Aerobic Fitness and Upper Extremity Strength in Patients Aged 11 to 21 Years With Spinal Cord Dysfunction as Compared to Ideal Weight and Overweight Controls

Lana M. Widman, MS¹; Richard Ted Abresch, MS¹; Dennis M. Styne, MD¹; Craig M. McDonald, MD^{1,2}

¹University of California Davis School of Medicine, Davis, California; ²Shriners Hospitals for Children Northern California, Sacramento, California

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Abstract

Objective: To determine whether the aerobic fitness, upper extremity strength, and body composition in groups of adolescents with mobility impairment due to thoracic and upper lumbar spinal cord injury (SCI) or spina bifida (SB) are significantly different from those in groups of adolescents without mobility impairment who are of normal weight (CTRL) or overweight (OW).

Subjects: One hundred fifteen total subjects were evaluated including 59 female (19 SB, 9 SCI, 17 OW, and 14 CTRL) and 56 male (18 SB, 10 SCI, 8 OW, and 20 CTRL) participants aged 11 to 21 years.

Methods: Aerobic fitness was assessed using a ramp protocol with a magnetically braked arm ergometer. Heart rate and oxygen uptake (VO_2) were recorded. Peak isokinetic upper arm and shoulder strength values were determined with a dynamometer. Body composition was estimated using dual energy x-ray absorptiometry (DEXA). Male and female subjects were categorized as overweight if their percent body fat by DEXA exceeded 25% and 30%, respectively. Results were analyzed with an ANOVA using the Bonferroni correction. Significance was accepted at $P < 0.05$.

Results: The percent body fat of both the male and female SB and SCI subjects was significantly higher than CTRL but was not different than OW. In general, the shoulder extension and flexion strength in both the SB and SCI males and females was significantly lower than that of the CTRL and OW. The SCI and SB subjects had significantly reduced aerobic capacity (VO_2/kg) compared to the CTRL subjects but were not different than the OW subjects. During the maximal exercise test, the SB and SCI subjects reached exhaustion at significantly lower workloads than the CTRL and OW subjects.

Conclusions: Patients age 11 to 21 years with SB and SCI had reduced aerobic capacity that was associated with being overweight and having reduced upper extremity strength. These data suggest that interventions to increase strength and fitness and to manage weight should be recommended in this population.

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Key Words: Spinal cord injuries; Spina bifida; Adolescence; Obesity; Body composition; Rehabilitation; Fitness; Cardiovascular disease

Please address correspondence to R. Ted Abresch, Department of Physical Medicine and Rehabilitation, University of California Davis, One Shields Avenue, TB191, Davis, CA, 95616; phone: 530.752.9085; fax: 530.752.3468 (e-mail: rtabresch@ucdavis.edu).

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INTRODUCTION

Despite the relatively recent increase in life expectancy of people with spinal cord injury (SCI) (1,2) and spina bifida (SB) (3), cardiovascular disease (CD) is more prevalent among adults with spinal cord dysfunction than in the able-bodied population and is a leading cause of death (4–6). This is generally attributed to a more sedentary lifestyle (7,8) and not related to the disabling condition (5,9). In the able-bodied population, cardiorespiratory fitness and strength are strongly associated with an individual's risk of developing CD (10–13). Clinicians are urged to assess fitness in their patients and to recommend increasing physical activity to improve cardiores-

Table 1. Characteristics of the Spinal Cord Injury Group

Subject	Age Tested, y	Duration of Injury, y	Injury Level: Right Motor	Injury Level: Left Motor	Injury Level: Right Sensory	Injury Level: Left Sensory	History of Autonomic Dysfunction?	ASIA Level	Complete	Gender
1	11.4	1.2	L2	L2	L2	L2	N	A	Complete	F
2	20.7	9.8	T5	T5	T5	T5	N	A	Complete	F
3	13.1	8.8	T12	T12	T12	T12	N	A	Complete	F
4	17.2	2.1	T10	T10	T10	T10	N	C	Incomplete	F
5	18.9	16.5	T4	T4	T4	T4	N	A	Complete	F
6	18.9	7.6	L5	L3	L4	L4	N	D	Incomplete	F
7	17.9	5.8	L1	L1	L2	L2	N	A	Complete	F
8	17.8	4.9	T4	T4	T4	T4	N	A	Complete	F
9	11.5	3.2	T12	T12	N	N	N	B	Incomplete	F
10	15.4	1.2	T4	T4	T4	T4	Y	A	Complete	M
11	11.5	1.3	T11	T11	T11	T11	N	B	Incomplete	M
12	18.7	9.5	T6	T6	T6	T6	N	B	Incomplete	M
13	19.2	3.3	T6	T6	T6	T6	N	A	Complete	M
14	15.2	1.4	T9	T8	T9	T8	N	A	Complete	M
15	18.4	2.7	T11	T11	T11	T11	N	D	Incomplete	M
16	15.8	9.0	T4	T4	T4	T4	N	A	Complete	M
17	18.6	1.2	T6	T6	T6	T6	N	A	Complete	M
18	11.0	5.5	T6	T6	T6	T6	N	A	Complete	M
19	12.6	11.8	T3	T4	T3	T4	N	A	Complete	M

piratory function in those patients who exhibit one or more risk factors for CD and metabolic syndrome (11). For individuals with mobility impairment due to spinal cord dysfunction, poor fitness and diminished strength have been shown to negatively impact their ability to function independently in addition to health outcomes (14,15). Manns et al (16) reported a strong, statistically significant correlation of cardiorespiratory fitness with objective measures of physical independence in a group of 21 adults with paraplegia. Additionally, Hjeltne and Jansen (17) found a significant association between cardiorespiratory endurance and the rates of urinary tract infections, osteoporosis, and independence in activities of daily living in a group of 72 subjects with SCI. The subjects with the lowest values for peak oxygen uptake had the highest number of infections and lowest rates of independence.

It follows that adolescents with SCI and SB may have a similar association of cardiovascular fitness and strength with CD risk factors. And since there is strong evidence that appearance of these risk factors in childhood tracks into adulthood (18,19), it is important to identify at-risk individuals during adolescence or childhood. Although a fair number of studies have been conducted to assess strength and cardiorespiratory fitness in able-bodied adolescents (20–23), few studies have been conducted to assess these parameters in adolescents with mobility impairment. Van den Berg-Emons et al (8) assessed

fitness in a small group (N = 14) of young adults (mean age = 18 ± 4 years) with SB and found them to be significantly less fit by comparing their peak VO_2 values to 70% of normative values from cycle ergometry. However, it is well established that physiological and metabolic responses to arm ergometry differ significantly from those of cycling or running. Sherman et al (24) used a gender-, age-, and arm span-matched control group, both groups completing an arm-crank ergometry protocol, and also found adolescents with SB to be significantly less fit.

The purpose of this project was to assess upper extremity strength and aerobic fitness in a population of adolescents with mobility impairment due to SCI and SB and to compare their values to those of a group of adolescents without impairment using the same upper extremity testing protocols. We hypothesized that shoulder strength, which is critical for independent wheelchair propulsion and wheelchair transfers, would be greater in a population of individuals who use wheelchairs. We also hypothesized that aerobic fitness, indicated by peak oxygen uptake, maximum workload achieved, resting heart rate, aerobic efficiency defined by the increase in oxygen uptake per unit of power output (25), and percent of oxygen uptake reserve at specified workloads, would be reduced for subjects with SB or SCI and that it would be inversely correlated with total body fat percentage for all subject groups.

METHODS

Subjects

One hundred fifteen adolescents (aged 11–21 years) with and without mobility impairment due to spinal cord dysfunction were recruited from Shriners Hospital for Children Northern California and from the community. All subjects under 18 and their parents provided written assent or consent. Subjects 18 years and older provided written assent. For the nondisabled, overweight (OW) was defined by total body fat percentage according to the standards proposed by Williams et al (26), ie, $\geq 30\%$ for females and $\geq 25\%$ for males. Body fat percentage was used as a criterion instead of the more widely used body mass index (BMI) because BMI cutoff values for defining obesity have not been clearly established for adolescents with disabilities. The subjects with SB or SCI were not subcategorized by weight. An inclusion criterion for SB and SCI groups was lesion/injury at thoracic level or below with no upper extremity impairment. All of the SCI subjects and 32 of the SB subjects used a wheelchair for all of their mobility needs. Table 1 describes the injury characteristics of the SCI group. Five subjects with SB were partially ambulatory but had significantly impaired gait requiring braces, crutches, or other mobility assistance.

Anthropometrics

For all subjects able to stand erect, height was measured to the nearest centimeter with a wall-mounted stadiometer. For subjects unable to stand erect, stature was measured with a supine stadiometer. Every effort was made to account for any contractures. Weight was obtained to the nearest kilogram with a wheelchair balance scale (Detecto, St Louis, MO). Body composition was obtained with dual energy x-ray absorptiometry (Hologic QDR 4500, Hologic, MA). Pubertal stage was assessed by self-assessment survey utilizing line drawings to represent the 5 Tanner stages (27).

Strength

Peak dynamic strength values were obtained with a LIDO Dynamometer (Loredan Biomedical, West Sacramento, CA). For shoulder flexion and extension, the subjects sat on a chair with their feet flat on the floor, wrist in neutral position, and elbow in full extension. Subjects who used wheelchairs sat in their wheelchairs with feet fully supported on the footrests and with the rear wheels locked. Range of motion ranged from 90° flexion (arm pointed forward at shoulder height) to 180° flexion (arm pointed straight up). For elbow flexion and extension, subjects were supine with the upper arm in approximately 45° of abduction. Range of motion was from 0° (fully extended) to 90° of elbow flexion. Subjects performed 3 maximum extensions and 3 maximum flexions for each elbow and shoulder. The peak value for torque was calculated as the mean peak value between the right and left arms and recorded in

newton-meters. Peak torques were then normalized by total body weight for comparison.

Aerobic Fitness

Values for HR_{rest} and VO_{2rest} were obtained after the subjects were seated quietly for 3 minutes. These values were obtained while the subjects were seated in order to best represent the functional aerobic capacity starting values for exercise. A seated position was used for determination of baseline VO_2 and HR because it has been shown that some individuals with spinal cord dysfunction exhibit an increased HR and VO_2 while lying (28).

There are no prediction equations available that can be used to estimate values for maximum oxygen uptake (VO_{2max}), anaerobic threshold (AT), or maximum heart rate (HR_{max}) (22,29) in adolescents with disabilities using upper extremity exercise. Therefore, peak oxygen uptake (VO_{2peak}), AT, aerobic efficiency, and peak heart rate (HR_{peak}) were determined for each subject by arm crank ergometry (ACE) using a standard ramp protocol on a magnetically braked arm ergometer (Lode, Groningen, The Netherlands). Subjects were asked to crank the arm ergometer at a constant speed of 70 rpm for 2 minutes at 0 watts of resistance. The resistance was then increased in a ramp fashion at a rate of 10 watts/minute. Subjects were verbally encouraged to continue until exhaustion. Heart rate (HR), oxygen uptake (VO_2), carbon dioxide production (CO_2), and power output (PO) were recorded breath by breath with a metabolic cart (Medgraphics, St Paul, MN) using a facemask. The values obtained for VO_{2peak} and HR_{peak} were used as a proxy measures for VO_{2max} and HR_{max} . Additionally, the maximum power output (PO_{max}) was recorded.

DATA ANALYSIS

Strength

Peak values for torque were referenced relative to total body weight to account for disparate body sizes and then expressed in newton-meters per kilogram. Subjects were separated by gender and diagnosis, then data were compared between the groups using a one-way ANOVA with Bonferroni multiple comparison analysis to examine differences between groups.

Aerobic Fitness

In 1998, Swain (30) introduced the concept of oxygen uptake reserve (VO_2R) as an individualized quantitative method of reporting cardiorespiratory fitness using the following equation:

$$VO_2R = VO_{2peak} - VO_{2rest}$$

As an individual improves in fitness, maximum capacity (VO_{2max}) increases and oxygen delivery efficiency improves; VO_{2rest} decreases, thereby increasing VO_2R . Percentage of VO_2R ($\%VO_2R$) is then used as an indication of exercise intensity specific to that individual.

Table 2. Subject Anthropometrics*

	Diagnosis	n	Age, y	Height, cm	Weight, kg	BMI, kg/m ²	Body Fat %
Females	CTRL	14	16.8 ± 2.3	165.3 ± 5.9	56.3 ± 8.1	22.1 ± 4.2	25.7 ± 4.1
	OW	17	15.7 ± 2.8	162.5 ± 10.5	82.0 ± 25.2†	34.5 ± 5.9†	40.7 ± 7.0†
	SB	19	15.9 ± 1.9	142.4 ± 11.4†‡	64.7 ± 13.5†	31.4 ± 5.3†	46.2 ± 5.0†
	SCI	9	16.4 ± 3.5	162.4 ± 11.9	66.3 ± 22.8†	23.9 ± 6.3†	40.4 ± 10.3†
Males	CTRL	20	16.0 ± 2.8	168.5 ± 11.1	61.1 ± 14.1	21.3 ± 3.4	16.1 ± 5.2
	OW	8	17.4 ± 2.6	180.5 ± 9.0†	101.7 ± 12.1†	31.3 ± 3.2†	32.8 ± 5.2†
	SB	18	16.7 ± 2.7	147.3 ± 9.8†‡	60.6 ± 15.1†	28.0 ± 6.6†	36.3 ± 9.3†
	SCI	10	15.6 ± 3.1	158.0 ± 15.4†	65.8 ± 23.6†	25.1 ± 7.3	33.4 ± 13.5†

*Data are mean ± standard deviation. BMI, body mass index; CTRL, control; OW, overweight; SB, spina bifida; SCI, spinal cord injured.

†Significantly different from CTRL, $P \leq 0.05$.

‡Significantly different from OW, $P \leq 0.05$.

As an individual's fitness improves, the %VO₂R at a given work output (PO) decreases. In this way, %VO₂R can be used to compare cardiorespiratory fitness status between groups of nonhomogeneous individuals such as adolescents.

Anaerobic threshold (AT) is another concept used to describe aerobic fitness. It indicates that point during a bout of exercise of increasing intensity at which the metabolic demand of the working muscles exceeds the respiratory system's ability to deliver sufficient oxygen for aerobic metabolism. It is influenced by metabolic efficiency in the oxygen delivery system. Very fit individuals will have an AT that is very close to their maximum oxygen uptake. When expressed as a percentage of the VO_{2max}, it can be used to assess relative aerobic efficiency between individuals. AT was calculated using the V-slope method developed by Wasserman (25) and expressed as a %VO₂R for each individual.

The slope of VO₂ as a function of increasing work output is a measure of aerobic work efficiency (25). If the muscles are unable to extract the oxygen required to

perform the exercise, then the slope will be shallower than normal. In this protocol, subjects began cranking with no resistance. There was no difference in VO₂ between unloaded cycling and at PO less than 15 watts for any of the subjects. This was most likely due to the inertia of the ergometer flywheel. For this reason, the slope of VO₂ as a function of PO was calculated for PO from 20 watts to 40 watts for each subject, then averaged over each gender and group. The slope of the resulting regression was compared between groups.

RESULTS

Anthropometrics

The age, height, weight, BMI, and whole body fat percentage for each group are presented in Table 2. There was no difference in mean age between any of the groups. Both the male and female SB groups were significantly shorter than the other 3 groups. For both males and females, the control group was significantly lighter than the OW, SB, and SCI groups, which were not significantly different from each other. The male and

Table 3. Peak Torque Values (N-m/kg)*

		Shoulder Flexion	Shoulder Extension	Elbow Flexion	Elbow Extension
Female	CTRL	0.51 ± 0.07	0.67 ± 0.14	0.37 ± 0.05	0.45 ± 0.09
	OW	0.38 ± 0.10†	0.46 ± 0.11†	0.32 ± 0.05	0.34 ± 0.06†
	SB	0.46 ± 0.14	0.52 ± 0.18†	0.38 ± 0.11	0.43 ± 0.12‡
	SCI	0.40 ± 0.10	0.46 ± 0.18†	0.40 ± 0.09	0.36 ± 0.10
Male	CTRL	0.70 ± 0.14	0.94 ± 0.19	0.61 ± 0.15	0.57 ± 0.10
	OW	0.51 ± 0.10†	0.72 ± 0.22†	0.49 ± 0.12	0.43 ± 0.10
	SB	0.54 ± 0.14†	0.62 ± 0.14†	0.58 ± 0.20	0.56 ± 0.14
	SCI	0.54 ± 0.18†	0.73 ± 0.20†	0.59 ± 0.17	0.59 ± 0.18

*CTRL, control; OW, overweight; SB, spina bifida; SCI, spinal cord injured.

†Significantly different from CTRL, $P < 0.05$.

‡Significantly different from OW, $P < 0.05$.

Table 4. Summary of Aerobic Testing Values*

	Females			
	CTRL	OW	SB	SCI
VO _{2peak} mL	1173.5 ± 298	1176.1 ± 368	899.9 ± 280†‡	894.9 ± 230†‡
VO _{2peak} per kilogram, mL/kg	21.0 ± 4.8	14.9 ± 3.8†	14.2 ± 4.2†	15.1 ± 6.5†
VO _{2rest} mL	214 ± 55.9	268 ± 62.4	202 ± 44.1	227 ± 46.3
PO _{max} W	56.4 ± 11.4	53.8 ± 12.7	48.9 ± 15.3	43.7 ± 7.4
%VO _{2R} at AT	39.1 ± 11.7	36.1 ± 21.5	49.5 ± 10.6	46.3 ± 11.8
HR _{rest} bpm	84.6 ± 15.1	84.6 ± 8.2	99.8 ± 16.1†‡	97.0 ± 13.2†‡
HR _{peak} bpm	159.2 ± 20.2	158.8 ± 19.8	167.3 ± 19.3	155.2 ± 17.0

	Males			
	CTRL	OW	SB	SCI
VO _{2peak} mL	1889.1 ± 632	2237.4 ± 507	1189.2 ± 371†‡	1174.2 ± 335†‡
VO _{2peak} per kilogram, mL/kg	30.8 ± 6.0	22.2 ± 5.2†	20.6 ± 7.6†	19.0 ± 5.8†
VO _{2rest} mL	279 ± 74.9	380 ± 84.3	231 ± 49.6	254 ± 74.7
PO _{max} W	83.0 ± 21.0	99.5 ± 22.7	61.9 ± 17.9†‡	60.2 ± 20.1†‡
%VO _{2R} at AT	40.2 ± 15.2	41.3 ± 11.2	44.5 ± 11.1	46.5 ± 13.3
HR _{rest} bpm	79.1 ± 12.2	88.0 ± 13.4	96.7 ± 14.1†	92.6 ± 18.6
HR _{peak} bpm	169.7 ± 24.2	183.1 ± 17.0	163.4 ± 18.7	166.2 ± 14.4

*Values are mean + standard deviation. CTRL, control; OW, overweight; SB, spina bifida; SCI, spinal cord injured; VO₂, oxygen uptake; PO, power output; AT, anaerobic threshold; HR, heart rate.

†Significantly different from CTRL, $P < 0.05$.

‡Significantly different from OW, $P < 0.05$.

female SB and OW groups had significantly higher BMI values than the control groups, while the SCI groups did not exhibit significant differences. The percent body fat of the OW, SB, and SCI groups was significantly higher than the percent body fat of the CTRL groups of the same gender, but they were not significantly different from each other.

Strength

There was no significant difference in any of the peak strength values between the SB and SCI groups for either gender despite the fact that there were a few individuals who were not wheelchair users in the SB group (Table 3). As seen in Table 3, the main differences in strength were seen in shoulder extension and flexion. Both the male and female CTRL groups had significantly greater shoulder extension strength values than the OW, SB, and SCI groups of the same gender, which were not significantly different from each other. The male CTRL group also had significantly higher shoulder flexion than the male OW, SB, and SCI groups. However, the female CTRL group had similar shoulder flexion values to the SB and SCI groups and significantly higher values than the OW group. Pubertal stage, as measured by Tanner score, was not a significant covariate that altered the analysis of strength measures between the groups.

Aerobic Fitness

Results from aerobic fitness testing are shown in Table 4. Although previous studies have shown a significant effect of pubertal stage on VO_{2peak} in adolescents, in this group Tanner stage was not a significant covariate on the VO_{2peak} per kilogram for either males or females. Therefore, it was excluded in further analyses of aerobic fitness. Within each gender, the SB and SCI groups had significantly lower VO_{2peak} values at rest than the CTRL and OW groups did. When body mass was taken into account, the SB, SCI, and OW groups had significantly lower VO_{2peak} per kilogram values than the CTRL group, but they were not significantly different from each other.

For the males, the CTRL and OW groups reached similar maximum work outputs (PO_{max}) (86 ± 4.4 watts and 93 ± 8.5 watts, respectively), while both the SB and SCI groups reached exhaustion at significantly lower levels (62 ± 4.9 watts and 60 ± 6.6 watts, respectively) than either the CTRL or OW subjects. There was no difference between the SB and SCI groups. While the female groups did not demonstrate significant differences, the relationship between the groups was similar to the male groups. For both the males and females, there were no significant differences between the diagnosis groups for AT when expressed as a percentage of VO_{2R}. However, there was a tendency for the SB and SCI groups to reach AT at a higher percentage of their VO_{2R}.

Figure 1. Percent of oxygen uptake reserve ($\%VO_{2R}$) during submaximal arm crank ergometry.

All of the groups reached similar maximum heart rates (HR_{peak}), but the male and female SB groups had significantly higher resting heart rates (HR_{rest}) than the CTRL group of the same gender. The mean HR_{rest} for the female SCI groups was also higher than the CTRL and OW groups, but the HR_{rest} for the male SCI groups showed a trend to being increased, which was not statistically significant ($P < 0.1$).

During ACE, the SB and the SCI groups had similar values for $\%VO_{2R}$ at specific workloads but both groups had significantly higher $\%VO_{2R}$ than the CTRL and OW groups did (Figure 1). The same relationship was seen during unloaded cycling ($PO = 0$ W). However, the female CTRL and OW groups had nearly identical profiles, while the male CTRL group had higher $\%VO_{2R}$ than the male OW group at all PO levels.

Overall, there was a strong inverse correlation between $\%BF$ and VO_{2max} per kilogram (Figure 2). The female SB group had the lowest correlation ($r = -0.263$, $P = 0.28$), most likely due to the low variability in $BF\%$ and VO_{2peak} within the group. The male SCI group exhibited a strong correlation coefficient, but it was not statistically significant.

For aerobic efficiency, the CTRL and OW groups had significantly greater increases in VO_2 per PO than those of the SB or SCI groups in both genders (Figure 3).

DISCUSSION

This study is the largest to date regarding aerobic fitness, upper extremity strength, and body composition in groups of adolescents with thoracic and upper lumbar spinal cord injury (SCI) or spina bifida (SB), and groups of adolescents without mobility impairment who are normal

weight (CTRL) and overweight (OW). These findings illustrate the utility of the arm-crank ergometry test using a validated ramp protocol as a method for assessing the aerobic fitness of individuals who are unable to use a bicycle ergometer or treadmill.

The majority of the SB and all of the SCI subjects in this study used a wheelchair for daily mobility and were solely dependent on their upper extremity strength and fitness to maintain their mobility and independence. Contrary to our hypothesis, these groups had significantly weaker shoulder strength, which is a primary muscle group used in wheelchair propulsion (31,32) and wheelchair transfers (33). They also exhibited poorer aerobic fitness as evidenced by the significantly lower maximal VO_2 per kilogram and the higher cardiovascular stress at equivalent workloads. The SB and SCI subjects also exhibited reduced endurance, as evidenced by their lower PO_{max} values. This measurement can be considered a combination of aerobic fitness and strength, as it is difficult to determine whether a subject stops due to muscular fatigue or cardiorespiratory fatigue. However, all subject groups reached similar maximum heart rates, which implies that most individuals were limited by cardiorespiratory fatigue.

The more objective measure of $\%VO_{2R}$ also supports the conclusion that the subjects with SB and SCI were less aerobically fit than the CTRL and OW subjects. Since VO_{2R} is a measure of relative effort or exercise intensity, it can be used to compare submaximal values between individuals. In addition to being less aerobically fit, the SB and SCI subjects had significantly higher total body fat percentage, including higher percent fat in the trunk and arms. This is further evidence for the conclusions reached

Correlation Coefficients:

Group	Correlation coefficient (r)	Significance
Female CTRL&OW	-0.597	$p \leq 0.001$
Female SB	-0.263	$p = 0.276$
Female SCI	-0.824	$p \leq 0.050$
Male CTRL&OW	-0.617	$p \leq 0.001$
Male SB	-0.735	$p \leq 0.001$
Male SCI	-0.601	$p = 0.066$

Figure 2. Relationship of peak oxygen uptake to total body fat percentage. CTRL group includes OW subjects.

in previous studies (28,34), that is, that daily wheelchair propulsion is insufficiently strenuous to elicit cardiovascular or muscle adaptation in adolescents. Figure 2 shows the relative decline in aerobic fitness with increasing body fat for all of the subject groups. The exception to this relationship is with the female SB group. However, this group was more homogenous, in terms of whole body fat percentage, than the other groups. It may be that increasing body fat is correlated with decreasing aerobic fitness only up to a point, and that there is a “floor effect.”

The one anomalous result found was that the subjects with SB and SCI reached their AT at a higher $\% \text{VO}_2 \text{R}$ than the controls. AT is a measurement that is defined by the metabolic efficiency of the oxygen delivery and uptake at the exercising muscle. It is related to the specificity of the test being used to assess aerobic fitness and cannot be compared between different methods. For example, a competitive bicyclist will have a higher AT when performing a maximum oxygen uptake

test on a bicycle ergometer than when being assessed on a treadmill. Despite the fact that the SB and SCI subjects had reduced aerobic capacity, they exhibited greater metabolic efficiency when exercising with their arms when compared to the ambulatory subjects, who are more accustomed to walking and running.

One unknown variable in this study was the contribution of the nonexercising muscle to the oxygen uptake and strength values. Although the controls performed the ACE and strength tests in the same seated or supine position as the SB and SCI subjects, it was difficult to prevent them from recruiting their lower extremities and lower abdominal muscles to maintain balance or to increase leverage. However, there were still significant differences at rest, during unloaded cranking, and at low workloads, suggesting that the lower extremities did not have a significant influence. This study is limited by its small sample sizes that prevent us from knowing whether nonsignificant changes have adequate power to be meaningful. The conclusions are

FEMALES

MALES

Figure 3. This figure illustrates the difference in aerobic efficiency by showing the increase in oxygen uptake (VO_2) per unit of work (PO).

from a convenience sample of our clinic population, which may be substantially different from clinics that put a much greater emphasis on weight management.

The results of this project support previous reports that individuals with physical disabilities are less fit and weaker than those without disabilities (8,9,16,34), even though many of these studies were conducted with small subject groups or used comparisons against normative data obtained with different protocols. What these data illustrate, however, is that profound differences are evident even during adolescence in both congenital and traumatic spinal cord dysfunction. Many of these changes are associated with increased percent body fat, as there were few differences observed among the SB, SCI, and OW groups.

CONCLUSION

Adolescents with SB and SCI had reduced aerobic capacity that was associated with being overweight and having reduced upper extremity strength. These data suggest that interventions to increase strength and fitness and to manage weight should be recommended in this population. The similar reductions in the fitness and strength values of the SB and SCI groups along with the OW able-bodied group suggest that their reduced fitness is strongly influenced by obesity. Although Norman et al (35) concluded that decreased fitness in OW adolescents could be attributed to the increased metabolic demand of moving their larger bodies through space, the use of ACE in this project eliminates that confounding factor.

The results of this project provide insight into the strength and aerobic fitness of adolescents with spinal

cord dysfunction. It has been widely reported (8,36,37) that these individuals will generally have higher rates of obesity and body fat percentage. It appears that increased adiposity is strongly associated with fitness in adolescents with and without spinal cord dysfunction. Future studies should address the lifelong consequences of a decrease in strength and fitness and an increase in obesity for individuals with mobility impairment due to spinal cord dysfunction.

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