17,000 BOUTS OF MOBILITY

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INTRODUCTION

An estimated 1.5 million people use manual wheelchairs in the United States [1]. Despite the frequent use of manual wheelchairs, there exists only a small, but growing literature base describing daily wheelchair usage, often in terms of daily travel distance and time spent wheeling [2-4]. While daily usage is certainly important for design and prescription of wheelchairs, it is also necessary to understand the complexity of mobility. The complex details of mobility can influence propulsion training and motivate relevant research, in addition to affecting wheelchair design and prescription.

One research group has reported on the frequency of stops over a fixed distance, where a stop was defined as traveling some minimum distance over seven seconds [2]. While this reflects the continuity of movement, a more thorough description of the actual mobility bouts is needed. Bouts of mobility have been previously defined to describe transitions between stationary activities [5].

The goal of the current study was to characterize bouts of mobility wheeled by a typical population of full-time, adult users.

METHODS

A convenience sample of 19 adults with some affiliation to the local spinal cord injury rehabilitation center, and who used manual wheelchairs as their primary mobility devices were recruited for this study with IRB approval. Subjects signed informed consent forms prior to beginning their participation in the study. Each of the participant's wheelchairs was instrumented with a solid-state, triaxial, MEMS-based acceleration logger with a ±2g range and a sampling rate of 10Hz. This logger was mounted on one of the wheels for periods between 1 to 2 weeks (depending on subject availability). This method of measuring manual wheelchair movement has been described previously [6] and offers a rate of accuracy better than 90% across a range of speeds and indoor and outdoor surfaces.

The collected acceleration data was processed to determine wheelchair velocity [6]. A bout of mobility was then defined as starting when wheeling occurred for at least 5 seconds as a speed $\geq$ 0.12 m/s (i.e., a minimum distance of 0.6 m). A bout continued until the wheelchair was stopped (i.e., traveled less than 0.76 m) over 15 seconds. These thresholds were determined empirically as described in previous work [5].

RESULTS

Description of Population

Participants included 15 men and 4 women, ages 22-67 (median = 35). Participants had been using a wheelchair fulltime for 1.5 – 36 years prior to the study (median = 10). Twelve participants had spinal cord injuries, while the remaining diagnoses varied.

Bout Characterization

A total of 17,246 bouts were measured over 4,354 hours, across 19 subjects. The distance and duration of bouts were not normally distributed, but had a tendency towards shorter bouts (Figure 1, Table 1). The median bout was only 8.5 m and lasted 21 seconds. Velocity, on the other hand, was normally distributed around 0.46 m/s (SD = 0.21 m/s). Bouts were separated by a median time of 96 seconds. In fact, fewer than 15% of bouts were separated by more than 15 minutes.

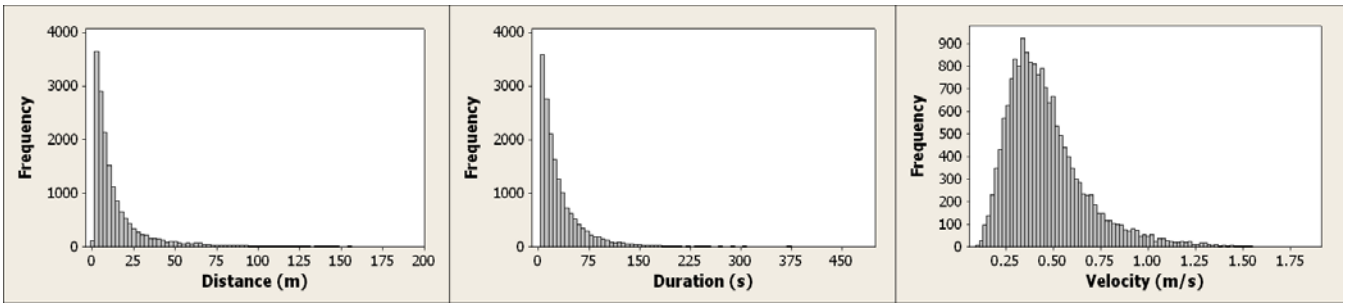

Figure 1: Histograms of the primary bout descriptors: from left to right – distance, duration, and velocity.

Table 1: Typical Bout Parameters

	Mean (stdev)	Median (Range)
Bout distance (m)	21.4 (60.3)	8.5 (0.8 – 1969.8)
Bout duration (s)	38 (64)	21 (5 – 2053)
Average bout velocity (m/s)	0.46 (0.21)	0.42 (0.09 – 1.88)

Bout distance and duration were highly correlated, with a Pearson correlation coefficient of 0.936. Although also statistically significant ($p = 0.000$), correlations with velocity were smaller, with the correlation between distance and velocity equal to 0.422, and the correlation between duration and velocity equal to 0.287.

As evident from the significant correlation, there were differences in bout velocities depending on the distance of a bout. For example, the average speed of bouts with a distance at or exceeding the 75th percentile distance (18.5 m) was 0.63 m/s while the average speed of bouts within the 25th percentile distance (4.1 m) were 0.35 m/s.

DISCUSSION

The skewness of bout distance and duration is not surprising, as this has been reported previously [5]. These results emphasize the importance of considering the distribution when reporting on measures of wheeling distance and duration, as parametric descriptors may be misleading. Perhaps more surprisingly, the velocity was normally distributed. This suggests a tendency towards a single, preferred speed of propulsion.

The clustering of bouts of mobility (50% of bouts separated by less than 1.5 minutes) was another interesting result observed in this study. Such clustering suggests that movement is not evenly distributed throughout the day, and thus daily descriptors of movement alone are not sufficient. Among other consequences, the clustering of movement will influence fatigue and function of the wheelchair user.

The typical velocity of a bout was approximately 0.4 m/s. This is considerably slower than the 0.79 m/s reported by Tolerico et al. [2], and may reflect differences in population, or more likely differences in methodology. As expected, the longer bouts tended to be wheeled more quickly. It is likely that the longer bouts occurred outdoors or in large, open environments, as it is difficult to wheel 18.5 m continuously in a small space. Therefore, with 75% of bouts being shorter, and probably in smaller environments, training of wheelchair propulsion techniques should reflect this typical use. Wheeling 4.1 m at 0.35 m/s may require different strategies than wheeling 18.5 m at 0.63 m/s. Furthermore, equipment can be optimized for the typical wheeling behaviors of an individual. Another implication for the low speeds recorded in this study is their effect on research studies. It is important that studies addressing energy expenditure associated with propulsion, as well as kinetics and kinematics, reflect the slow speeds and short distances typically propelled with a manual wheelchair.

The typical bouts wheeled in a manual wheelchair were of comparable duration, but greater distances and speeds to those measured in a power wheelchair [5]. When a power wheelchair was used indoors, mobility bouts were approximately 4 m, 18 seconds,

and 0.22-0.28 m/s. Bouts wheeled outdoors were faster, at 0.44 m/s. Intuitively, one might expect that the provision of power would result in faster, not slower bouts of mobility. One possibility is that users have more control in manual wheelchairs and feel safer at higher speeds. Alternatively, the individuals who use manual wheelchairs are likely to have greater functional abilities. However, the population who used power wheelchairs was independent in driving their chairs. This result requires further exploration.

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