Effects of seat height, wheelchair mass and additional grip on a field-based wheelchair basketball mobility performance test

De Witte, A. M.H.; Van Der Slikke, R. M.A.; Berger, M. A.M.; Hoozemans, M. J.M.; Veeger, H. E.J.; Van Der Woude, L. H.V.

DOI
10.3233/TAD-190251

Publication date
2020

Document Version
Accepted author manuscript

Published in
Technology and Disability

Effects of seat height, wheelchair mass and additional grip on a field-based wheelchair basketball mobility performance test

OBJECTIVE: The purpose of this study was to determine the effects of seat height, wheelchair mass and grip on mobility performance among wheelchair basketball players and to investigate whether these effects differ between classification levels.

METHODS: Elite wheelchair basketball players with a low (n=11, class 1 or 1.5) or high (n=10, class 4 or 4.5) classification performed a field-based wheelchair mobility performance (WMP) test. Athletes performed the test six times in their own wheelchair, of which five times with different configurations, a higher or lower seat height, with additional distally or centrally located extra mass, and with gloves. The effects of these configurations on performance times and the interaction with classification were determined.

RESULTS: Total performance time on the WMP test was significantly reduced when using a 7.5% lower seat height. Additional mass (7.5%) and glove use did not lead to changes in performance time. Effects were the same for the two classification levels.

CONCLUSIONS: The methodology can be used in a wheelchair fitting process to search for the optimal individual configuration to enhance mobility performance. Out of all adjustments possible, this study focused on seat height, mass and grip only. Further research can focus on these possible adjustments to optimize mobility performance in wheelchair basketball.

Keywords: *Wheelchair mobility performance - Wheelchair configuration - Wheelchair basketball – Classification - Paralympic*

Introduction

Wheelchair mobility performance, defined as the ability of a wheelchair athlete to perform athlete-wheelchair activities such as driving forward, driving backward or turning with a wheelchair [1], is an important performance aspect in wheelchair basketball. Overall (team) performance may be improved by focussing on mobility performance which is dependent on a combination of ergonomic factors associated with the athlete, the wheelchair and the interface between them [2]. Athlete characteristics, such as physical capacity and muscle strength, can influence mobility performance as well as wheelchair settings such as wheelchair mass and camber. Furthermore, adjustments in the athlete-wheelchair interface, such as seat height and handrim grip, have been shown to have an effect on mobility performance[3,4]. Insight in the relationship between mobility performance and the athlete, wheelchair and interface characteristics could help athletes, coaches and wheelchair technicians to improve the overall performance of the individual athlete and thus also the team performance.

Mobility performance can be influenced by changes in the wheelchair and interface configuration. Seat height can have an effect on mobility performance in wheelchair basketball through its influence on the stability of the wheelchair-athlete combination and the propulsion technique or efficiency[5,6,7,8]. Most studies on the effects of seat height in wheelchair handling focused on physiological and mechanical responses in laboratory settings, and mainly in the context of daily life activities or sports such as wheelchair racing[4]. The conclusions of these laboratory studies may, therefore, not be directly transferrable to wheelchair basketball. In wheelchair basketball, for instance, it is often desirable for centre players to sit as high as possible for optimal ball handling at the expense of stability. Whether seat height (when manipulated within reasonable and allowable ranges) actually has an effect on mobility performance in wheelchair basketball is therefore unknown, although a recent study indicated that seat height is a predictor of mobility performance[2].

The same is true for wheelchair mass, which has been studied and discussed before in relation to performance, but mainly in forward velocity conditions[3,9]. In a study with able-bodied participants on a wheelchair treadmill, additional mass (5 and 10kg) did not result in a significant higher physical strain[3]. Sagawa et al. [9] also found no effects of additional mass (5kg) on sprint performance, but a decrease in performance in the Stop-and-Go test for the able-bodies subgroup. However, Cowan et al. [10] found that average self-selected velocity decreased when the mass of the wheelchair was increased with 9.05kg. The effect of wheelchair mass is ambiguous in the current literature and the effect on mobility performance in wheelchair basketball is also unknown.

In wheelchair racing and wheelchair rugby, it is common to use gloves to increase the friction between hand and rim. Gloves had a beneficial effect on wheelchair handling skills in rugby players and racers were able to achieve higher top end velocities by applying larger peak forces on the handrim [11,12,13]. Additional grip can, therefore, also be advantageous to mobility performance in wheelchair basketball.

Considering the limited transfer of knowledge from results of laboratory studies with able-bodied participants with respect to activities of daily life, the effects of seat height, wheelchair mass and glove use on mobility performance in wheelchair basketball might be studied using a recently developed standardized field-based test. The wheelchair mobility performance assessed using this test was considered to be representative for the mobility performance in wheelchair basketball matches [14].

In exploring the effect of different wheelchair and interface configurations on mobility performance, the classification of athletes in wheelchair basketball should be taken into account [4]. Active trunk stability and rotation have been identified as central components determining performance [15] and are key factors in the current wheelchair basketball classification system [16]. Due to less trunk function it is expected that low class players are not able to compensate for the larger distance between shoulder and handrim in the higher seat height position and, therefore, performed less. Furthermore, players with a low classification have less power output than players with a higher classification [17] and based on this relationship, it is expected that the extra mass condition should have more effect on the low classification group. Therefore, the aim of this study was to determine the potential effects of seat height, wheelchair mass and additional grip on wheelchair mobility performance while performing a standardized field-based wheelchair mobility performance test, and to determine whether these effects are different for wheelchair basketball athletes of either low or high classification.

Methods

Participants

Twenty-one elite wheelchair basketball players participated (national team member or player first division) in this study with fourteen men and seven women (Table 1). Eleven players had a classification of 1 or 1.5 (low classification group) and ten players had a classification of 4 or 4.5 (high classification group). Participants gave written informed consent prior to participating. This study was approved by the Ethics Committee of the Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands (2016-091R1).

Procedure

Participants had to perform the Wheelchair Mobility Performance (WMP) test, which consists of 15 sport specific tasks and has been shown to be a valid and reliable test to assess mobility performance capacity in wheelchair basketball [14]. All 15 tasks were carried out in succession, separated by standardised rest periods to avoid fatigue (see Supplementary Material I). Participants were familiar with the WMP test because of their participation in previous experiments.

The participants performed the WMP test six times in their own wheelchair of which five times with different configurations. Tire pressure was standardized at seven bar. The first time the WMP test was performed, no wheelchair configurations were changed (control condition). After the first test, the wheelchair was changed to one of five conditions in a randomised order to eliminate learning or fatigue effects. All adjustments were made by a highly-experienced wheelchair technician. The five configurations were: 1) 7.5% lower seat height; 2) 7.5% higher seat height; 3) 7.5%

additional mass centrally placed at the wheel axis (mass central); 4) 7.5% additional mass distributed evenly at 0.3m in front of and behind the wheel axis (mass distal); 5) use of rubber coated gloves to increase grip on the handrim without changes to seat height or mass. Although a percentage of the seat height was used for adjustment, the change was measured with a reference point on the top of the participant's head. When the wheelchair was adjusted, all other wheelchair configurations were kept as in the original configuration.

Each WMP test took about 6.5 minutes and was followed by a rest period of 15-30 minutes to allow recovery and to make adjustments to the wheelchair before the next test. For each participant, the WMP tests were performed on the same wooden indoor basketball court on one day.

Data acquisition and analysis

All WMP tests were video recorded from the side of the field with two high-definition video cameras (CASIO EX-FH100, 1280*720, 20-240mm) with a frame rate of 30Hz. The outcome of the WMP test was total performance time (sec) and was manually determined from video analyses using Kinovea (Kinovea 0.8.24, France). Next to total performance time, the performance times on the 3-3-6m sprint (task 7) and the combination task (task 15) were analysed separately. Previous research indicated that these performance time, as well as the total performance time on the entire WMP test were found to be valid, reliable and sensitive to change [14,18].

Statistical analysis

The assumption of normality was checked by visual inspection of the distribution of the data and a Shapiro-Wilks test was performed of the data within the groups.

Homogeneity of variance was checked using Levene's test. There were no violations of these assumptions. Descriptive statistics for performance measurements were, therefore, presented as mean ± standard deviation.

Two-way mixed design analyses of variance were used for seat height (low-control-high), added mass (control-central-distal) and glove use (control-gloves) separately to determine whether these wheelchair and interface configuration have an effect on performance times of the 3-3-6m sprint (task 7), combination task (task 15) and the total WMP test time and to determine whether the effects of these adjustments were influenced by classification (interaction effect).

For the independent variable seat height and mass, Tukey post hoc tests were performed when their main effect was found to be significant. When a significant interaction was observed, t-tests with Bonferroni correction were used to examine the interaction effect. In addition, Cohen's *d* effect sizes (ES) were calculated for the differences between pairs of conditions [19]. The (absolute) magnitude of the ES was classified as large (≥0.80), medium (0.50-0.79) small (0.20-0.49) or trivial (0-0.19) [19]. All statistical analyses were performed using IBM SPSS statistics version 22 (IBM Corporation, Armonk, NY, USA) and *p*-values below 0.05 were considered significant.

Results

All 21 athletes performed the control condition. One low class athlete didn't perform the lower seat height position and glove use trials, and one high class athlete didn't perform the WMP test with additional mass centrally placed. Due to differences in group size, the results of the control condition for the different configurations showed small differences as can be seen in Tables 2,3 and 4.

For the performance time on the 3-3-6m sprint (Table 2), no significant differences were found between the seat heights. On the combination task, performance times in the lower seat position (*M*=14.60s, *SD*=1.40) were 0.26s (ES=0.19) faster compared to the higher seat position (*M*=14.86s, *SD*=1.32). Furthermore, there was a significant main effect of seat height for the total performance time (*p*=.002) (Table 2/Figure 1). Post-hoc tests showed significant differences between the lower seat height condition and the control condition, and between the lower and higher seat height conditions. The performance with a lower seat condition resulted in a 1.69s faster performance than the control condition (*p*=.014) and a 1.75s faster performance than with a higher seat height (*p*=.002). However, the effect sizes were classified as trivial, i.e. ES=0.18 and ES=0.19 respectively. The difference in total performance time between the control conditions and the higher seat height conditions was not significant. Overall, there were no statistically significant interaction effects observed between the seat height conditions and classification (for 3-3-6m sprint, *P*=.394; for combination task, *p*=.546; for total WMP test, *p*=.158).

There were no significant main effects observed for wheelchair mass (Table 3). Furthermore, no significant interaction effects were found between classification and wheelchair mass (3-3-6m sprint, *p*=.475; Combination, *p*=.415; Total WMP test, *p*=.215).

The differences in performance times on the WMP test between the trials with and without the use of gloves were not found to be significant (Table 4). Moreover, there were no significant interaction effects between classification and glove use for all three outcome variables (3-3-6m sprint, p=.372; Combination, p=.354; Total WMP test, p=.721).

Discussion

In this study, we determined the effect of seat height, mass and glove use on mobility performance in a standardized field-based wheelchair basketball test in elite wheelchair basketball players and we determined whether these effects are different for players with a low or high classification. The key findings of this study are that (1) a 7.5% lower seat height resulted in a faster performance on the total wheelchair mobility performance (WMP) test and on the combination task, and (2) 7.5% extra mass or the use of gloves did not lead to a significant change in performance time. Furthermore, high and low classification players showed similar responses to the interventions.

Performance times on the combination task and on the total WMP test were significantly influenced by seat height. Moreover, as can be seen in Table 2, the differences in all performance outcomes between high and low seat height have a positive value. This means that athletes performed the three different test parts faster with a 7.5% lower seat height than that they were used to, compared to the condition in which they had to perform the test with a 7.5% higher seat height. Based on the results of this study, one can assume that lowering the seat height then they were used to has a positive effect on mobility performance time in wheelchair basketball. In practice, the range of possible seat heights may be larger than the tested ±7.5% range. The optimal individual seat height is dependent on the athlete and the requirements of the game. The association between seat height and performance is by definition not linear because there is a limit to the seat height at which the handrims can be used. A trend in seat height can be seen, but the optimal seat height cannot be determined based on the present data, as only three heights have been tested. Previous studies focused on the effect of seat height on physiological parameters, propulsion technique and mechanical efficiency in wheelchair propulsion, and their results are in line with the results of the present study. Van der Woude et al. [20] observed that raising the seat height above the standardized position resulted in a higher oxygen uptake and reduced mechanical efficiency, which underlines the results in this study where more complex wheelchair handling tasks were tested. Lower seat height positions have been associated with increases in handrim contact and push-time and a reduction in push frequency [7,21,8]. The increased handrim contact time and longer push time could explain the increase in mobility performance in the present study because it allows a longer power transfer.

Extra mass (7.5%), distally or centrally attached to the wheelchair, did not significantly change the outcome variables and no interaction effect with classification was observed. Extra mass was expected to decrease mobility performance time, as it is assumed that extra mass would have a negative effect on forward acceleration and braking. However, no noteworthy differences between the conditions were observed in performance times, despite the relatively large extra mass of 5 to 9kg. This was somewhat surprising. Within the project that included this study, Van der Slikke et al. [22] observed kinematic data of mobility performance with inertial sensors. 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. However, this was only determined for the WMP-test as a whole and not for the separate tasks of the WMP-test. Future research using accelerometer data can shed light on the actual differences in acceleration and braking between conditions during the different test parts. The results were quite similar to previous research with daily life focus, which found no effect of extra mass on wheeling velocity [3,9]. However, when the sensitivity to change of the WMP test was studied, the performance times on the total WMP test decreased significantly 4.40s when 10 kg extra mass was attached to the wheelchair [18]. In the present study the extra mass varied, but was in all cases less than 10kg, which could explain these differences. The outcomes measure time in the present study shows no significant difference.

We also evaluated the effect of distributed mass addition, which not only influenced linear acceleration and braking, but also rotational acceleration as it changes the system's moment of inertia. For the combination task and overall performance, which contains rotations, again to our surprise, no differences were observed. However, inertial sensor data showed reduced maximal rotational speed and rotational acceleration during the whole WMP-test when the extra mass was distributed [22]. With the current knowledge and results of both studies, there is still no clear answer to what extent added mass influences mobility performance while no differences were observed in performance time despite the fact that there were differences in kinematic outcomes. Synchronization of both systems, to get an overview of time and kinematic outcomes for all separate tasks, is recommended. It appears that changes up to 7.5% extra mass, even when distally added, does not lead to large decreases in performance time.

In several wheelchair sports, such as wheelchair rugby and wheelchair racing, the use of gloves is common and the benefits on performance are scientifically proven [11,12,13]. However, this study does not show a positive or a negative significant effect on mobility performance in wheelchair basketball. Moreover, no significant differences were observed in kinematic outcomes [22]. The time to get used to the use of gloves was, however, very short and the reported experience of the athletes was very diverse, from very comfortable to very disadvantageous. Players indicated that ball handling was more difficult due to reduced ball feeling. As such, the test results indicated that the benefits of glove use are highly linked to both wheelchair and ball handling. It is an option to place the extra grip only on a specific part of the hand so ball feeling isn’t influenced, a solution should be extra grip in the palm of the hand and not at the fingers. Another option to measure the effect of grip on propulsion is the use of a pressure sensor on the gloves to highlight the effect of grip on muscle fatigue in the hand used for propulsion. Further research with longer adaptation periods, other grip material and placing and use of sensor gloves is therefore recommended.

No interaction effects of classification were observed in this study for the different wheelchair configurations. It was expected that classification could cause different performance effects as a result of changes in the seat height and the mass. Low-class players have less trunk function and in a higher seat height position it was expected that they would not be able to compensate for the larger shoulder-handrim distance. Furthermore, due to the relationship between power output and classification [16], it was expected that the extra mass condition would have a more substantial effect on the low classification group. However, athletes with a low classification did not respond differently, in terms of performance time needed, to a wheelchair adjustment compared to athletes with a high classification. The results have to be interpreted with care, given the limited datasets (n=21). However, in practice, a dataset of eleven elite low-class players is in itself very exceptional.

Limitations and recommendations

This study examined the potential effects of ergonomic wheelchair settings in a standardized field-based test with experienced elite wheelchair basketball players of different classifications. The methodology used is in line with the recommendations of Mason et al. [4] to achieve the highest level of internal and external validity when studying the effect of wheelchair and athlete-wheelchair characteristics on mobility performance in wheelchair basketball. However, the choice for this method also imposes some limitations:

All experimental conditions were performed in a randomised order to eliminate learning or fatigue effects. The resting periods between the tests allowed full recovery of the players. However, the experimental setting was not optimal to acquire total adaptation to the new seat heights and the use of gloves. We do not expect that the short adaptation period has biased our conclusions. It is plausible that a longer adaptation period would have led to more obvious differences and it is recommended to use longer adaptation time in further research. In the current study, all tests took place at the same day, so the adaptation time was limited.

Another limitation (and strength) of this study is the choice to apply adjustments to the subjects' own wheelchairs, assuming that their own wheelchair was optimally tuned. Based on this assumption, the wheelchair seat height was individually raised and lowered with 7.5% and the mass was increased with 7.5%. These percentages were chosen to simulate realistically possible seat heights but have been chosen arbitrarily. The same applied to the choice of 7.5% extra mass and the distance of 0.3m for the distributed mass, it had to be realistic and operable for the athletes. However, all manipulation settings were experienced as very small by the players. With this approach the number of possibilities for wheelchair adjustments was however limited. A multi-adjustable wheelchair could be beneficial for research purposes. The multi-adjustable wheelchair must first be tuned to the settings of their own wheelchair, and from that point, manipulations should be made with the same methodology as used in this study. When the influence of various settings on performance is known, it is desirable to work towards a model in which the various settings can be combined.

Within the limitations, the results of this study can be used by athletes, coaches and wheelchair technicians to improve individual and team mobility performance. This study provides insight in the performance effects of key wheelchair configurations. The methodology can be used in a wheelchair fitting process to search for the optimal individual seat height to enhance mobility performance. Because the choice to only use time as outcome measure, the processing is usable for everyone and this gives the possibility to use it in daily practice of the professional. A lower seat height resulted in a faster performance time. At the same time, it is known that the highest wheelchair position (according to IWBF regulations) is a priority for athletes playing in the center position. A higher seat height position enables greater effectiveness in the number of rebounds, blocks of shots. Coaches and wheelchair athletes have to look thoroughly at the optimum between mobility performance and game performance.

The WMP test is easy to use and little material is required. This study focused only on seat height, mass and grip while several other adjustments can be made to the wheelchair, such as changes in camber and wheel size. Further research can focus on these adjustments to optimize mobility performance in wheelchair basketball.

Acknowledgement

We would like to thank Coen Vuijk of Motion Matters for his time, creativity and effort to modify all wheelchairs during this study.

Conflict of interest statement

None.

References

[1] Mason B, van der Woude LHV, Lenton JP, Goosey-Tolfrey V. The effect of wheel size on mobility performance in wheelchair athletes. *J Sports Med.* 2012; 33(10): 807-12.

[2] Veeger TT, De Witte AMH, Berger MAM, Van Der Slikke RMA, Veeger DH, Hoozemans MJ. Improving mobility performance in wheelchair basketball. *J Sport Rehabil.* 2017; 28(1):59-66.

[3] de Groot S, Vegter RJ, van der Woude LHV. Effect of wheelchair mass, tire type and tire pressure on physical strain and wheelchair propulsion technique. *Med Eng Phys.* 2017; 35(10): 1476-1482.

[4] Mason B, Van der Woude L, Goosey-Tolfrey V. The ergonomics of wheelchair configuration for optimal performance in the wheelchair court sports. *Sports Med.* 2013; 43(1): 23-38.

[5] de Groot S, Gervais P, Coppoolse J, Natho K, Bhambhani Y, Steadward R, Wheeler G. Evaluation of a new basketball wheelchair design. *Technol Disabil.* 2003; 15(1): 7-18.

[6] Majaess GG, Kirby RL, Ackroyd-Stolarz SA, Charlebois PB. Influence of seat position on the static and dynamic forward and rear stability of occupied wheelchairs. *Arch Phys Med Rehabil.* 1993; 74(9): 977-82.

[7] Masse LC, Lamontagne M, O'Riain MD. Biomechanical analysis of wheelchair propulsion for various seating positions. *J Rehabil Res Dev. 1992; 29*(3): 12-28.

[8] Vanlandewijck Y, Daly D, Spaepen A, Theisen D, Pétré L. Biomechanics in handrim wheelchair propulsion: Wheelchair-user interface adjustment for basketball. *Edu Physical Tr Sport.* 1999; 33(4): 50-53.

[9] Sagawa Y, Watelain E, Lepoutre F, Thevenon A. Effects of wheelchair mass on the physiologic responses, perception of exertion, and performance during various simulated daily tasks. *Arch Phys Med Rehabil.* 2010; 91(8): 1248-54.

[10] Cowan RE, Nash MS, Collinger JL, Koontz AM, Boninger ML. Impact of surface type, wheelchair weight, and axle position on wheelchair propulsion by novice older adults. *Arch Phys Med Rehabil.* 2009; 90(7): 1076-83.

[11] Lutgendorf M, Mason B, van der Woude L, Goosey-Tolfrey VL. Effect of glove type on wheelchair rugby sports performance. *Sports Technol.* 2009; 2(3-4): 121-28.

[12] Mason BS, van der Woude LH, Goosey-Tolfrey VL. Influence of glove type on mobility performance for wheelchair rugby players. *Am J Phys Rehabil.* 2009; 88(7): 559-70.

[13] Rice I, Dysterheft J, Bleakney A, Cooper R. The influence of glove type on simulated wheelchair racing propulsion: A pilot study. *Int J Sports Med.* 2016; 37(01): 30-35.

[14] de Witte AMH, Hoozemans MJM, Berger MAM, van der Slikke RMA, van der Woude LHV & Veeger D. Development, construct validity and test–retest reliability of a field-based wheelchair mobility performance test for wheelchair basketball. *J Sports Sci.* 2017; 36(1): 23-32.

[15] Gil SM, Yanci J, Otero M, Olasagasti J, Badiola A, Bidaurrazaga-Letona I, Iturricastillo A, Granados C. The functional classification and field test performance in wheelchair basketball players. J Hum Kin. 2015; 46(1): 219-30.

[16] International Wheelchair Basketball Federation. (2014). *Official wheelchair basketball rules 2014*. Incheon, Korea: International Wheelchair Basketball Federation.

[17] Vanlandewijck YC, Spaepen AJ, Lysens RJ. Wheelchair propulsion: Functional ability dependent factors in wheelchair basketball players. *Scand J Rehabil Med.* 1994; 26(1): 37-48.

[18] de Witte AMH, Sjaarda FS, Helleman J, Berger MAM, van der Woude LHV, Hoozemans MJM. Sensitivity to change of the field-based wheelchair mobility performance test in wheelchair basketball players. *J Rehabil Med.* 2017; 50(6): 556-62.

[19] Cohen J.Statistical power analysis. *Curr Dir Psychol Sci.* 1992 ; 1(3) : 98-01.

[20] van der Woude LHV, Veeger DJ, Rozendal RH, Sargeant TJ. Seat height in handrim wheelchair propulsion. *J Rehabil Res Dev.* 1989 ; 26(4) : 31-50.

[21] Samuelsson KA, Tropp H, Nylander E, Gerdle B. The effect of rear-wheel position on seating ergonomics and mobility efficiency in wheelchair users with spinal cord injuries: A pilot study. *J Rehabil Res Dev.* 2004; 41(1): 65-74.

[22] van der Slikke RMA, de Witte AMH, Berger MAM, Bregman D, Veeger DH. Wheelchair mobility performance enhancement by changing wheelchair properties;

what is the effect of grip, seat height and mass?. *Int J Sports physiol perform. 2018; 13*(8): 1050-58.

Table 1 Player characteristics (n=21)

	Mean (SD)	Classification group	
		Low (1-1.5) (n=11)	High (4-4.5) (n=10)
Age (y)	30.1 (11.4)	34.6 (9.5)	25.1 (11.7)
Mass (athlete+wheelchair) (kg)	84.1 (14.0)	82.1 (13.1)	86.6 (15.5)
Experience (y)	9.0 (9.3)	8.0 (6.8)	10.1 (11.7)

Table 2 Mean and standard deviation (SD) of performance times (s) for the 3-3-6 m sprint, combination task and the total performance time on the wheelchair mobility performance (WMP) test for the control condition (CC) and the manipulation conditions seat height higher (SHH) and seat height lower (SHL). The table is complemented with the mean differences (s) between the manipulation conditions and control condition and Cohen's *d* effect sizes.

	Classification	Control Condition (CC)		Seat Height Higher (SHH)		Differences in time (s) between CC-SHH	Effect Size	Seat Height Lower (SHL)		Differences in time (s) between CC-SHL	Effect Size	Differences in time (s) between SHH-SHL	Effect Size
		Mean (s)	SD	Mean (s)	SD			Mean (s)	SD				
3-3-6msprint	Total	7.35	0.75	7.32	0.84	0.03	0.03	7.16	0.99	0.19	0.21	0.16	0.17
	Low (n=10)	7.94	0.50	7.92	0.74	0.02	0.02	7.89	0.90	0.05	0.07	0.04	0.04
	High (n=10)	6.76	0.42	6.72	0.37	0.04	0.10	6.43	0.28	0.32	0.91	0.28	0.88
Combination	Total	14.70	1.38	14.86	1.32	-0.16	-0.12	14.60	1.40	0.10	0.07	0.26*	0.19
	Low	15.51	1.24	15.64	1.29	-0.13	-0.10	15.51	1.18	-0.01	0.00	0.12	0.11
	High	13.90	1.02	14.09	0.82	-0.19	-0.20	13.70	0.95	0.20	0.21	0.39	0.44
Total WMP	Total	88.90	9.25	88.96	8.88	-0.06	-0.01	87.22	9.45	1.69*	0.18	1.75*	0.19
test	Low	95.34	7.74	95.00	7.53	0.34	0.04	94.25	6.85	1.08	0.15	0.74	0.10
	High	82.47	5.38	82.93	5.39	-0.46	-0.09	80.18	5.60	2.29	0.42	2.75	0.50

*Significant difference (*p*<0.05)

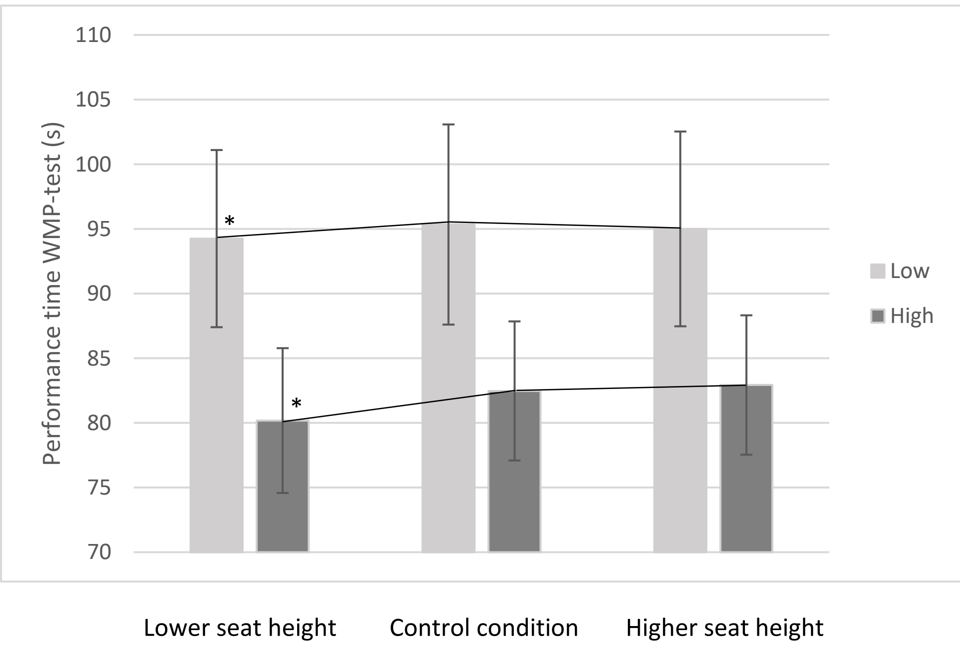

Figure 1. Performance times (s) of low and high class players on the Wheelchair Mobility Performance Test. *Significant difference (*p*<0.05) between lower seat height and control condition and between lower seat height and higher seat height position.

Table 3 Mean and standard deviation (SD) of performance times (s) for the 3-3-6 m sprint, combination task and the total performance time on the wheelchair mobility performance test for the control condition (CC) and the manipulation conditions mass central (MC) and mass distal (MD). The table is complemented with the mean differences (s) between the manipulation conditions and control condition and Cohen's *d* effect sizes.

	Classification	Control Condition (CC)		Mass Central (MC)		Differences in time (s) between CC-MC	Effect Size	Mass Distal (MD)		Differences in time (s) between CC-MD	Effect Size	Differences in time (s) between MC-MD	Effect Size
		Mean (s)	SD	Mean (s)	SD			Mean (s)	SD				
3-3-6msprint	Total	7.51	0.91	7.33	0.82	0.18	0.21	7.38	0.96	0.13	0.13	-0.05	-0,06
	Low(n=11)	8.11	0.75	7.89	0.64	0.22	0.31	8.06	0.75	0.05	0.07	-0.16	-0,24
	High (n=9)	6.78	0.43	6.64	0.33	0.14	0.37	6.56	0.36	0.22	0.62	0.08	0,23
Combination	Total	14.91	1.42	14.96	1.43	-0.05	-0.03	14.99	1.46	-0.08	-0.05	-0.03	-0,02
	Low	15.66	1.28	15.63	1.23	0.03	0.02	15.85	1.30	-0.19	-0.15	-0.22	-0,17
	High	14.01	1.03	14.15	1.27	-0.14	-0.13	13.94	0.84	0.07	0.08	0.21	0,20
Total WMP	Total	90.52	10.11	89.37	9.10	1.15	0.12	90.21	9.65	0.31	0.03	-0.84	-0,09
test	Low	96.73	8.69	94.71	8.31	2.03	0.24	96.40	8.03	0.33	0.04	-1.69	-0,21
	High	82.92	5.50	82.84	4.82	0.08	0.02	82.64	4.85	0.28	0.06	0.20	0,04

Table 4 Mean (±SD) performance times (s) for the 3-3-6 m sprint, combination task and the total performance time on the wheelchair mobility performance test for the control condition (CC) and the manipulation condition Gloves. The table is complemented with the mean differences (s) between the manipulation condition and control condition and Cohen's *d* effect sizes.

	Classification	Control Condition (CC)		Gloves (G)		Differences in time (s) between CC-G	Effect Size
		Mean (s)	SD	Mean (s)	SD		
3-3-6msprint	Total	7.45	0.93	7.38	0.86	0.07	0.08
	Low (n=10)	8.14	0.78	7.93	0.73	0.21	0.28
	High (n=10)	6.76	0.42	6.83	0.59	-0.07	-0.14
Combination	Total	14.80	1.48	14.80	1.58	-0.01	-0.01
	Low	15.69	1.34	15.83	1.55	-0.14	-0.09
	High	13.90	1.02	13.78	0.76	0.12	0.13
Total WMP	Total	89.65	10.37	88.74	10.09	0.91	0.09
test	Low	96.83	9.15	96.14	8.01	0.70	0.08
	High	82.47	5.38	81.34	5.38	1.13	0.21

Supplementary material I

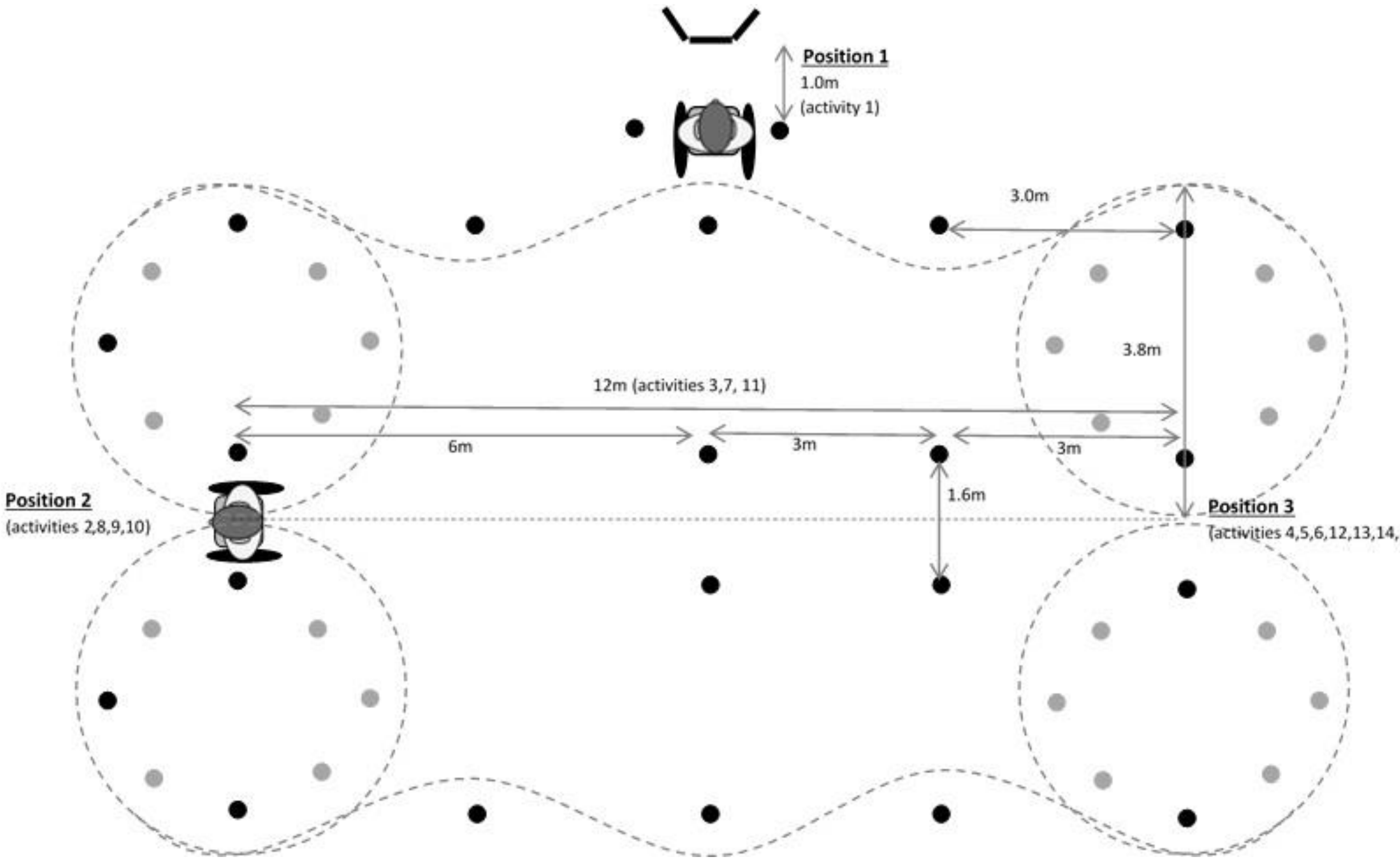

Figure 2 Set up of the gym for the wheelchair mobility performance test.

Wheelchair mobility performance test

The measurement outcome of the test is time (s). The time is recorded for each activity and the sum of the 15 separate activities is overall performance time. Time is recorded based on video-analysis and time started when the wheelchair started to move and stopped when the wheelchair was stationary. For each starting and stopping position the wheel axis should coincided with the pawns. All ball-handling moves performed during the test had to be in accordance with the IWBF rules for dribbling.

Activity 1: Tik-Tak box

Athlete starts on position 1, between two pawns 1 meter from the tik-tak box. The athlete has to perform 3 short movements. On the start signal, the athlete drives forward and makes a collision with the tik-tak box at the left side and drives backward back to the pawns. The athlete repeats the movement but makes a collision with the tik-tak box in the middle and the third time the athlete makes a collision with the right side of the tik-tak box. The performance time of test 1 is the time necessary to complete the three movements.

Activity 2: 180° Turn on the spot (left)

Athlete moves to the start position (position 2) while facing outwards (figure 2). Athlete starts from a stationary position with their wheel axis between the pawns). After the start signal the athlete makes a half turn on the spot (180 degrees) to the left.

Activity 3: 12 meter sprint
The athlete stays on the same place and is now facing inwards due to activity 2. The athlete starts from standstill and sprint as quick as possible 12 meter. The athlete has to stop the wheelchair on the 12 meter between the pawns.

Activity 4: 12 meter rotation (right)
The athlete is facing outwards now at position 3. The athlete starts from standstill and performs a curve of 12 meter to the left (radius 1.9m) as quickly as possible. The athlete has to stop the wheelchair on position 3.

Activity 5: 12 meter rotation (left)
The athlete performs the same activity as activity 4, however, this time to the left direction.

Activity 6: 180° Turn on the spot (right)
The athlete performs the same activity as activity 2, however, this time to the right direction. In other words, on position 3 the athlete changes from facing outwards to inwards.

Activity 7: 3-3-6m sprint
The athlete performs a 12 meter sprint forward with full stops at 3, 6 and 12 meters from position 3 back to position 2. Starting and stopping should be performed as quickly as possible. The stops are assessed visually by the trainer/coach. The rotation of the wheels must come to a complete standstill.

Activity 8: 3-3-6m rotation (left)
The athlete is back on position 2 and facing outwards. The athlete starts from standstill and performs a curve of 12 meter to the left as quickly as possible with stops at a quarter circle (3 meter), a half circle (6 meter) and then back to the starting position.

Activity 9: 3-3-6m rotation (right)
The athlete performs the same activity as activity 6, however, but this time to the right.

Activity 10: 90°- 90° turn on the spot with stop (left)
The athlete performs a half turn on the spot (180 degrees) to the left with a stop at 90°. On position 2 the athlete changes facing outwards to inwards.

Activity 11: 12 meter dribble
The athlete performs a 12 meter sprint while dribbling the ball and stops at 12 meter. The athlete moves from position 2 to 3.
Activity 12: 12 meter rotation dribble (right)
The athlete performs a curve of 12 meter to the right while dribbling the ball. The athlete has to stop at position 3.

Activity 13: 12 meter rotation dribble (left)
The athlete performs a curve of 12 meter to the left while dribbling the ball. The athlete has to stop at position 3 and is facing outwards.

Activity 14: 90°- 90° turn on the spot with stop (right)
The athlete performs the same activity as activity 10 on position 3 (facing outwards to inwards), however, this time to the right direction.

Activity 15: Combination
The athlete performs a 12 meter sprint (to position 2), a turn right or left, a 12 meter slalom and a turn back to position 3. All activities are performed in succession.