SPEED AND STROKE CYCLE CHARACTERISTICS DURING THE 100-M RACE FOR PARAPLEGIC ATHLETES

John W. Chow and Woen-Sik Chae
Department of Kinesiology, University of Illinois, Urbana, Illinois, USA

The purpose of this preliminary study was to evaluate the speed changes and selected stroke cycle characteristics during the 100-m wheelchair race for paraplegic athletes. Four male and two female T4 and one male and 3 female T3 wheelchair racers served as the subjects. Two S-VHS camcorders (60 fields/s) were panned horizontally to cover the first and second 50 m of the 100-m race, respectively. The maximum speeds recorded ranged from 5.53 m/s to 7.66 m/s. The distance and time needed to reach the maximum speed ranged from 43.9 m and 11.2 s (a T4 female) to 82.2 m and 18.9 s (a T3 female), respectively. The subjects in this study have lower maximum speeds than able-bodied runners and they need longer distance and time to reach their maximum speeds when compared their able-bodied counterparts.

KEY WORDS: kinematics, wheelchair sports, disability, paraplegic, sprinting

INTRODUCTION: An able-bodied runner's acceleration in moving from a stationary position to maximum speed, and deceleration after the maximum speed has been reached, have interested scientists for several decades. In general, an able-bodied runner can reach the maximum speed in about 30-50 m and can maintain the maximum speed for 20-40 m before decelerating toward the end of a 100-m run. Although the speeds of able-bodied subjects during sprinting are well-documented, the corresponding data for the wheelchair racers are not currently available.

Opportunities for sports competition among wheelchair athletes have increased steadily in the last few decades. Track and field events are official events of the Paralympic Games and are popular among wheelchair athletes. A number of studies have been conducted to examined the stroking characteristics of racing wheelchair propulsion. Although kinematic characteristics of wheelchair stroking during competitions have been described (Goosey, Fowler, & Campell, 1997; Ridgway, Pope, & Wilkerson, 1988), most previous studies on the mechanics of wheelchair propulsion were conducted in laboratory settings using stationary wheelchair ergometers, wheelchair roller systems, or treadmills. It is not sure whether mechanical characteristics (e.g., stroke rate, speed, etc.) obtained during wheelchair stroking over an equipment are similar to the characteristics determined from stroking over the ground.

In view of the lack of information on the changes in speed and stroking characteristics of racing wheelchair propulsion during sprinting, the purpose of this preliminary study was to evaluate the speed changes and selected stroke cycle characteristics during the 100-m wheelchair race for paraplegic athletes. It was anticipated that the results obtained from this study would have implications for the design of training programs and provide some base line data for future research in this area.

METHODS: The data collection was completed during a track and field training camp organized by the Wheelchair Sports USA (WSUSA). Four male and two female T4 (functional upper extremities, abdominal, and lower back muscles) and one male and 3 female T3 (same as T4 except no functional abdominal and lower back muscles) track athletes of the training camp served as the subjects. Nine of the subjects were outstanding juniors and only adult subject represented the U.S. in two Paralympic Games. All subjects signed informed consent documents before attending the camp.

Trials. The subjects were asked to complete two 100-m races with maximum effort and a 15-min rest between the two trials. Two subjects were tested at one time and competed in adjacent lanes to simulate a normal competition. Two S-VHS camcorders (Panasonic AG455, 60 fields per second) were used to record the subjects' performances. The two cameras, covered the first and second 50 m of the 100-m race, respectively, were placed on tripods at an approximate distance of 35 m from the lanes that used for data collection. Forty-two background markers were placed at 5-m intervals along lanes 5 and 8. The subjects were videotaped during the entire 100 m, including the start. In this process the camera was panned horizontally (i.e., rotated about a vertical axis) so that both subjects of each trial remained within the optical field of the cameras throughout the entire performance.

Data reduction. For the purpose of this study, a stroke cycle begins at the instant at which the hands make initial contact with the handring and ends at the moment immediately prior to the next initial contact. The *contact distance* of a stroke is defined as the shortest distance between the location of the bottom of the front wheel and the starting line at the instant of initial hand contact (Figure 1). The trial with the shorter 100-m time from each subject was selected for subsequent analysis. A Peak motion measurement system was used to extract coordinate data from the video recordings. For each trial being analyzed, the video fields for the instants of initial contacts with the handring were analyzed. Five points were digitized from each field – the bottom of the front wheel and four markers forming a rectangle around the front wheel (Figure 2). The contact distance of a stroke was determined using the procedures described by Hay and Koh (1988).

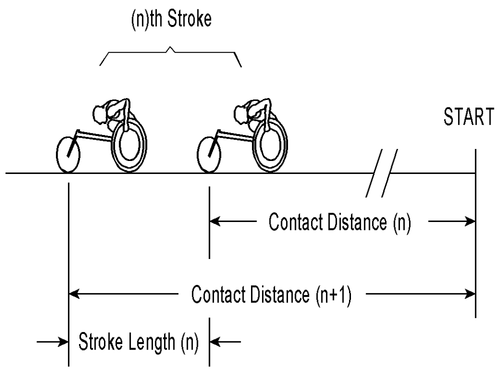

Figure 2 - Spatial parameters.

Consider an initial hand contact of a stroke to occur in a region bounded by markers F(i), F(i+1), N(i), and N(i+1) in Figure 2. A straight line connecting the bottom of the front wheel (T) and (S) — the intersection of the extensions of N(i) F(i) and N(i+1) F(i+1) — will intersect line F(i) F(i+1) at point P. Since the x- and y-coordinates of the four markers and point T are known values, the coordinates of points S and P can be evaluated by simple plane geometry. Because the distance between markers F(i) and F(i+1) is 5 m, the distance between projected point P and F(i) can be computed using simple proportion.

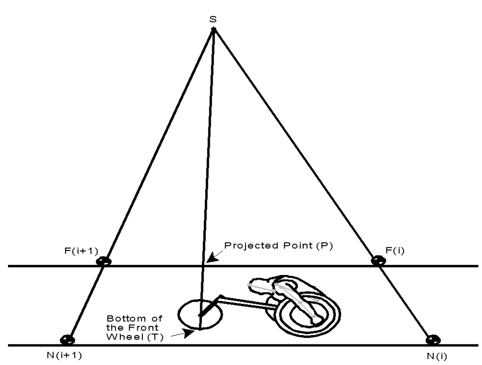

Figure 2 - Front wheel location.

The contact distance is obtained by summing the distance from P to F(i) and the distance from F(i) to the starting line (a known distance). Because the video field rate is known, the *contact time* of a stroke, defined as the time elapsed between the initial hand contact and the firing of the starting gun, can be determined by counting the number of video fields captured from the firing of the starting gun to the initial hand contact.

For each trial, the contact distances were smoothed using the quintic spline. The *stroke length* (SL) was computed as the difference between the contact distance for a stroke and the contact distance for the next stroke (Figure 1). The *stroke time* is the time to complete a stroke and the *stroke frequency* (SF) is the reciprocal of the stroke time. The average speed of a stroke was determined by dividing the stroke length by the corresponding stroke time. The instant at which the hands break contact with the handring (hand release) is used to divide a stroke into two phases — the push phase (from initial contact to hand release) and recovery phase (from hand release to initial contact). The time durations for the push and recovery phases [push time (PT)

and recovery time (RT), respectively] were determined from the identification numbers of the fields showing the instants of hand contact and hand release, and the time interval between consecutive fields (1/60 s). The phase duration expressed as a fraction of the stroke time was also determined.
The maximum speed phase (MSP) is defined as the part of the 100-m race that consists of the five consecutive strokes that together have the largest average speed value. The time and distance taken to reach the first stroke of MSP and the stroke characteristics during MSP were determined. Stroke characteristics during the last 10 m (final phase, FP) were also determined. For each parameter obtained in this study, means and standard deviations were computed for each medical class and gender group.

RESULTS AND DISCUSSION: The speed and stroke cycle characteristics from each subject are averages over five strokes (for MSP) or over 2-3 strokes (for FP).
Maximum speed phase. The maximum speeds recorded ranged from 5.53 m/s (a T3 female) to 7.66 m/s (a T4 male). These values are much smaller than the corresponding values found in able-bodied runners (Best & Partridge, 1930; Chow, 1987; Henry, 1954). The average maximum speed for T4 males is comparable to the speed achieved by senior males (7.3±0.3 m/s) and greater than the speed exhibited by junior males (6.0±1.0 m/s) at the 750-m mark of the 800m race (Goosey et al., 1997). As expected, males had greater maximum speeds than females of the same medical class (Table 1).

Table 1 Mean (SD) of Speed and Stroke Cycle Characteristics

	Maximum Speed Phase				Final Phase			
	T3		T4		T3		T4	
	Male	Female	Male	Female	Male	Female	Male	Female
Speed (m/s)	6.79	5.91 (0.30)	7.33 (0.46)	6.17 (0.04)	6.44	5.86 (0.29)	7.21 (0.53)	6.14 (0.08)
Stroke Length (m)	3.87	2.93 (0.13)	4.04 (0.41)	2.73 (0.18)	3.86	3.18 (0.26)	4.08 (0.40)	2.97 (0.04)
Stroke Freq (Hz)	1.76	2.02 (0.09)	1.82 (0.09)	2.28 (0.16)	1.67	1.85 (0.10)	1.77 (0.08)	2.07 (0.06)
Stroke Time (s)	0.57	0.50 (0.02)	0.55 (0.03)	0.44 (0.03)	0.60	0.54 (0.03)	0.57 (0.03)	0.48 (0.01)
Push Time (s)	0.10	0.12 (0.02)	0.11 (0.03)	0.13 (0.01)	0.10	0.12 (0.02)	0.10 (0.02)	0.14 (0.02)
Relative Push Time (%)	17.5	24.1 (3.1)	20.6 (5.1)	29.7 (5.1)	16.7	22.9 (5.0)	18.1 (4.3)	28.2 (5.2)
Recovery Time (s)	0.47	0.38 (0.01)	0.44 (0.05)	0.32 (0.05)	0.50	0.42 (0.05)	0.47 (0.04)	0.35 (0.04)
Rel Recovery Time (%)	82.5	75.9 (3.1)	79.4 (5.1)	70.3 (5.1)	83.3	77.1 (5.0)	81.9 (4.3)	71.8 (5.2)
%RT / %CT	4.70	3.20 (0.53)	4.12 (1.42)	2.42 (0.59)	4.99	3.53 (1.11)	4.83 (1.75)	2.61 (0.67)

The speed at 50-m mark is the speed of the stroke when the wheelchair crossed the 50-m line. On average, the subjects attained 98.6% of their maximum speeds at the 50-m mark. The distance and time needed to reach the beginning of the MSP ranged from 43.9 m and 11.2 s (a T4 female) to 82.2 m and 18.9 s (a T3 female), respectively. Comparing to able-bodied runners, wheelchair racers generally need longer time and distance to reach their maximum speeds. The lower maximum speed and the longer time needed to reach the maximum speed explain why wheelchair racers have much greater 100-m times than able-bodied runners.
Males had much greater SL than their female counterparts during MSP. The SL values during

the MSP displayed by the male subjects in this study are comparable to those for senior males reported by Goosey et al. (1997) and greater than the SL values reported by Ridgway et al. (1988). On the other hand, the SL values during the MSP for our female subjects are shorter than the SL values exhibited by senior females at the 750-mark of the 800-m race (Goosey et al., 1997). On average, females had greater SF than males in the MSP. In achieving the maximum speed, females tended to emphasize the SF while males put more stress on stroke length. It is not sure whether the differences are due to the differences in muscular strength and physique, or other factors. Overall, females needed more strokes to complete the 100-m race.
Within each medical class, males had greater %RT-%PT ratio for the MSP than females (Table 1) The ratios are much greater than the corresponding values recorded at the end of the 800-m race (Goosey et al., 1997; Ridgwood et al., 1988). The differences are probably related to the fatigue an athlete suffered at the end of the 800-m race.
Final phase. The decrease in speed from the MSP to FP ranged from zero (a male and a female T4) to 5.2% (a T3 male). In other words, two of the subjects did not reach their maximum speed until the end of the 100 m. There seems to be minimum changes in SL for males from the MSP to FP. However, slight increase in SL was observed among the female subjects. The decrease in SF found in all groups is likely related to the presence of fatigue. Despite a decrease in stroking speed, an increase in %RT-%PT ratio was found in all groups when going from the MSP to FP. It seems that when the subjects became tire toward the end of the 100 m, they tended to shorten the PT and elongate the RT.

CONCLUSION: The present study represents the first attempt to describe the speed and stroke cycle characteristics during the 100-m wheelchair race performed by quadriplegic athletes. Wheelchair racers have lower maximum speeds than able-bodied runners and they need longer distance and time to reach their maximum speeds when compared their able-bodied counterparts. Despite the small sample size, the results within each medical class and gender group are quite consistent. More quantitative data, especially those collected during major competitions, are needed for the development of a data base on performance characteristics. Future research efforts should focus on new stroking techniques, training methods, and equipment that will shorten the duration of acceleration and increase the maximum speed.

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