08	-0.01	
	Rotation	Sp Curve Avg	-0.15															
Turn best 2		-0.28	Abs max	-0.21	-0.61	0.08	-0.13	-0.04	-0.12	-0.06	0.12	-0.12	0.01	0.05	0.00	-0.27	0.07	
		Acc Avg	-0.07	Abs avg	-0.18	-0.18	-0.14	0.05	-0.06	-0.11	-0.11	0.07	-0.10	-0.04	-0.02	-0.21	-0.20	0.24

Table 3, Two-Way mixed ANOVA assumptions tests and interaction outcomes. The left two columns show the number of outliers (all genuine) and the number of not-normal distributions (out of 12) per class group in the WMP outcomes. The middle 5 columns show: the characteristics of the studentized residuals; with the number of outliers; the number of times data showed non-normality (out of 12); the number of times the Leven's test showed no equality of variances (out of 12); if there was equality of covariance matrices as determined by the Box's test; if differences between groups are equal as tested by the Mauchly's test of sphericity. The right 3 columns show the interaction effect of condition*class, based on the within subject, with F value, the significance and partial η^2 .

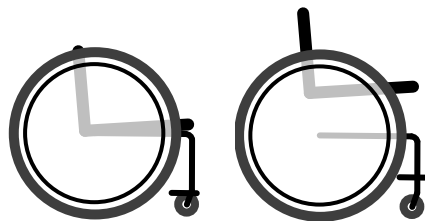
			Data		Studentized residuals							
			Outliers	Distribution	Outliers	Q-Q plot	Levene's	Box's test	Mauchly's	F _(5,65)	Significance	partial η^2
Forward	Sp	Avg	1	-	-	-	2	no	-	0.90	0.48	0.07
		Best 2	5	1	-	-	4	no	-	0.46	0.80	0.03
	Acc	2m Avg	2	6	-	6	0	no	-	1.52	0.20	0.11
Rotation	Sp	Curve Avg	-	2	-	-	-	-	-	0.97	0.44	0.07
		Turn best 2	9	-	-	-	-	-	-	0.70	0.63	0.05
	Acc	Avg	3	1	-	-	-	no	no	1.33	0.26	0.09



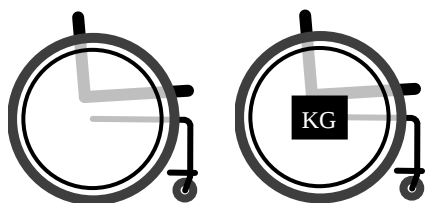
Neutral (N) vs.
High (H)



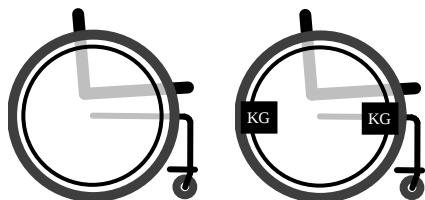
Neutral (N) vs.
Low (H)



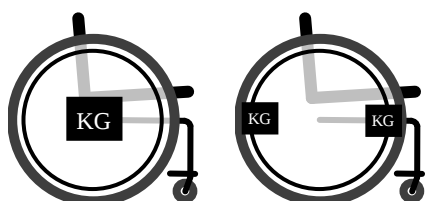
Low (L) vs.
High (H)



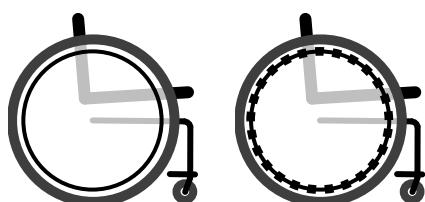
Neutral (N) vs.
Mass Central (MC)



Neutral (N) vs.
Mass Distributed (MD)



Mass Central (MC) vs.
Mass Distributed (MD)



Neutral (N) vs.
Grip (G)

Figure 1, seven comparisons based on five conditions compared to neutral and two mutual comparisons.

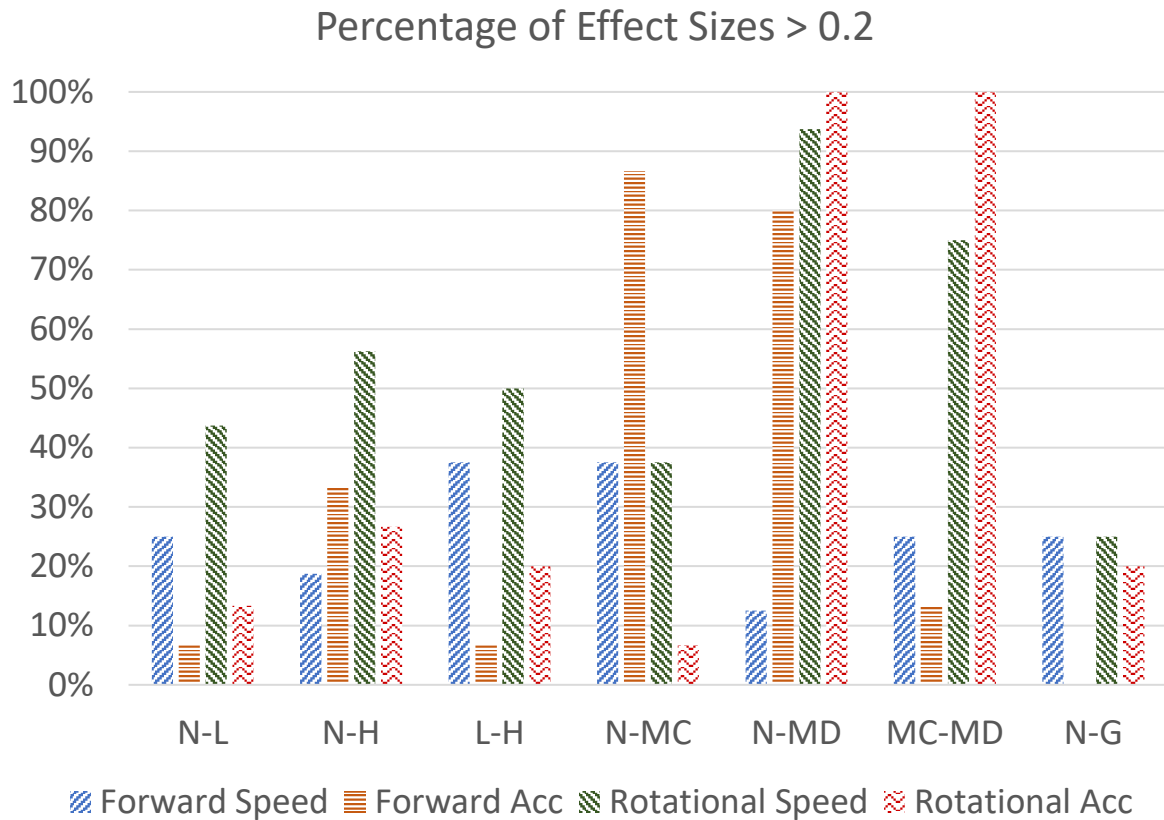


Figure 2, this graph shows the percentage of small (≥ 0.2) - large effect sizes between conditions, grouped by order (speed / acceleration) and direction (forward / rotational). For forward and rotational speed this is a percentage of 16 (2x WMP-overall + 14 for each test), and for the forward and rotational acceleration this is a percentage of 15 (1x WMP-overall + 14 for each test). Mind that not all outcomes are expected to differ (e.g. forward speed in a turn on the spot), so 100% is not always the upper limit (see Table 2 for details).