GENDER DIFFERENCES IN THE KINETIC FEATURES OF MANUAL WHEELCHAIR PROPULSION

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INTRODUCTION

Research into manual wheelchair propulsion (MWP) has documented resulting cumulative trauma and repetitive strain disorders in manual wheelchair users (MWU). Researchers have asserted such injuries can be reduced by proper wheelchair fit and propulsion technique. Such assertions are based on the opinion that better wheelchair fit and efficient propulsion technique improves MWP physiological and biomechanical efficiency. (1)

Most researchers, however, have not considered the gender of the MWU. Reasons for considering the gender of the MWU include differences in the anthropometrics (2) and kinematics of wheelchair propulsion (3). Fay, et al (2) has demonstrated significant difference between genders in linear and circumference measures, but similar proportions between genders when considering ratios of stature to linear measure and weight to circumference measure. A muscularity ratio demonstrated more muscular upper arms in males. Fay, et al (3) later demonstrated statistically significant differences in the joint angles for gender groups based on anthropometric percentile pairings and a high degree of difference for groups based on anthropometrically similar pairings. One postualted reason for greater difference between similar pairings versus percentile pairings was due to strength differences between females and males with similar linear anthropometrics. It was suggested that further investigation into differences in the force generated between these pairings may shed light on the kinematic observation.

METHODS

Nine female and eight male subjects were randomly selected from a database of 13 females and 31 males who had participated in the recording of velocity and bilateral three-dimensional pushrim forces and moments during manual wheelchair propulsion. Mean maximum force, rate of force application, moment and rate of moment application and number of propulsion cycles were evaluated under three speed conditions (2 mph, 4 mph, and start from rest). For the 2 and 4 mph trials, the subject was instructed to push the wheelchair at the indicated speed. Feedback of speed was provided via a bar graph appearing on a computer monitor positioned in front of the subject. For the last speed condition, the subject started from rest and accelerated as fast as possible to 4 mph. All trials last for 20 seconds.

Statistical analysis of the data was performed to determine the correlation between right and left sides; right and left variables with high corelation were averaged into one variable. An independent samples t-test to compare the randomly selected groups.

An effort was also undertaken to compare males and females of similar anthropometric measures. For this comparison, the male subjects' measures were subtracted from the females'. Two pairings were made between males and females whose anthropometric differences for upper extremity measures (circumference of the biceps, elbow wrist and length of upper and forearms) summed to less than 10 cm and upper extremity correlation coefficients exceeded 0.95. Analysis was performed for only the start up trial.

RESULTS AND DISCUSSION

Statistically significant differences between gender groups were found for all variables except the rate of resultant force application at 2 mph and 4 mph (Table 1). This demonstrates the females, in general, do not produce as much force tangental to the pushrim as do males. In addition, the rate of force application was significantly less. These effects were even more highly significant for the start up trials where subject started from rest. Considered alone, these results suggest the musculature of women, as a group, does produce the pushrim force and moment levels of men. This would further indicate that women require more propulsive cycles than do men to reach and maintain a specified speed. Evaluation of the number of propulsion cycles between groups did not show a statistically significant difference between genders, but results trended toward women having more cycles both at start up and while maintaining a specified speed. Statistical differences were less pronounced for the anthropometrically matched pairs during the start up trial (Table 2); however, males did produce higher forces and moments and the number of cycles required to reach the specified speed were less.

Gender Differences in Kinetics of MWP

The observation of reduced force and moment production and rate of production for females in the randomly selected group tends to validate the observation made in [2] that smaller circumference measures and reduced muscularity ratio (circumference:limb length) are related. Conclusions of [3] found highly significant differences in the joint angles for groups based on anthropometrically similar pairings. It is interesting to note variation in force and moment levels for the second pairing in this study which could be the result of differing kinematics. However, the overiding conclusion is that differences were reduced when the anthropometrically similar parings were considered. This may indicate that with proper physical training and wheelchair setup, females may perform at levels similar to males.

SUMMARY

Randomly selected groups of males and females who use manual wheelchairs were compared for the maximum average pushrim force, moment and number of propulsion cycles to attain and maintain a specified speed. Statistically significant differences were found via an independent samples t-test for total applied force, the rate of applied force, applied axle moment, rate of applied axle moment. Trends toward statistical significance were noted for the rate of resultant pushrim force at 2 and 4 mph and number of cycles to attain and maintain the specified speed. Upon considering anthropometrically matched gender pairs, the previously noted differences were reduced with only tangential pushrim force and axle moment significant. It is proposed that appropriate physical training and wheelchair setup may improve performance of females.

REFERENCES

[1] Burnham R (1994). "Upper extremity peripheral nerve entrapments among wheelchair athletes." Arch. Phys. Med. & Rehab. 75:518-24.

[2] Fay BT, Boninger ML, Cooper RA (2000). Gender-based anthropometric differences of manual wheelchair users. Proceedings of the 22nd Annual RESNA Conference. *In Press.*

[3] Fay BT, Boninger ML, Cooper RA (1999). Gender differences in the kinematics of manual wheelchair propulsion. Proceedings of the 22nd Annual RESNA Conference.

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Table 1: Force and Moment Comparison for randomly selected gender groups.

Speed = 2mph

Quantity	Female avg	Male avg	p-value
Fr (N)	58.37 (18.50)	84.28 (28.49)	0.030
Fr ROR (N/s)	4.35 (1.65)	5.38 (2.30)	0.278
Ft (N)	30.98 (15.58)	50.02 (19.57)	0.031
Ft ROR (N/s)	1.459 (0.59)	3.26 (2.17)	0.016
Mz (N-m)	10.33 (5.19)	16.67 (6.52)	0.031
Mz ROR (N-m/s)	0.48 (0.20)	0.72 (0.20)	0.016

Speed = 4mph

Quantity	Female avg	Male avg	p-value
Fr (N)	83.023 (19.029)	121.880 (37.335)	0.018
Fr ROR (N/s)	6.704 (2.097)	10.396 (5.677)	0.104
Ft (N)	39.196 (19.592)	59.069 (17.360)	0.042
Ft ROR (N/s)	2.404 (0.863)	4.017 (1.216)	0.007
Mz (N-m)	13.064 (6.530)	19.687 (5.786)	0.042
Mz ROR (N-m/s)	0.801 (0.288)	1.339 (0.405)	0.007

Speed = Start Up

Quantity	Female avg	Male avg	p-value
Fr (N)	83.705 (14.452)	165.561 (41.047)	0.000
Fr ROR (N/s)	5.145 (1.162)	13.056 (5.411)	0.001
Ft (N)	52.245 (21.294)	88.233 (23.793)	0.004
Ft ROR (N/s)	2.856 (0.853)	5.876 (2.405)	0.003
Mz (N-m)	17.413 (7.097)	29.408 (7.930)	0.004
Mz ROR (N-m/s)	0.953 (0.284)	1.958 (0.802)	0.003

Table 2: Force and Moment Comparison for anthropometrically paired males and females.

Pairing 1			
Quantity	Female avg	Male avg	p-value
Fr (N)	78.755	103.559	0.086
Fr ROR (N/s)	5.067	10.419	
Ft (N)	20.700	23.968	0.047
Ft ROR (N/s)	1.161	1.795	0.135
Mz (N-m)	6.898	7.988	0.047
Mz ROR (N-m/s)	0.387	0.598	0.135
Vmax (m/s)	1.537	1.926	0.071
V ROR (m/s-s)	0.0148	0.0165	0.033
Pairing 2			
Quantity	Female avg	Male avg	p-value
Fr (N)	95.016	103.589	0.027
Fr ROR (N/s)	5.191	10.419	0.206
Ft (N)	39.691	23.968	0.154
Ft ROR (N/s)	4.031	1.795	0.233
Mz (N-m)	13.229	7.988	0.154
Mz ROR (N-m/s)	1.343	0.598	0.232
Vmax (m/s)	1.624	1.926	0.054
V ROR (m/s-s)	0.014	0.016	0.052