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Drag and sprint performance of wheelchair basketball players

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Abstract—The purpose of this study was to measure the wheelchair drag and maximal sprint performance abilities of wheelchair basketball players and to make comparisons between male and female players. A group of nine male and eight female wheelchair basketball players attending a national training camp consented to serve as subjects. Each subject completed six coast-down trials at speeds from a walking pace (1 to 1.5 m/s) to maximal for determining wheelchair drag and then performed four maximal sprint trials from a stationary start over the length (35 m) of the gymnasium floor. A portable computer that recorded the time to the nearest 0.001 second of each half revolution of a rear wheel was attached to the wheelchair of each subject. The drag force during the coast-down trials and the power output during the sprint trials were determined from the recorded data. Differences between the genders in a number of subject and trial variables were evaluated by *t*-tests using the 0.05 level of significance. There were no significant differences between the means of the male and female groups in age (27 vs. 28 yrs), wheelchair mass (12.0 vs. 11.61 kg), or regression predicted drag forces at speeds of 2 m/s (5.3 vs. 5.5 N) and 5 m/s (16.7 vs. 13.5 N). The male subjects were significantly heavier (78.3 vs. 59.1 kg) and had a higher tire pressure (123 vs. 94 psi). In the sprint trial results, the males exhibited a significantly higher maximal speed (4.75 vs. 4.08 m/s), higher peak acceleration (1.32 vs. 1.03 m/s/s), and a higher peak power output (530 vs. 264 w).

Key words: *ergometry, exertion, paraplegia, sport wheelchair, wheelchairs.*

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INTRODUCTION

In the evaluation of a manually propelled wheelchair for use as a means of personal mobility, two of the key factors are the energy demands of propelling the wheelchair and the energy or power input capacity of the user. The measurement of wheelchair dynamics has generally been confined to laboratory situations with the use of devices that simulate actual wheelchair locomotion. Studies of caster drag and flutter (1), rolling resistance (2), and air drag (3) have contributed to our understanding of the various components that determine the overall energy demands of wheelchair propulsion, while determinations of the oxygen uptake (4,5), anaerobic power (4), and instantaneous power outputs (6) of wheelchair users during simulated wheelchair locomotion help indicate the limits of manual wheelchairs as human mobility devices.

The purpose of this study was to make a further contribution to this body of knowledge by reporting the overall drag and power requirements of propelling a sport model wheelchair in a group of basketball players and noting their maximal power output during a sprint effort under actual wheelchair use conditions. These additional insights into the demands of wheelchair propulsion and the capacities of wheelchair users should aid our understanding of some of the limits to wheelchair locomotion.

METHODS

Informed consent was obtained from nine male and eight female wheelchair basketball players, who

were invited participants at the 1991 Canadian national training and team selection camp, to serve as subjects. All subjects had played competitive basketball at the national level for at least 2 years, and six males and six females had competed internationally. The average number of years of competition was between 7 and 8 years for the male and female groups. The mass of the subject, wheelchair, and of a rear wheel were determined to the nearest 0.05 kg using a calibrated scale. The subject's age and basketball classification level, and the wheelchair's normal tire pressure were ascertained by questioning the subject. The subject's own wheelchair was instrumented with a portable computer, a magnetic reed switch, and two magnets placed 180° apart on one of the rear wheels in order to sense and record the time to the nearest 0.001 second of each half revolution of the rear wheel. Each subject then completed six coast-down trials on a hardwood gymnasium floor with the coast-down speed varied from slow (1.5 m/s) to maximal (4.5 m/s) over the six trials. The linear correlations between speed and time in the coast-down trials averaged 0.91 (SD = 0.09), and the mean coefficient of variation in estimating the coast-down deceleration was 4.05 percent (SD = 2.07). Wheelchair drag force and power were determined for each of the six coast-down speeds, and a nonlinear regression equation relating drag force and power versus speed was established for each subject. The drag forces at nominal speeds of 2 m/s and 5 m/s were calculated from the individual regression equations for further analysis. The speeds of 2 m/s and 5 m/s were selected, since they represented the average speed during wheelchair basketball (7) and the top speed achieved during the sprint trials. Details of the basic recording system and method for determining the drag have been previously reported (8). Each subject then completed four sprint trials which consisted of wheeling as fast as possible from one end of the gymnasium to the other from a stationary starting position with a self-selected rest interval of at least 30 seconds between each trial. The maximal speed, acceleration, propulsive force, and power for each trial were determined from the recorded motion (distance and time) of the wheelchair, the known mass of the subject and wheelchair, and a calculated estimate of the moments of inertia of the casters and rear wheels.

Group means of age, body mass, classification, wheelchair mass, tire pressure, drag force at 2 and 5 m/s, and maximal sprint speed, acceleration, force, and power were calculated for the male and female subjects, and *t*-tests were used to determine the equality of the group means. A *t*-value with a probability of 0.05 or less was considered indicative of a significant difference between the male and female means for the variable tested.

RESULTS

Table 1 presents the individual and group mean values for the basic subject information and the drag force at nominal speeds of 2 m/s and 5 m/s based on the individual regression equations. **Figures 1** and **2** provide a plot of the drag force versus speed for each coast-down trial for the male and female subjects, respectively. **Figures 3** and **4** are similar plots for the relationship between power loss during the coast-down trials versus speed. There were no significant gender differences in age, class, wheelchair mass, or drag force at either 2 or 5 m/s. Males, however, had a significantly higher body mass and tire pressure.

The individual and group means for the sprint trials are contained in **Table 2**. The maximal speed, acceleration, propulsive force, and power were all significantly higher for the male subjects. The maximal speed of the females represented 86 percent of the male's maximal speed, while the female's maximal power was only 50 percent of the male value.

DISCUSSION

The male and female subjects were reasonably matched in terms of age and level of potential as reflected in their classification for basketball competition. Their relative level of ability in wheelchair basketball was also similar, since the sample was drawn from invited participants in comparable national level training and team selection camps, and their length and level of experience in competitive basketball were similar.

The larger body mass of the male subjects reflects the gender difference in body size in the general population, while the lack of a group difference in the mass of the wheelchairs indicates the lack of differential design in sport model

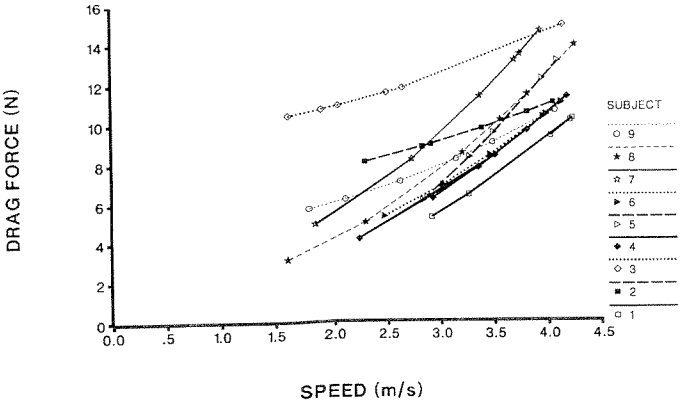

Figure 1.
Drag force versus speed in coast-down trials for male subjects.

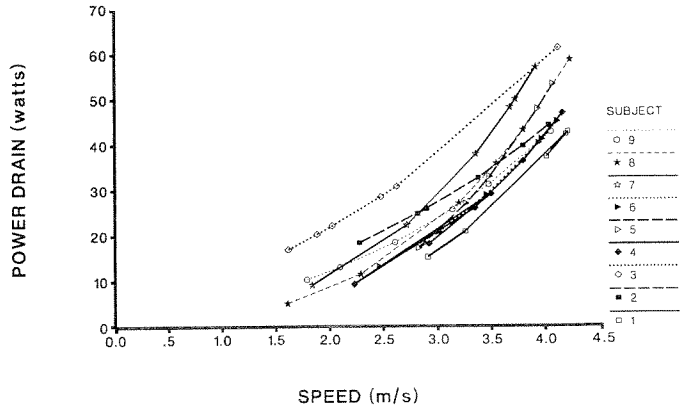

Figure 3.
Power drain versus speed in coast-down trials for male subjects.

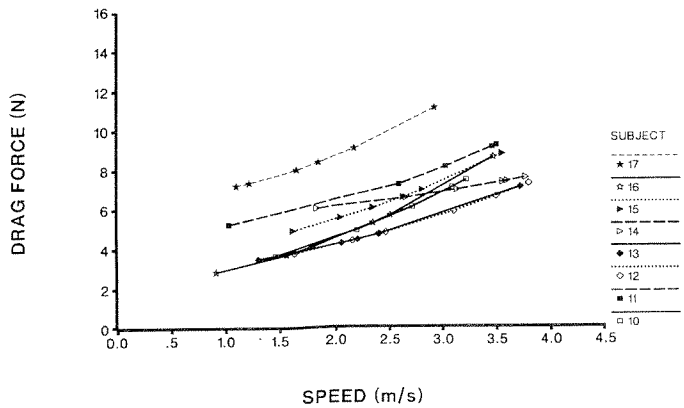

Figure 2.
Drag force versus speed in coast-down trials for female subjects.

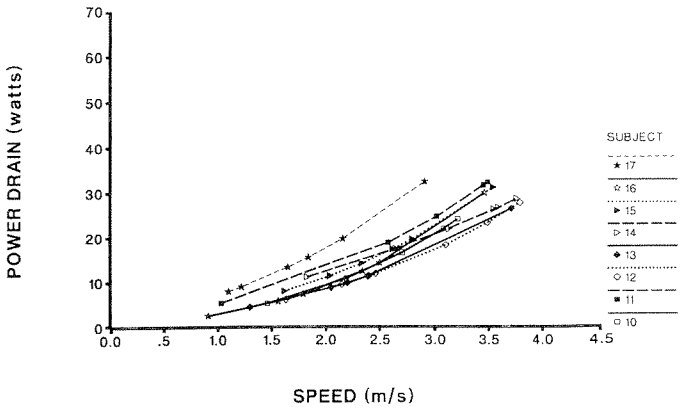

Figure 4.
Power drain versus speed in coast-down trials for female subjects.

higher tire pressure, but also should place a greater stress on proper wheelchair maintenance and adjustment to minimize drag forces.

In general, the values for drag in the current study are in agreement with previously reported values during actual wheeling (8) or a simulated situation on a treadmill (5). There was also reasonable agreement between subjects within the current sample with a few exceptions. Subject no. 3 had an unusually high drag force at 2 m/s, and it was noted during the coast-down trials that his wheelchair displayed caster shimmy and flutter at the lower speeds (see **Figure 1**). No explanation was apparent for the high drag at 2 m/s for subject no. 17; however, it could be partly due to her relatively high body mass and use of low pressure tires, or to an unidentified mechanical problem. The reasons for these individual differences in drag values are beyond the scope of the data collected, but the determination of wheelchair drag and comparison to normal values can indicate the presence of mechanical or other problems needing identification and correction. A fairly simple coast-down race between players of approximately the same body weight (to identify who slows down more rapidly when coasting down from the same speed) could be used to identify wheelchairs that need further inspection and/or adjustment. Interested individuals should consult Cooper (10) for a comprehensive review of design and other factors affecting wheelchair performance.

The male-female differences in the sprint performance data are in general agreement with previous studies of gender differences in muscle strength and power output (11). While the females were able to achieve a maximal speed close to the male value (86 percent), their maximal acceleration (78 percent), propulsive force (63 percent), and power (50

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Table 2.
Sprint trial data.

Subject	Sex	Speed (m/s)	Accel (m/s/s)	Force (N)	Power (watts)
1	M	5.07	1.39	120	540
2	M	4.98	1.31	144	633
3	M	4.80	1.44	150	555
4	M	4.75	1.36	129	553
5	M	4.67	1.48	138	529
6	M	4.74	1.20	107	388
7	M	4.87	1.33	146	564
8	M	4.62	1.17	148	630
9	M	4.26	1.22	134	381
10	F	4.34	1.34	86	286
11	F	4.15	1.04	97	326
12	F	4.33	0.98	75	257
13	F	4.12	1.13	82	246
14	F	4.21	1.02	102	373
15	F	3.64	0.93	77	185
16	F	3.73	0.79	58	156
17	F	4.11	1.00	105	283
Mean	M	4.75	1.32	135	530
Mean	F	4.08	1.03	85	264
P(t)		<.01	<.01	<.01	<.01

Average of maximal values from four trials per subject.
Accel = acceleration

percent) were relatively lower. That is, it would take the females a longer time to reach peak speed due to their lower propulsive muscular efforts against a similar drag at lower speeds. Whether or not females could improve their propulsive force and power output values relative to the males with a greater emphasis on strength training is open to question, but worthy of investigation.

A follow-up analysis of gender differences in rear wheel and push rim diameters indicated that the rear wheels of the males were significantly ($p = 0.02$) larger (64.1 vs. 60.9 cm) as were their push rims (57.6 vs. 54.4 cm, $p = 0.04$). The push rim to rear wheel diameter ratio, however, was not significantly different between the males and the females (0.899 vs. 0.894, $p = 0.72$) indicating that the propulsive gear ratio was similar. This indicates that the maximal linear speed of the push rims was lower for the females (3.65 m/s) compared to the male value (4.27 m/s) and reflects a gender difference in maximal hand speed during wheelchair propulsion.

The power drain values in **Figures 3** and **4**, which represent the power input needed to maintain a constant velocity, are well below the average maximal power outputs of the basketball players during the sprint trials. The higher power values in the sprint trials, therefore, do not reflect the demands of wheeling at a constant speed, but are an

indication of the subject's capacity to increase the kinetic energy or speed of the wheelchair-user system under the given conditions. It is a generally accepted property of concentric muscle contractions that peak power output of the muscle will occur at a contraction velocity of approximately 30 percent of the maximal velocity of shortening (12). It was observed during the processing of the sprint trial data that the peak power output occurred relatively early in the trial and therefore at a relatively low speed, which is consistent with this established property of muscle contraction. Controlled experiments with a higher resolution of power output and speed, however, are needed to quantify this property during the complex skill of wheelchair propulsion.

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