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Improving mobility performance in wheelchair basketball

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Abstract

OBJECTIVE: This study aimed to investigate which characteristics of athlete, wheelchair and athlete-wheelchair interface are the best predictors of wheelchair basketball mobility performance. **DESIGN**: Sixty experienced wheelchair basketball players performed a wheelchair mobility performance test to assess their mobility performance. To determine which variables were the best predictors of mobility performance, forward stepwise linear regression analyses were performed on a set of 33 characteristics, including ten athlete, nineteen wheelchair and four athlete-wheelchair interface characteristics. **RESULTS**: Eight of the characteristics turned out to be significant predictors of wheelchair basketball mobility performance. Classification, experience, maximal isometric force, wheel axis height and hand rim diameter - which both interchangeable with each other and wheel diameter - camber angle, and the vertical distance between shoulder and rear wheel axis – which was interchangeable with seat height - were positively associated with mobility performance. The vertical distance between the front seat and the footrest was negatively associated with mobility performance. **CONCLUSION**: With this insight, coaches and biomechanical specialists are provided with statistical findings to determine which characteristics they could focus on best to improve mobility performance. Six out of eight predictors are modifiable and can be optimized to improve mobility performance. These adjustments could be carried out both in training (maximal isometric force) and in wheelchair configurations (e.g. camber angle).

Keywords: wheelchair configuration – athletic performance – Paralympic – wheelchair-athlete interface

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Introduction

Wheelchair basketball is one of the most popular Paralympic sports with professional competitions at a high level. At these high levels, coaches are always trying to improve the overall game performance of their team, for instance by adjusting tactics and improving performance of individual players. For the latter, both ball skills and wheelchair handling skills - or "mobility performance" - are essential. Mobility performance in itself is dependent on both physical performance and capacity, and quality of wheelchair handling. Thus, mobility performance is not only dependent on physical athlete characteristics like strength, power and aerobic capacity, but also on the interface between athlete and wheelchair. In mobility performance, key determinants are the ability to accelerate, sprint, brake or rotate [1-3].

De Witte et al. (2017)[4] recently developed and validated a wheelchair mobility performance test (WMP test) for the assessment of mobility performance in wheelchair basketball players. With this test it is possible to validly and reliably measure mobility performance in a controlled setting. The WMP test consists of a set of 15 mobility exercises such as a 12-meter sprint and a rotation, with and without handling a ball. It provides the opportunity for coaches to actually quantify the mobility performance of the players and to monitor changes due to, for instance, their training schemes. Mobility and game performance of an athlete can be improved in different ways, for example, by improvement of physical performance, which will influence wheelchair handling, but also by optimization of the wheelchair configuration [5-8]. The characteristics that potentially can be modified to enhance mobility performance can be divided in three categories: athlete characteristics, wheelchair characteristics and characteristics describing the interface between athlete and wheelchair [1]. Athlete characteristics are, for example, body dimensions, strength, impairment, gender or age. Wheelchair characteristics consist mainly of the wheelchair configurations, for example the seat height or the length of the wheelbase. Characteristics of the interface between the athlete

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and the wheelchair include, for example, the athlete's sitting position or the position of the shoulder relative to the hand rims. Within all three categories characteristics are known that influence mobility performance and, if modifiable, can be adjusted to improve mobility performance [5,6,9-11].

However, most studies related to mobility performance have focused on the effect of just one or a couple of athlete, wheelchair or athlete-wheelchair characteristics [5,6,9-11]. As a consequence, it is not really known which of those characteristics have the most impact on performance. Besides, these studies mainly investigated these relationships in healthy participants or in daily life wheelchairs, this makes the translation to wheelchair basketball mobility performance difficult. For coaches and biomechanical specialists, to be able to improve mobility performance, it would be helpful to know which characteristics are the most beneficial or limiting regarding athlete, wheelchair or athlete-wheelchair interface. With the developed WMP test and additional measurements of wheelchair, athlete and athlete-wheelchair interface characteristics, it is now feasible to collect data that allow such in-depth analyses. Therefore, the goal of the present study is to investigate which athlete, wheelchair and athlete-wheelchair interface characteristics are the best predictors of mobility performance in wheelchair basketball.

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Methods

Subjects

Sixty wheelchair basketball players participated in this study with 44 men and 16 women. The age of the participants ranged from 12 to 50 years with an average of 25.0 (SD 9.4) years. All participants were active in the Dutch first division or at international level. Participation was not restricted to certain classification levels. Twenty athletes had a classification equal to or below 2.5 (low classification group) and forty athletes had a

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classification equal to or higher than 3.0 (high classification group), see also table 1. Before testing, the participants and/or their parents signed an informed consent form. The study was approved by the Ethical Committee of the Faculty of Behavioral & Movements Sciences, Vrije Universiteit Amsterdam, the Netherlands (2015-26).

Design

Before the measurements started, participants were verbally introduced to the procedures and the wheelchair mobility performance test (WMP test) was demonstrated with a video. The participants were asked to refrain from smoking, drinking caffeine or alcohol for at least 2 hours prior to testing. The handedness, the cause of the disability, the competition in which they played and the years of experience in playing wheelchair basketball were noted. After that, six reflective markers were placed on the following anatomical landmarks: on the dorsal side of the distal radioulnar joint, on the lateral epicondyle of the humerus, on the radial head of the elbow, on the acromial angle of the right shoulder and just lateral to the coracoid process on both shoulders (Figure 1). In order to measure wheelchair settings and anthropometrics, pictures were taken of both frontal and sagittal views of the athlete in their own wheelchair.

The athletes performed a self-selected warm-up before starting the test using their regular game warm-up. The tests were performed in their own sports wheelchair and with their usual wheelchair configurations. The tires of the wheelchair were inflated to minimal 7 bar dependent on tire type. The participants had to perform the WMP test, which consists of 15 tasks [4]. To be able to study the predictors for each important key determinant of mobility performance individually (i.e. sprint, brake and rotation), not only the total time needed for the WMP test, but also the performance of four tasks separately were included in the analyses of this study. These four tasks were the 12-meter sprint, the 12-meter sprint with stops, the rotation (clockwise / counter clockwise) and the rotation with stops (clockwise / counter clockwise)

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(Figure 2). The WMP test includes standardised rests between tests to avoid fatigue. With the 12-meter sprint, the athlete started from a standstill and had to sprint as fast as possible for 12 meters at the end of which the athlete had to arrive at a standstill again (Figure 2A). For the 12-meter sprint with stops, the athlete had to sprint for 12 meter again, but he or she had to come at a full stop at 3, 6 and 12 meter (Figure 2B). The rotation task consisted of riding a curve of 12 meter with a radius of 1.9 meter, beginning from a standstill and ending at the starting position in a standstill, performed in both clockwise and counter clockwise directions (Figure 2C). For the rotation task with stops, the athlete had to ride the curve but had to stop at a quarter of the curve (3 meters) and halfway (6 meters), before coming to a standstill at the starting position (Figure 2D). For a detailed description of the complete WMP test, the study from De Witte et al. (2017) can be consulted. Also, in the supplemental material I of this study a schematic representation of the WMP test can be found.

Data acquisition

To measure wheelchair configurations and anthropometrics, two cameras (CASIO EX-FH100) were used to produce a photo in the frontal plane of the athlete in the wheelchair (Figure 1A) and in the sagittal plane, one with the athlete keeping his or her hands on the top of the hand rim (top dead center: TDC) (Figure 1B) and one with keeping his or her hands on their lap (Figure 1C). All lengths and angles of the athlete, wheelchair and the interface between athlete and wheelchair were determined using Kinovea (Kinovea, 0.8.15, France), as described in Table 2 and shown in Figure 1. The validity and reliability of Kinovea has been tested in vertical jumps and turned out to be a very reliable and valid way to measure jump height [12]. The markers were used as reference points. Two reference frames, both with a height of 0.25m and a width of 0.25m, were visible in the pictures and were used to calibrate the pictures. In the frontal plane, one frame was placed in line with the axis of the rear wheels of the wheelchair and one frame was placed in line with the axis of the front wheels. In the sagittal plane, one

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reference frame was placed in line with the axis of the closest rear wheel and one frame was placed in line with the front wheel nearest to the camera. For the maximal isometric force the Mecmesin Advanced Force Gauge (Mecmesin Ltd, Broadbridge Heath, West Sussex, UK), with an accuracy of ±0.1% of full-scale values, was used. The participants applied maximal force for five seconds with both arms, the mean over five trials was calculated.

All measurements added up to a total of 33 variables and were divided in three categories: ten variables describing athlete characteristics, nineteen variables concerning wheelchair characteristics and four variables describing the interface between athlete and wheelchair characteristics (Table 1). As outcome variables, the time the participants needed for each task was determined based on frame counts using video analyses in Kinovea and was recorded in seconds. The time needed for the two directions in the rotation tasks were summed. Overall performance was determined as the sum of the time needed for each of the 15 tasks of the WMP test. Thus, in total five outcome variables were taken into account: 12m sprint time, 12m sprint with stops time, rotation time, rotation with stops time and total time on the WMP test.

Statistical analysis

Descriptive statistics were used to characterize the study population. Mean and standard deviation (SD) were used for normally distributed variables, otherwise median and interquartile range (IQR) were calculated. The normality of distributions of the variables was explored visually using histograms, q-q plots and box-plots and using the Kolmogorov-Smirnov test.

To determine which variables among the athlete, wheelchair and athlete-wheelchair interface characteristics are the best predictors of mobility performance in the WMP test, forward stepwise linear regression analyses were performed. All variables had sufficient collinearity tolerance (>0.10) and therefore were included in the regression analysis. A significance level of $p<0.05$ was used to include the characteristics as predictor variables in the

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regression models. Regression analyses were performed for each of the five outcome variables (12m sprint time, 12m sprint with stops time, rotation time, rotation with stops time, total time on the WMP test) separately. For each outcome variable a regression analyses was performed with all athlete, wheelchair and interface characteristics included. Retrospectively, the statistical power (1-β error probability) was analysed using effect size f^2, predictor number of the actual models, α error probability of 0.05 and sample size with G*Power 3.1 software [13]. The rest of the statistical analyses were performed using SPSS 23.0 (IBM Corporation, Armonk, New York, USA).

Results

Descriptives

In Table 1 all characteristics and outcome variables are listed and split according to the earlier described categories. The number of included participants for each variable is shown – which was different among variables due to missing values related to disability of participants or visibility on the pictures – together with the minimum and maximum value, the mean and the standard deviation for normally distributed variables and median and IQR for not normally distributed variables. The time (s) the participants needed for the different tasks is shown in the last part of the Table.

Best predictors of performance

Table 3 shows the regression models resulting from the forward stepwise procedure for each of the five outcome variables with all the predictor variables as input. In total, eight out of the 33 characteristics appeared in the regression models. Only four of those eight characteristics were included as predictors for multiple outcome variables, the others for just one task. The vertical distance between shoulder and rear wheel axis (I2) and the vertical distance between front seat height and footrest (W5) were included in three and four models,

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respectively, where a smaller vertical distance between front seat height and footrest and a larger vertical distance between shoulder and rear wheel axis was associated with a better performance. However, the vertical distance between shoulder and rear wheel axis was not a significant predictor for the 12-meter sprint with and without stops. Classification and average maximal isometric force were included in two and three models, respectively, both variables were associated with a better performance on the 12-meter sprint, 12-meter sprint with stops and rotation. Wheel axis height (W7), hand rim diameter, experience and camber angle (W6) appeared in only one of the models. The amount of variance explained by the models was between 38% and 60%. The statistical power (1-β error probability) of all models was >0.95, which is considered to be acceptable [14].

Discussion

The aim of this study was to investigate which athlete, wheelchair, and athlete-wheelchair interface characteristics are the best predictors of mobility performance in wheelchair basketball. With this insight, coaches and biomechanical specialists are provided with statistical findings to determine characteristics to improve mobility performance. When all characteristics are evaluated together, eight different variables - three athlete, four wheelchair and one athlete-wheelchair interface characteristic - were included as significant predictors for the different performance tasks of the WMP test. Classification, experience, maximal isometric force, wheel axis height (W7), hand rim diameter, camber angle (W6), and the vertical distance between shoulder and rear wheel axis (I2) are positively associated with mobility performance, while the vertical distance between the front seat height and the footrest (W5) is negatively associated with mobility performance. However, not all of these variables are modifiable and can thus be used to improve mobility performance. Without those non-modifiable variables (i.e. classification and experience), six modifiable variables remain.

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The inclusion of classification in both sprint models is in line with the findings of Cavedon et al. (2015)[8] and Gil et al. (2015)[15], who found significant correlations between sprinting and classification. Furthermore, Cavedon et al. (2015)[8] found, also in line with this study, significant correlations between experience and sprinting, while Gil et al. (2015)[15] did not. These results indicate that, as expected, classification and experience should be taken into account by coaches and trainers. However, these variables are non-modifiable and may, therefore, not be the best variables to focus on.

The modifiable athlete variable maximal isometric force was included as a predictor in the 12-meter sprint, the rotation and the total test model. A higher force was associated with a better performance in the models. This is in line with the findings of Granados et al. (2015)[7], who reported that forces assessed using multiple strength tests were significantly higher in athletes of a First-Division team compared to athletes of a Third-Division team. Wheelchair athletes that are able to produce higher forces on the hand rim are likely to reach higher accelerations and thus better performances on both tasks. However, it is not suggested that coaches and trainers should focus purely on the maximal isometric force itself. The actual (maximal) forces that are exerted during handling the wheelchair while attempting the best performance on the WMP test tasks would be preferable information. Unfortunately, isometric force was measured instead. At the moment it is possible to measure the exerted hand force during riding itself with, for example, a SmartWheel (Three Rivers Holding, Mesa, AZ, USA). However, the relatively large mass of the SmartWheel itself will influence the performance and, therefore, the data gathered would not be useful in this situation. Still, increasing the force that an athlete can produce might improve their performance. Furthermore, this isometric force is measured while sitting in the chair and the configuration of the chair can influence the amount of force that can be produced.

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Two of the modifiable wheelchair variables that were predictors of mobility performance were hand rim diameter and wheel axis height (W7): an increase in diameter or height was associated with a better performance on the 12-meter sprint with and without stops, respectively. This is in line with Guo et al. (2006)[16] who reported that the work that was done during a full propulsion cycle was significantly higher when a larger hand rim was used, although this result was found in able bodied participants. It has also been found that smaller wheels resulted in a greater rolling resistance and, therefore, an increased physiological demand and that the performance on a 20-meter sprint was better with a 65 cm wheel compared to a 59 cm wheel [17,9]. Although wheel diameter itself was not included as predictor in the models, wheel axis height and hand rim diameter were highly correlated with wheel diameter (r=.76 and r=.89, respectively; see also the correlations between predictor variables in the supplemental material II). So it might be the case that for the WMP test not only a larger hand rim but also larger wheel diameters and a higher wheel axis heights are beneficial. However, it should be noted that larger hand rim sizes result in a higher cardiorespiratory stress and lower mechanical efficiency during a 15-minute exercise test [18]. So when the cardiorespiratory system becomes the limiting factor, which might be the case in a match situation, a larger hand rim might not result in a better performance.

Another interesting modifiable wheelchair variable that appeared in one of the models was camber angle (W6). An increase of one single degree camber angle was associated with an as much as 1.67 s faster time on the total WMP test. However, Mason et al. (2012)[10] reported that a camber angle of 24° has clear negative effects on both linear and rotational movements. They indicate that 18° looks like the optimal angle, but 20° would still be fine. Since the mean camber angle in this study was nearly 18° (range 15-21°), the possibility to increase the camber angle with beneficial results might be limited.

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In several studies it is found that seat height – defined as the distance between the floor and the top of the head or defined in terms of elbow angle - affects wheelchair performance in healthy non-wheelchair users, spinal cord patients and wheelchair basketball players [8,11,19]. The seat height affects physiological parameters, propulsion technique, mechanical efficiency and basketball specific tasks, with optimal seat heights when the elbow angle was 100°-130° and with lower seat height having a clear negative effect on the performance. It should be noted that two of these studies tested the participants in daily use wheelchairs or wheelchair ergometers. Although, in the current study, rear seat height and elbow angle were not included in the regression models themselves (Table 3), other variables which are highly correlated were included (see also the correlations between predictor variables in the supplemental material II). Vertical distance between shoulder and rear wheel axis (I2) and vertical distance between front seat height and footrest (W5) were included in four and three models, respectively, and are highly correlated with elbow angle (I4:I2: r=.68) and/or rear seat height (W9:I2: r=.84; W9:W5: r=.54). But also the wheel axis height (W7) was highly correlated with elbow angle (r=.66) and hand rim diameter with both rear seat height and elbow angle (r=.55 and r=.69, respectively), and were both included in the models. A larger vertical distance between the shoulder and the rear axis (I2) was associated with a better performance. However, according to van der Woude et al. (1989, 2009)[11,19] this association might not be linear, but more curvilinear. Surprisingly, a larger vertical distance between front seat height and footrest (W5) was associated with a decreased mobility performance. This would mean that performance would be better if vertical distance between the shoulder and rear wheel axis would be larger and the vertical distance between the front seat height and footrest would be smaller. This can be accomplished by increasing the rear seat height and decreasing the front seat height and thereby increase the hip angle. Often players with a low classification use a so-called "bucket" seat, where the front of the seat is higher up than the back of the seat and thus the hip angle smaller. Mason et al.

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(2010)[2] reported that highly impaired players found that the "bucket" seat was useful for creating more stability in the wheelchair. Although less impaired players also felt more stable, they also found that it hindered their performance due to the impaired ability to use their trunk. So minimizing the "bucket" seat as much as possible for the athlete might have a positive effect on their mobility performance. Moreover, when you decrease this distance, the hip-angle increases and the feet go backwards, this has also been found to be beneficial for the manoeuvrability and thus for the performance of the athlete [2]. It should be noted that classification is positively correlated with both rear seat height (r=.50) and elbow angle (r=.58) and that athletes with a lower classification often have a lower rear seat height. Increasing the seat height in athletes with a lower classification is only possible if athletes are well strapped to the wheelchair, however, the stability will be impaired due to the increase in seat height. So the benefit of increasing rear seat height might be limited for some athletes.

This study is the first to evaluate such an amount of variables together in wheelchair athletes and provides a comprehensive overview of wheelchair-athlete characteristics and their associations with performance. It provides a good insight in which variables might be most important for mobility performance. Coaches, trainers and mechanics can use this information to effectively optimize mobility performance in wheelchair basketball players. The inter-researcher reliability for the data analysis was not an issue, since the analysis has been executed by only one researcher. The validity and reliability of Kinovea has been tested in vertical jumps and turned out to be a very reliable and valid way to measure both flight time and jump height [12]. This suggests that it is a sufficient way for the measurements of the lengths in this study. The WMP test has found to be a valid test to measure the mobility performance of wheelchair basketball athletes [4]. Using a forward stepwise approach the best predictors of performance were identified based on statistical associations. Considering that only a sample of wheelchair basketball players is studied, some of the findings may be caused by chance, resulting in

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statistical associations and not because of actual relationships in the population, causing these findings to be difficult to explain. However, the sample is representable for the population of professional wheelchair basketball players, and it should be investigated if the same associations will be found in other populations, such as amateur wheelchair basketball players. The forward stepwise procedure was chosen to arrive at a set of variables that best predict performance. Due to collinearity of predictors some of the variables in the final regression models might be interchangeable with other (comparable) variables as indicated above and this should be taken into account when interpreting and explaining the final regression models (see also the correlations between predictor variables in the supplemental material II). Current literature is insufficient to deal with these interactions between different characteristic, so this study only addressed the statistical associations between characteristics and mobility performance. It was decided not to include certain variables beforehand. For instance, classification or the athlete's power could have been forced into the regression model before running the stepwise procedure. This would have resulted in the best predictors of performance independent of classification as confounding variable. This is, however, a different research question but a logical next step after the explorative approach of the present study although these kinds of questions are better studied in experimental settings. The results of the present study can guide the development of questions for follow-up (experimental) studies to arrive optimal (mobility) performance in wheelchair basketball and other wheelchair sports.

Conclusion

The findings of the present study provide coaches and biomechanical specialists with statistical findings to determine on which characteristics they can focus best to improve mobility performance such as wheel axis height and maximal isometric forces. It gives an indication of how certain variables can be modified to improve mobility performance. Not only can these findings help to improve mobility performance, but also to prevent injuries. When

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the wheelchair can be modified to enhance mobility performance, the load on the musculoskeletal system needed to achieve the same performance may be less, reducing the risk of injury. However, for all variables mentioned in this discussion, it should be determined what their optimal values are to improve mobility performance without increasing the risk of injuries.

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Conflict of interest:

The authors declare that there are no conflicts of interest.

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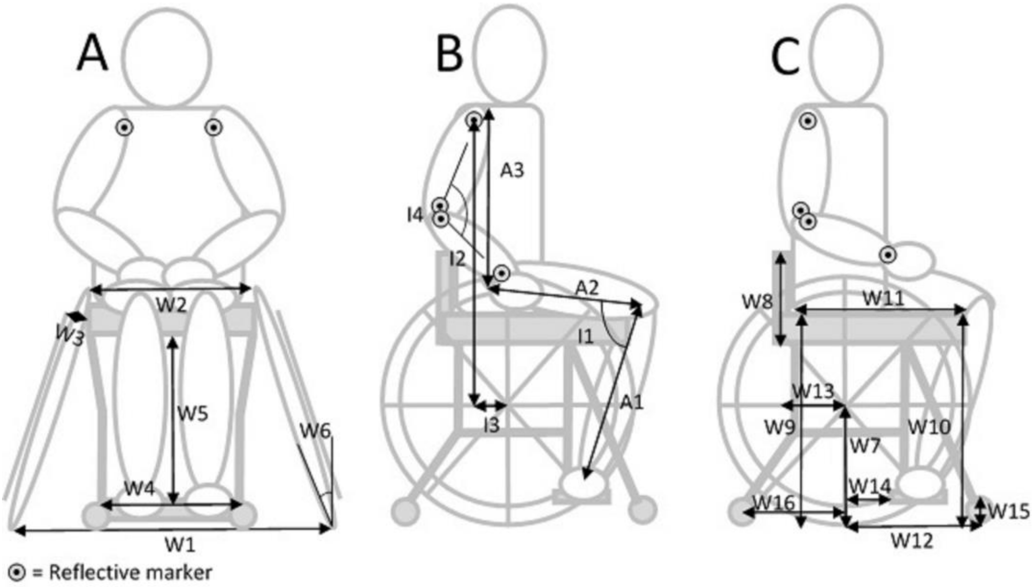

Figure 1. Example of the characteristics measured in Kinovea. The exact explanation of the codes is listed in table 2.

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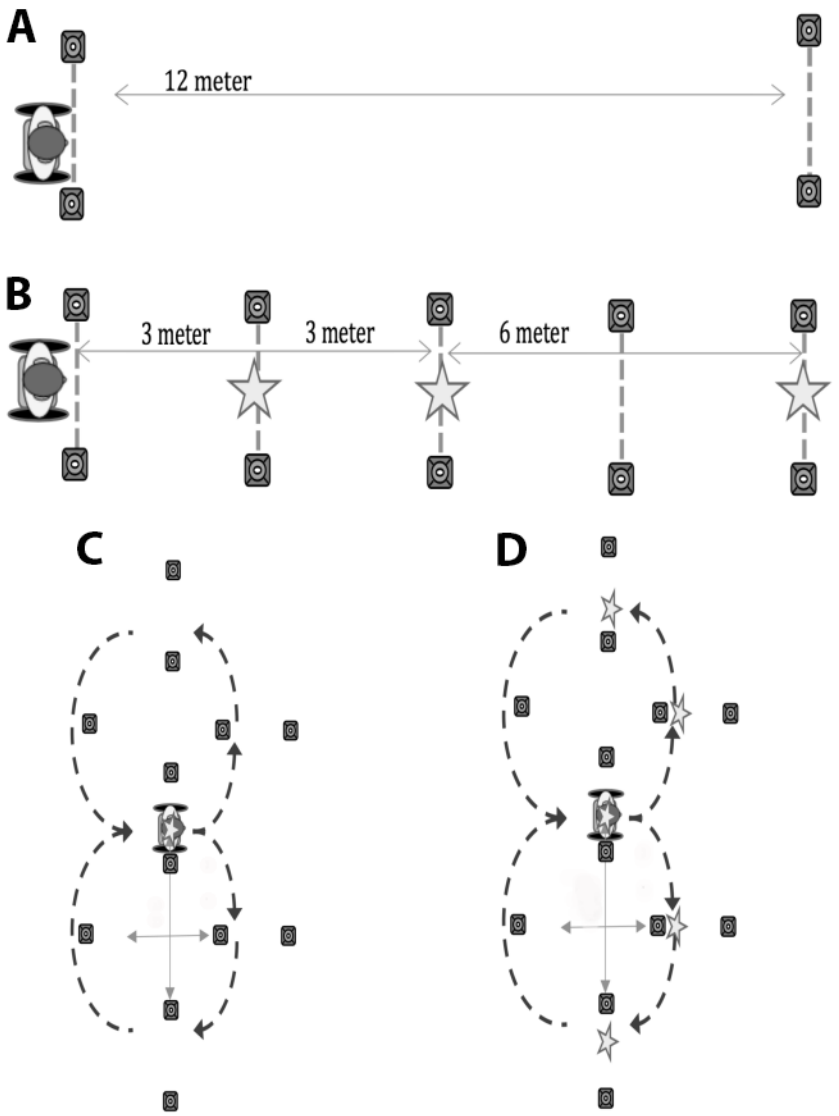

Figure 2. Wheelchair Mobility Performance test tasks: A) 12-meter sprint; B) 12-meter sprint with stops (stars); C) rotation clockwise/counterclockwise; D) rotation clockwise/ counterclockwise with stops

Table 1. Descriptive statistics of all variables with mean and standard deviation (SD) for normally distributed variables and median and interquartile range (IQR) for not normally distributed (*) variables. N=Newton; kg=kilogram, cm=centimetres; °=degrees; sec=seconds.

Code in figure 1	Variable (unit)	n	Minimum	Maximum	Mean/Median*	SD/IQR*
	Athlete characteristics					
-	Age (years)	56	12	50	23*	13.8*
-	Experience (years)	60	0	27	7*	7.8*
-	Classification (low/high)	Low (≤2.5): 20				
-		High (≥3.0): 40				
-	Weight athlete + wheelchair (kg)	49	45	123	81.2	15.7
-	Maximal isometric force (N)	51	152	817	496.3	128.8
-	Fore arm length (cm)	57	19	31	25.8	3.0
-	Upper arm length (cm)	58	24	34	30.1	2.4
A1	Lower leg length (cm)	54	30	45	38.0	3.7
A2	Upper leg length (cm)	56	28	47	38.3	4.8
A3	Trunk length (cm)	57	33	56	46.1	5.4
	Wheelchair characteristics					
-	Wheel diameter (cm)	49	56	70	63.6	2.8
-	Hand rim diameter (cm)	59	52	62	56.8	2.5
-	Ratio hand rim/wheel	48	0.85	0.93	0.894	0.019
W1	Width wheelbase (cm)	58	70	92	80.9	4.8
W2	Distance TDC (cm)	57	34	50	42.5	3.3
W3	Distance hand rim and tire (cm)	57	2	4	3.1	0.6
W4	Distance between front wheels (cm)	57	26	44	30.9*	5.1*
W5	Vertical distance front seat height and footrest (cm)	55	31	53	43.0	4.2
W6	Camber angle (°)	57	15	21	17.8	1.3
W7	Wheel axis height (cm)	58	28	36	31.3	1.7
W8	Height back support (cm)	57	11	28	18.0	4.1
W9	Rear seat height (cm)	59	45	70	58.2	6.1
W10	Front seat height (cm)	58	48	72	58.2	4.5
W11	Seat depth (cm)	58	32	54	41.9	4.1
W12	Length wheelbase (cm)	58	31	48	39.8	3.8
W13	Horizontal distance rear axis and back support (cm)	58	12	25	19.0	3.2
W14	Horizontal distance footrest and rear axis (cm)	56	17	48	35.9	7.0
W15	Front wheel diameter (cm)	58	5	9	6.5*	1.4*

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Code in figure 1	Variable (unit)	n	Minimum	Maximum	Mean/Median*	SD/IQR*
	Athlete characteristics					
W16	Horizontal distance anti-tip wheel and rear axis (cm)	57	17	27	23.9*	3.1*
	Athlete/Wheelchair interface					
I1	Knee angle (°)	54	50	114	80.3	14.2
I2	Vertical distance shoulder and rear wheel axis (cm)	57	52	91	73.1	8.8
I3	Horizontal distance shoulder and rear wheel axis (cm)	57	1	22	10.5	4.6
I4	Elbow angle (°)	57	77	168	122.4	21.6
	Outcome variables					
-	12-meter sprint (sec)	56	4.3	6.0	4.97	0.38
-	12-meter sprint + stops (sec)	57	5.3	8.6	6.94	0.72
-	Rotation (sec)	57	10.3	15.1	11.98*	1.11*
-	Rotation + stops (sec)	57	11.6	19.5	15.24	1.67
-	Total (sec)	56	65.6	96.3	79.12	7.30

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Table 2. Overview of variables with the description of the measurement and the corresponding code for Figure 1.

Code in figure 1	Variable	Description
	Frontal view	
W1	Width wheelbase	Distance between the ground contact points of the rear wheels
W2	Distance TDC	Distance between the tops of the rear wheels
W3	Distance hand rim and tire	Distance between the midpoints of hand rim and the tire
W4	Distance between front wheels	Distance between the front wheels where they are attached to the frame
W5	Vertical distance front seat height and footrest	Distance between the seat and the top of the footrest
W6	Camber angle	The angle between the vertical and the rear wheel (=90°-W6)
	Sagittal view – hands on the lap	
-	Wheel diameter	Diameter of the rear wheel, measured manually
-	Hand rim diameter	Diameter of the hand rim attached to the rear wheel, measured manually
-	Ratio hand rim/wheel	Ratio between hand rim diameter and rear wheel diameter
W7	Wheel axis height	Height of the rear axis measured from axis to ground contact point
W8	Height back support	Height of the back support measured from the seat
W9	Rear seat height	Vertical distance between ground contact point and the rear end of the seat
W10	Front seat height	Vertical distance between ground contact point and the front end of the seat
W11	Seat depth	Horizontal distance between the front and rear end of the seat
W12	Length wheelbase	Distance between the ground contact point of the rear wheel and the ground contact point of the front wheel
W13	Horizontal distance rear axis and back support	Horizontal distance between the rear axis and the midpoint of the back support
W14	Horizontal distance footrest and rear axis	Horizontal distance between the rear axis and the frontal end of the footrest
W15	Front wheel diameter	Diameter of the front wheel
W16	Horizontal distance anti-tip wheel and rear axis	Horizontal distance between the rear axis and the anti-tip wheel
	Sagittal view – hands on TDC	
-	Fore arm length (-)	Length of the fore arm, measured manually
-	Upper arm length (-)	Length of the upper arm, measured manually
A1	Lower leg length	Length of the lower leg from knee to ankle
A2	Upper leg length	Length of the upper leg from hip to knee
I1	Knee angle	Angle of the knee joint
I2	Vertical distance shoulder and rear wheel axis	Vertical distance between the shoulder acromial angle marker and the rear axis
I3	Horizontal distance shoulder and rear wheel axis	Horizontal distance between the shoulder acromial angle marker and the rear axis

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Code in figure 1	**Variable**	**Description**
A3	Trunk length	Distance between acromial angle marker and the hip joint
I4	Elbow angle	Angle of the elbow joint with hand on TDC

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Table 3. Regression models variables together and the five different tasks as outcome variables. B= unstandardized regression coefficient; β= standardized regression coefficient; R^2= the coefficient of determination.

All together

Outcome variable	**Predictor (code in figure 1)**	**B**	**β**	***p*-value**	**R²**
12-meter sprint	(Constant)	8.619		<0.001	
	Wheel axis height (W7)	-0.094	-0.322	0.027	
	Classification low/high (-)	-0.282	-0.376	0.004	
	Maximal isometric force (-)	-0.001	-0.411	0.007	0.51
12-meter sprint + stops	(Constant)	15.032		<0.001	
	Hand rim diameter (-)	-0.173	-0.568	<0.001	
	Vertical distance front seat height and footrest (W5)	0.059	0.363	0.004	
	Classification low/high (-)	-0.617	-0.438	0.001	
	Experience (-)	-0.046	-0.319	0.010	0.60
Rotation	(Constant)	12.784		<0.001	
	Max. isometric force (-)	-0.003	-0.372	0.005	
	Vertical distance front seat height and footrest (W5)	0.125	0.507	<0.001	
	Vertical distance shoulder and rear wheel axis (I2)	-0.062	-0.513	0.001	0.54
Rotation + stops	(Constant)	18.701		<0.001	
	Vertical distance shoulder and rear wheel axis (I2)	-0.129	-0.677	<0.001	
	Vertical distance front seat height and footrest (W5)	0.144	0.368	0.014	0.38
Total	(Constant)	116.215		<0.001	
	Vertical distance shoulder and rear wheel axis (I2)	-0.551	-0.660	<0.001	
	Vertical distance front seat height and footrest (W5)	1.001	0.583	<0.001	
	Max. isometric force (-)	-0.019	-0.347	0.006	
	Camber angle (W6)	-1.671	-0.284	0.026	0.60

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