Published in final edited form as:

J Biomech. 2017 February 28; 53: 120–126. doi:10.1016/j.jbiomech.2017.01.007.

Assessing kinematics and kinetics of functional electrical stimulation rowing

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Abstract

Hybrid functional electrical stimulation (FES) rowing has positive effects on cardiovascular fitness, producing significantly greater aerobic power than either upper body or FES exercise alone. However, there is minimal information on the kinematics, kinetics, and mechanical efficiency of FES-rowing in the spinal cord injured (SCI) population. This study examined the biomechanics of FES-rowing to determine how motions, forces, and aerobic demand change with increasing intensity. Six individuals with SCI and six able-bodied subjects performed a progressive aerobic capacity rowing test. Differences in kinematics (motion profiles), kinetics (forces produced by the feet and arms), external mechanical work, and mechanical efficiency (work produced/volume of oxygen consumed) were compared in able-bodied rowing vs. SCI FES-rowing at three comparable subpeak workloads. With increasing exercise intensity (measured as wattage), able-bodied rowing increased stroke rate by decreasing recovery time, while FES-rowing maintained a constant stroke rate, with no change in drive or recovery times. While able-bodied rowers increased leg and arm forces with increasing intensity, FES-rowers used only their arms to achieve a higher intensity with a constant and relatively low contribution of the legs. Oxygen consumption increased in both groups, but more so in able-bodied rowers, resulting in able-bodied rowers having twice the mechanical efficiency of FES-rowers. Our results suggest that despite its ability to allow for whole body exercise, the total force output achievable with FES-rowing results in only modest loading of the legs that affects overall rowing performance and that may limit forces applied to bone.

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Keywords

FES-rowing; kinematics; kinetics; mechanical efficiency; aerobic work

Introduction

Each year, 11,000 people sustain a spinal cord injury (SCI) in the United States, resulting in an estimated 276,000 people living with a chronic SCI in the US (University of Alabama at Birmingham, 2014). SCI is a life-changing event, resulting in multisystem impairment causing physiological, neurological, and psychological changes. Moreover, the SCI population is at the low end of the fitness spectrum, representing a form of “accelerated aging” (Groah et al., 2012). Hence, after an SCI, there is increased risk of cardiovascular morbidity and mortality (DeVivo et al., 1999; Myers et al., 2007), greater rates of obesity (Groah et al., 2011) and diabetes (Qin et al., 2010), and profoundly accelerated osteoporosis due to rapid decrease in bone density to approximately 60% of normal bone mass (Jiang et al., 2006).

Currently, there is no cure for SCI and effective interventions to maintain and improve health and well-being after injury are needed. Regular physical activity has important multi-system health benefits, and more vigorous exercise is associated with greater benefits (Nelson et al., 2007). SCI does not alter this effect, and in fact may make exercise of critical importance to health (Groah et al., 2012; Hooker and Wells, 1989; Nash et al., 2012; West et al., 2014a). However, this population is typically restricted to only upper body exercise, which involves a smaller amount of muscle mass and limits cardiovascular adaptations compared to lower extremity or combined activities (Figoni, 1993; Gates et al., 2002; Pitetti et al., 1994; Rimaud et al., 2012; West et al., 2014b). To overcome both of these limitations, functional electrical stimulation (FES) of the lower body combined with upper body exercise actively engages more muscle mass and demands greater cardiovascular adjustments and hence can lead to broad health benefits (Petrofsky and Phillips, 1984).

Hybrid FES-rowing allows the SCI population to exercise their upper and lower limbs concurrently (Laskin et al., 1993). In contrast to other forms of exercise (arms only, FES leg cycling, or FES leg cycling with arm exercise), FES-rowing is unique in that it provides the coordinated engagement of both the innervated arms and the non-innervated legs. The integral performance of this whole body exercise increases the active muscle mass engaged, creating a muscle pump complimentary to the upper body, augmenting blood flow to the heart. Thus, hybrid FES-rowing results in significantly greater metabolic responses than arms only exercise or FES-cycling (Hettinga and Andrews, 2007, 2008; Taylor et al., 2011; Verellen et al., 2007; Wheeler et al., 2002). Other forms of FES exercise provide only modest axial loading of the legs, such as FES-cycling (Haapala et al., 2008; Szecsi et al., 2014) and result in little benefit to bone health (BeDell et al., 1996; Eser et al., 2003; Frotzler et al., 2008). Isolated isometric muscle stimulation has been shown to have a positive impact on bone health in those with SCI (Shields et al., 2006; Shields and Dudley-Javoroski, 2006), but has little effect on cardio-respiratory health. It has been suggested by

one case report that FES-rowing may provide sufficient magnitude and frequency of loading of the legs to result in therapeutic bone benefits (Gibbons et al., 2014).

Hybrid FES-rowing resembles able-bodied rowing, but the specifics of the rowing stroke, the loading produced, and the mechanical efficiency of those with SCI who habitually train with FES-rowing are unknown. Halliday (Halliday et al., 2004) showed in a single case that motion of the arms, ankle, and knee is similar in FES-rowing as compared to able-bodied rowing. However, FES-rowing demonstrates different rowing stroke timing and external forces at both the handle and feet compared to able-bodied rowing. Optimizing the health benefits of this exercise intervention requires better understanding the kinematics and kinetics of FES-rowing in relation to the aerobic work performed. Therefore, we developed an instrumented ergometer to measure kinetics and kinematics of rowing and open circuit spirometry to determine aerobic demand during both FES-rowing and able-bodied rowing. This allowed us to characterize rowing stroke, effective upper and lower body forces across exercise intensities, and mechanical efficiency of rowing. We hypothesize that greater rowing intensity would require greater upper and lower body forces and greater oxygen consumption in both able-bodied and FES-rowers. We additionally hypothesize that the magnitude of increase in upper and lower body forces, and oxygen consumption will be greater in able-bodied compared to FES-rowing as exercise intensity increases.

Methods

Participants

Individuals with SCI (n=6) were recruited from current patients in the Spaulding Rehabilitation Hospital SCI exercise program for FES-rowing and were actively rowing on a weekly basis. All the individuals with SCI were adults with spinal cord injury of American Spinal Injury Association A at the neurological level of C5-T12 (Table 1). All subjects were medically stable, able to follow directions, able to reach sufficient leg joint range of motion to row, and able to respond to electrical stimulation of the quadriceps and hamstrings muscles. Able-bodied control subjects (n=6) were recruited via flyers at university campuses. All able-bodied subjects were free of cardiovascular, neurological, and orthopedic conditions in the lower body. Able-bodied subjects had previous rowing experience either as former varsity athletes in college or current individual training (Table 2). All subjects had a complete medical history. All procedures were approved by the Institutional Review Board at Spaulding Rehabilitation Hospital, and all participants provided written informed consent.

Experimental Setup

An adapted Concept2 ergometer (Concept2, model D) used for FES-rowing was instrumented with five force transducers and one string potentiometer (Figure 1a). A uniaxial tension load cell (Strain Measurement Device S640-100, range 0–980 N; accuracy 0.02–0.03%) was placed in series with the chain connecting the handlebar with the flywheel. Four button-style compression load cells (Strain Measurement Device S4856-100, range 0–980 N; accuracy 0.05%) were mounted under the toe and heel of the right and left foot. A linear string potentiometer (Measurement Specialties SP1-50, range 0–1270 mm; accuracy

0.25%; cycle life 250 K) was mounted in series with the rowing seat at the rower rail back end.

A 4-channel electrical stimulator (Odstock, Salisbury, United Kingdom) was used to activate the quadriceps and hamstrings through surface skin electrodes placed over the muscle motor points. The Odstock stimulator was controlled by the rower via a handle switch. The stimulation intensity was set to pulses of 40 Hz with 400 μ s pulse width.

Oxygen consumption was determined via on-line computer-assisted open circuit spirometry (ParvoMedics, Sandy, UT). Expired O_2 and CO_2 were measured during all the rowing tests to determine O_2 consumption and CO_2 production. Expired O_2 and CO_2 gas fractions were measured with paramagnetic O_2 and infrared CO_2 analyzers. A heart rate monitor (Suunto, Vantaa, Finland) was used throughout the tests.

Experimental Design: Progressive aerobic capacity test

All subjects performed a progressive aerobic capacity rowing test. Subjects were asked to refrain from strenuous exercise over the 24 hours prior to the test to limit the impact of residual fatigue. During the progressive aerobic capacity test, the subjects performed FES-rowing or able-bodied rowing, increasing wattage every 2-minutes until volitional exhaustion. The initial stages used wattages that were subject specific and intended to represent 70%, 80%, and 90% of the peak achievable workload for each individual. This was estimated from the corresponding percentage of age-predicted heart rate for the able-bodied (220 beats/min-age), and from a prior peak aerobic capacity test that had been performed for the exercise program for those with SCI. The 2-minutes stages progressed without rest intervals and after the third stage, rowing intensity was increased progressively until subjects reached volitional exhaustion. This peak was used to derive the relative intensity of the first three stages. For those with SCI, the electrical stimulation of the quadriceps and hamstrings was increased as requested by the individual to achieve the target rowing intensity.

Data Analysis

Force and position data from the load cells and the string potentiometer were recorded at 100 Hz sampling frequency using NI LabVIEW software (LabVIEW System Design Software, National Instruments, USA) (Figure 1b). All data processing was performed offline using MATLAB software (MATLAB R2014b, The MathWorks Inc., Natick, MA). A low-pass first order Butterworth filter with a cutoff frequency of 10 Hz was used to remove unwanted noise. The data were divided into 1-minute intervals for each rowing test. For each stroke, the drive and recovery phases were obtained from the seat position. The drive phase was identified by the beginning of the catch (the most anterior horizontal seat displacement). The recovery phase began at the most posterior horizontal seat displacement and ended at the beginning of the next catch. The average minute stroke rate was obtained from the drive and recovery times. Each stroke was normalized to 100% rowing stroke to obtain average force-time stroke profiles for each minute. Peak handle and feet force was determined from the average force-time stroke profile for each minute.

The external work produced was evaluated assuming a 2D rowing model, governed by the laws of classical rigid-body mechanics. The legs, torso, and arm motions were considered to

occur entirely in the sagittal plan; all lateral and vertical displacements were assumed negligible. Due to the high-backed seat used in FES-rowing and thus the limited arm motion range, the horizontal displacement of the handlebar was approximated to that of the seat. The force recorded at the feet acts at a 45° angle from the horizontal, due to the orientation of the foot plates. Thus, only the horizontal force component was used to determine feet work. The handlebar was considered to act entirely in the same horizontal direction as the seat. The total external work was calculated for the feet and arms as a function of the force and seat displacement. For each minute, the average total external work per stroke was calculated as the area under the force-displacement curve using the trapezoidal method (1).

$$W_{\text{total,avg}} = \frac{W_{\text{total}}(0s - 60s)}{\text{no.of strokes}} = \frac{W_{\text{legs}} + W_{\text{arms}}}{\text{no.of strokes}} = \frac{\int_{0s}^{60s} \vec{F}_{\text{legs}} \cdot d\vec{s}_{\text{chair}} + \int_{0s}^{60s} \vec{F}_{\text{arms}} \cdot d\vec{s}_{\text{chair}}}{\text{no.of strokes}} \quad (1)$$

To account for the different kinetics of oxygen uptake with exercise intensity, the mechanical efficiency of each rowing test was calculated as the ratio of average total external work over the volume of oxygen consumed in the last 30 seconds of each 2-minute rowing intensity bout (2).

$$\text{Efficiency}(90s - 120s) = \frac{W_{\text{total,avg}}}{VO_2}(90s - 120s) \quad (2)$$

Rowing technique was characterized by stroke rate, drive time, and recovery time. These stroke characteristics are dependent on the individual rowing workload. For each rowing stage, the relative workload was obtained as a percent of individual peak wattage. Changes in stroke characteristics were assessed via repeated measures ANOVA to examine group differences, changes in relative total workload, and their interaction. The loading profile during rowing was characterized by the upper and lower body forces. Feet and arms forces are dependent of the individual average total work (i.e. total work/no. of strokes). Changes in feet and arms forces were assessed via repeated measures ANOVA to examine group differences, changes in average total work, and their interaction. Efficiency was assessed to characterize the relationship between external work produced and internal work required in both populations. Differences in efficiency between FES-rowers and able-bodied rowers were assessed using a two-sample t-test.

Results

Kinematics and Kinetics of FES-rowing

FES-rowing and able-bodied rowing showed a similar distribution of drive (quadriceps activation) and recovery (hamstrings activation, example in Figure 2) phases of the rowing stroke (drive phase: (47±9)% vs. (53±7)% of rowing stroke (p=0.2); recovery phase: (53±9)% vs. (47±7)% of rowing stroke (p=0.2)). However, FES-rowing had a different pattern of lower and upper body coordination in which the arm pull preceded the leg extension during drive phase such that the arms initiated the stroke with the legs following (Figure 2, 3). Able-bodied rowers had simultaneous lower limb, trunk, and upper body

coordination to initiate the drive phase, resulting in coordinated peak forces in the legs and arms and distinct drive and recovery phases (Figure 3). The altered coordination in the drive phase during FES-rowing is evidenced by half of drive time (30% of the rowing stroke) spent in the most anterior horizontal position, with no movement of the lower body (Figure 2).

Overall, FES-rowing resulted in lower force magnitudes for both upper and lower body compared to able-bodied rowing (both arms and legs $p < 0.01$). FES-rowing exerted higher upper (0.30 ± 0.11 body weight (BW)) than lower (0.22 ± 0.10 BW) body force ($p = 0.01$). On the opposite, able-bodied rowers had higher lower body force (0.97 ± 0.17 BW) compared to upper body force (0.81 ± 0.12 BW; $p < 0.01$; Figure 3). In FES-rowing, the handle pull showed a large variation (30 – 70% of the rowing stroke) and the peak handle force occurred anywhere within the rowing stroke, indicative of the variety of different rowing strategies employed by those with SCI. However, in able-bodied rowing, the handle pull was 20% of the rowing stroke, on average, and the peak handle force occurred consistently at 40 – 50 % of the rowing stroke. In FES-rowing, the force at the feet was nearly constant for most of the drive phase (Figure 3), while able-bodied rowing reached a clear peak feet force half way through the drive phase (Figure 3, at 25%).

Kinematics and Kinetics of FES-rowing with Increasing Intensity

The actual exercise intensities were lower than the intended intensities for both FES and able-bodied rowers. However, the data from each group derives from three distinct intensities with overlap between the two groups corresponding to approximately 60 and 70% of the peak wattage achieved. Across all intensities, FES-rowing had higher stroke rates and higher variability than able-bodied rowing (36 ± 6 vs. 25 ± 3 spm, $p < 0.01$; Figure 4). FES-rowing demonstrated no increase in stroke rate, whereas able-bodied rowing increased stroke rate with increasing intensity ($p = 0.02$; Figure 4). Overall, time during drive and recovery was lower in FES-rowing than able-bodied rowing (drive: 0.78 ± 0.15 vs. 1.27 ± 0.30 s, $p < 0.01$; recovery: 0.96 ± 0.30 vs. 1.12 ± 0.17 s, $p < 0.01$). Both groups maintained a constant drive time (Figure 4), whereas recovery time decreased in the able-bodied ($p = 0.05$) but not in FES-rowing (Figure 4). Thus, able-bodied rowing achieved higher intensity by increasing stroke rate via a decrease in recovery time. Relative time to complete the stroke length was different between drive and recovery phases between the two groups. FES-rowing required more time in the recovery phase (drive to recovery ratio: 0.81), while able-bodied rowing spent more time in the drive phase (drive to recovery ratio: 1.13). As a group, able-bodied rowing had a more consistent profile than FES-rowing, with 5 out of 6 able-bodied rowers increasing stroke rate and only 2 out of 6 FES-rowers increasing stroke rate.

Across all intensities, FES-rowing demonstrated lower magnitudes for both peak forces and work produced by upper and lower body. With increased workload, able-bodied rowers increased foot force ($p < 0.01$; Figure 5), while FES-rowers maintained a constant foot force (intensity-group interaction $p = 0.15$; Figure 5). FES-rowers had a constant, low foot force production ($\sim 20\%$ BW) despite the increased electrical stimulation throughout the rowing exercise. For the upper body, peak handle force increased for both able-bodied and FES-rowing (both $p < 0.01$; intensity-group interaction $p < 0.01$; Figure 5). Thus, to increase

external work, able-bodied rowers increase both upper and lower body forces, while FES-rowers only increase upper body force without a change in lower body force.

Efficiency

FES-rowers had lower oxygen consumption and produced less external work than able-bodied rowers across all intensities. The total work produced over the volume of oxygen consumption provides a measure of mechanical efficiency as the ratio of external work to internal work. Oxygen consumption increased in both groups, but more so in able-bodied rowers. Able-bodied rowers are two times more efficient than FES-rowers (0.199 ± 0.006 vs. 0.101 ± 0.022 (total work)/ VO_2 ; $p < 0.01$; Figure 6), producing more external work for a higher oxygen demand.

Discussion

We assessed the kinematics and kinetics of FES-rowing and able-bodied rowing in relation to the aerobic work performed. The FES stroke is characterized by a handle pull that precedes leg extension during the drive phase and by the lack of increase in stroke rate across intensities. This reliance upon handle pull results in a lack of increase in feet force across increasing intensities and may relate to lesser overall mechanical efficiency in FES-rowing. Taken together, these data show that the total force output achievable with FES-rowing results in only modest loading of the legs that affects overall rowing performance and that may limit forces applied to bone. With increasing exercise intensity, FES-rowers did not increase forces as much as able-bodied, and did not increase lower body forces at all.

It has been suggested that FES-rowing mirrors able-bodied rowing and provides a framework for whole-body exercise in the SCI population (Halliday et al., 2004). Although it certainly engages both the upper and lower body and can resemble able-bodied rowing, the kinematics and kinetics of FES-rowing are different. The coordination of upper and lower body in FES-rowing is characterized by the handle pull preceding leg extension, reducing drive time and contributing to the overall greater stroke rate. Additionally, our results show that FES stimulated muscles are limited in the amount of force produced. Regardless of the stimulation intensity during rowing, the contribution of the legs was constant and relatively low (10% BW). FES-rowing heavily relies on the upper body to produce higher exercise intensities. The low external forces and less work produced during FES-rowing likely derive from both physiological and biomechanical limitations.

Physiological changes in muscle

Although electrical stimulation allows for whole body rowing in those with SCI, the recruitment of muscle fibers is non-physiologic. FES-rowing uses higher stimulation frequencies (40 Hz) relative to physiological activation during voluntary exercise (10–20 Hz) (Eser et al., 2003). This pattern of stimulation results in high initial forces and therefore faster ATP consumption, which increases fatigue onset and potentially accounts for lower leg strength. Furthermore, artificial muscle activation through electrical stimulation does not result in orderly recruitment of muscle fibers to initially utilize aerobic and then anaerobic metabolism, as intensity increases. This is important to consider especially in the context of

a spinal cord lesion; after SCI, muscle fibers shift towards predominantly Type II fibers (fast, anaerobic, and highly fatigable) (Karamahmeto lu et al., 1995; P D Chilibeck, 1999). Hence, the adaptations to an SCI lead to smaller working muscles which have less capacity for aerobic metabolism during exercise (Barclay et al., 1993).

Biomechanical differences in FES rowing

Another important aspect of electrical stimulation in FES-rowing is that only the quadriceps and the hamstrings are used. Able-bodied rowing involves more muscles and it is likely to result in a higher joint moment compared to FES-rowing. An optimal timing of quadriceps and hamstrings stimulation might lead to coordinated upper and lower body movement and may increase force production.

Thus, considering both the physiological and biomechanical factors, it is not surprising that FES-rowing results in relatively small external force and work production compared to able-bodied rowing.

Row training at a higher intensity results in greater musculoskeletal and cardiovascular benefits in the able-bodied population (Meredith et al., 1987). These benefits could be limited in FES-rowing due to the low forces and the relative inefficiency. However, FES-rowing inefficiency would only have direct implications for rowing performance. The purpose of FES-rowing is not necessarily competition, but to allow whole-body exercise to improve health in those with SCI. In this aspect, FES-rowing can improve cardiovascular fitness and aerobic capacity (Hettinga and Andrews, 2008; Taylor et al., 2011). Improving bone health requires significant axial loading through the long bones of the legs. However, in FES-rowing the low force production limits the loading of the legs, resulting in loads that may be insufficient to recruit the mechanoadaptive sensitivity of human bone. Previous studies have shown that FES stimulation resulting in 40% BW loading was insufficient to alter bone density, but 150% BW loading increases bone density relative to non-loaded control legs (Dudley-Javoroski et al., 2012). Optimization of hybrid FES-rowing should consider the desired outcome. To optimize bone health, future work might seek to increase total force production, thereby increasing the loads on the lower body. This will result in an improved mechanical efficiency leading to an overall better rowing performance, as well as tap into the mechanosensitivity of bone.

One of the technical limitations of this study is the 2D rowing model which neglects out-of-plane motions. However, rowing occurs mostly in the sagittal plane and this assumption is even more valid for FES-rowing where the trunk is anchored, restricting out of plane motion. Additionally, the range of motion of the handlebar was assumed to follow seat trajectory. Given the lack of trunk use in FES-rowing and the short stroke length, the displacement of the handle pull can be approximated to that of the seat, but might result in an underestimation of upper body work produced. However, the current assumption introduces only a systematic error for both groups, and most likely does not alter the overall trend. Furthermore, the average age for able-bodied rowers is about 10 years less than for FES-rowers. However, a decade of difference at this range of the age spectrum is not likely to markedly impact the outcome variables. Also, it is possible that gender differences could confound the outcome variables. Nonetheless, body mass and aerobic capacity are more

important than gender in determining rowing performance (Yoshiga and Higuchi, 2003). Moreover, the striking differences between able-bodied and FES-rowers far exceed any prior differences in rowing performance observed in males and females. Additionally, different anthropometrical characteristics and levels of expertise can result in varying kinematic and kinetic rowing strategies. These effects are even greater in the SCI population, where level of injury and extent of the spinal cord lesion further increase the variability. We attempted to control for this by selecting able-bodied and SCI subjects who had similar and consistent rowing characteristics and levels of training. Nonetheless, we did see a higher variability in the SCI population, especially in mechanical efficiency, where the variability is two times higher in FES-rowing compared to able-bodied rowing.

Though FES-rowing has been investigated for training purposes for several years, only a few kinematic and kinetic parameters have been reported and only in single case reports (Davoodi and Andrews, 2004; Gibbons et al., 2014; Halliday et al., 2004). This is the first work characterizing FES-rowing within a group of subjects, allowing for broader comparisons and conclusions. We found that even though FES-rowing allows for whole body exercise, the overall performance is limited by inefficiency in rowing technique and low forces generated by the lower body. Although this may not impact the favorable aerobic benefits of this form of exercise, it does have implications for mitigating bone loss after a SCI. Increasing force production and loads on the lower body will further enhance the potential bone health benefits of FES-rowing.

Acknowledgments

This work was funded by a Northeastern University Dean's Scholarship (Adina E. Draghici). This study was supported by National Institute of Health (R01 HL117037). We thank all our subjects for their participation.

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Figure 1.

Experimental apparatus (a) Adapted Concept2 rowing ergometer instrumented with 5 force transducers (Handle, Left/Right Toe/Heel) and 1 string potentiometer (Seat); (b) Biofeedback system for real time data collection.

Figure 2. Rowing seat position for a representative able-bodied rower and FES-rower during one rowing cycle, with the horizontal axis normalized to 100% of the rowing stroke. Schematic representation of arms and legs at different points in the rowing cycle is shown below the graph.

Figure 3. External force output at the handle and at the feet for a representative able-bodied rower (left) and FES-rower (right). Standard deviations for the forces shown are less than 0.014 body-weight (BW) during 1 minute of rowing for these subjects.

Figure 4.

Stroke characteristics with increasing intensity in able-bodied rowing vs. FES-rowing. Data are group mean $\pm$ standard deviation at 6 consecutive minutes (with 2 minutes for each intensity stage). Note the different y scale for able-bodied vs. spinal cord injured.

Figure 5. Upper and lower body peak forces with increasing intensity in able-bodied rowing vs. FES-rowing (1-minute rowing intervals). Note the different x and y scales for able-bodied vs. spinal cord injured. Each symbol represents a different subject.

Figure 6. Mechanical efficiency with increasing intensity in able-bodied rowing vs. FES-rowing: (total work produced)/(VO₂ consumed) (last 30-sec of each 2-min rowing stage). Data are mean $\pm$ standard deviation.

Table 1

Spinal cord injured subjects characteristics

Participant	Lesion Level	ASIA Classification	Age (y)	Time Since Injury (y)	Weight (kg)	Height (m)	Sex
1	T4	A	43	20	54.59	1.803	M
2	T3	A	23	2	64.27	1.549	F
3	C6	A	38	15	87.36	1.702	M
4	T4	A	41	4	68.00	1.727	M
5	T1	A	34	3	86.91	1.854	M
6	T4	A	30	2	70.77	1.575	M

ASIA = American Spinal Injury Association

Table 2

Able-bodied subjects characteristics

Participant	Age (y)	Weight (kg)	Height (m)	Sex
1	23	64.09	1.727	F
2	22	74.09	1.778	F
3	22	103.6	1.880	M
4	22	65.18	1.727	F
5	28	89.55	1.854	F
6	21	68.45	1.778	M