Effects of Concurrent Respiratory Resistance Training on Health-Related Quality of Life in Wheelchair Rugby Athletes: A Pilot Study

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Purpose: To compare the effects of 9 weeks of training with a concurrent flow resistance (CFR) device versus a concurrent pressure threshold resistance (CPTR) device on health-related quality of life (HRQoL) in wheelchair rugby (WR) athletes. **Method:** Twenty-four male WR athletes (22 with tetraplegia, 1 with a spastic cerebral palsy, and 1 with congenital upper and lower limb deformities) were matched by lesion level, completeness of injury, and rugby classification prior to being randomly assigned to 1 of 3 groups: (1) CPTR (n=8), (2) CFR (n=8), or (3) controls (CON, n=8). Pre/post testing included assessment of HRQoL as measured by the Short-Form Health Survey Version 2.0 (SF-36v2). Manufacturer protocol guidelines for the CFR and CPTR groups were followed for breathing exercises. **Results:** Sixteen participants completed the study (CPTR=4, CFR=5, CON=7). The Mann-Whitney *U* rank order revealed significantly greater reductions in bodily pain ($P = .038$) and improvements in vitality ($P = .028$) for CFR versus CON. **Conclusion:** Results from this study suggest that training with a CFR device improves some aspects of HRQoL (eg, vitality and bodily pain) in WR athletes. Further research with a larger sample size is needed to examine the impact of these devices on improving HRQoL for wheelchair athletes. **Key words:** *quality of life, respiratory resistance training, SF-36, spinal cord injury*

Persons with cervical spinal cord injuries, also known as tetraplegia, experience physical and emotional challenges that impact their overall health-related quality of life (HRQoL).[1-4] According to the Centers for Disease Control and Prevention, HRQoL "refers to a person or group's perceived physical and mental health over time."[5(p1)] Over the last decade, numerous researchers investigating the effects of tetraplegia on HRQoL have identified physical activity as an important factor in improving the HRQoL of persons with this disability.[1,6-14] However, one challenge resulting from physical activity often faced by those with tetraplegia involves respiration. Respiratory complications have been shown to be negatively associated with life satisfaction[15] and HRQoL[16-18] for persons with spinal cord injury (SCI). In light of this, and given that wheelchair rugby (WR) is one of the fastest growing sports for persons with tetraplegia,[19] it is worth investigating whether training techniques designed to improve respiratory function, which in turn may increase physical activity, could enhance the HRQoL of WR players.

A training technique that has effectively improved respiratory function in persons with tetraplegia is concurrent respiratory resistance training (CRRT).[20-23] CRRT targets both inspiratory and expiratory muscles concurrently through the use of either a concurrent flow resistance (CFR) device[21] or a concurrent pressure threshold resistance (CPTR) device.[24] In general, studies investigating the effects of training with a CFR device[20-23] or a CPTR device[23] have reported improvements in lung function of persons with tetraplegia who trained with a CFR device.

Previously, we investigated the effects of training with a CFR device[22,23] and CPTR device[23] on physical parameters in wheelchair athletes. In the former, we observed a possible link between training with a CFR device and HRQoL.[22] In that study, wheelchair athletes reported being more comfortable and able to sit-up straighter, lift their arms higher, sneeze and cough harder, and take deeper breaths. Based on those promising results[22] and the overwhelming interest in enhancing HRQoL for this population,[1-3,6,7,10-13,16,17,25-39] it

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would seem prudent to investigate the potential impact of CRRT on the overall physical and mental health of persons with tetraplegia. Therefore, the purpose of this study was to compare the effects of training with a CFR device versus a CPTR on HRQoL in WR athletes. Based on both the qualitative data gathered during exit interviews in a previous study by Litchke et al[22] and the positive effects of training with a CFR device on respiratory function,[22,23] we hypothesized that 9 weeks of training with a CFR device would have a significant impact on HRQoL in WR athletes.

Methods

Participants

This study builds upon previously collected data in Litchke et al.[23] We reported the effects of a CFR device versus a CPTR device on lung function and aerobic capacity in WR athletes with tetraplegia. In the present study, using data from the same subjects, we focused on HRQoL for these WR athletes. The participants consisted of 24 competitive male WR athletes from 3 area teams in Texas. Demographics included ages from 17 to 35 years, time since injury from 6 months to 17 years, lesion level between C5 to C7, time playing rugby from 3 months to 16 years, and rugby classification from .5 to 3.5.[40] Eleven subjects had complete lesions, 11 had incomplete lesions, 1 had spastic cerebral palsy, and 1 had congenital upper and lower limb deformities. In an attempt to maintain the largest possible sample size, the participants with non-spinal cord lesions were included in the study. Participants were matched on 3 main factors: (1) rugby classification, (2) level of injury, and (3) completeness of injury. Based on these classifications, athletes were then randomly assigned to 1 of 3 groups: (1) CPTR group (n=8), (2) CFR group (n=8), or (3) a control group (CON, n=8). Of the initial 24 subjects, 16 returned for posttesting (CPTR=4, CFR=5, CON=7). Six athletes withdrew for unspecified reasons, and 2 athletes were dismissed from the study for noncompliance. Results from the 16 remaining subjects were used in the final data analyses.

Procedures

This study was conducted under the auspices of the Institutional Review Board of Texas State University-San Marcos, which provided ethical review of the study procedures. After providing a detailed description of the study procedure, written consent was obtained from each participant.

Detailed physiological testing and training procedures are provided in Litchke et al.[23] Specific to this study, the 36-item Medical Outcome Study Short-Form Health Survey Version 2.0 (MOS SF-36v2; Quality Metrics, 2007) was completed at the beginning and end of the 9-week CRRT period. Procedures for administration of this instrument, as outlined by Ware et al,[41] were followed precisely.

The CFR group trained with the Expand-a-Lung (Expand-a-Lung Inc, Miami, Florida) and the CPTR group trained with the PowerLung Performer model (PowerLung Inc, Houston, Texas). A thorough description of these CRRT devices can be found in Litchke et al.[23] Each participant was given verbal and visual instructions on how to use the CRRT device and then was asked to demonstrate the accurate use of the device to the primary investigator. Both groups were instructed to follow the user guide developed by the company throughout the 9-week period and to begin CRRT training with their respective devices set at level 1.

PowerLung training protocol

Participants in the CPTR group were instructed to perform all breathing exercises in a seated and upright position in a well-ventilated area. One breathing cycle required the participants to (a) inhale fully and forcefully through their mouth for 3 seconds, filling their lungs completely; (b) hold their breath for 1 to 2 seconds; (c) exhale fully, forcefully, and deeply through the mouthpiece for 3 seconds, emptying their lungs completely; and (d) pause for 1 to 2 seconds. Based on manufacturer guidelines, they were asked to perform 3 sets of 10 breathing cycles 3 times per day (in the morning, before exercise, and at night) every day for 9 weeks. On the days the participants did not exercise, they were asked to perform the breathing exercises only in the morning and at night. Once

Table 1. Domains of the SF-36v2

Domain	Acronym	Description
Physical Functioning	PF	Limitations in performing physical activities
Role Physical	RP	Problems with work or other daily activities due to physical health
Bodily Pain	BP	Pain frequency and extent role interferences due to pain
General Health	GH	Pertaining to global evaluations of general health, such as feeling well or ill
Vitality	VT	Perceived energy level
Social Functioning	SF	Extent to which mental or physical health interferes with normal social activities, such as visiting family or friends
Role Emotional	RE	Problems with work or other daily activities due to emotional health
Mental Health	MH	Reflects general mood or affect, including depression, anxiety, and positive well-being

they were able to perform the sequence 10 times without experiencing respiratory muscle fatigue, lightheadedness, or dizziness, they were instructed to increase the inspiratory and/or expiratory dial that controls resistance to airflow by 1 level.[23]

Expand-a-Lung training protocol

Participants in the CFR group were instructed to perform all breathing exercises in a seated, upright position while in a well-ventilated area. One breathing cycle required the participants to (a) inhale as slowly and deeply as possible through the mouthpiece; (b) hold their breath for 2 to 5 seconds; (c) exhale through the mouthpiece slowly until almost out of breath; and (d) forcefully blow out as much of the remaining residual air as possible. Participants were instructed to repeat this breathing cycle up to 10 times, with 10- to 20-second rest periods between each sequence. Based on manufacturer guidelines, they were asked to perform 1 set of 10 breathing cycles 3 different times per day (in the morning, before exercise, and at night) every day for 9 weeks. On the days the participants did not exercise, they were asked to perform the breathing exercises only in the morning and at night. Once they were able to perform the sequence 10 times without experiencing respiratory muscle fatigue, lightheadedness, or dizziness, they were instructed to increase the dial that controls resistance to airflow by 1 level.[23]

Measures

The primary measure used in this study was the SF-36v2, which has been validated for use with persons who have tetraplegia.[26,29,30,32-35,37,42,43] The SF-36v2 consists of 36 items, 35 of which are aggregated to score 8 dimensions of health, including (1) physical functioning (PF), (2) role physical (RP), (3) social functioning (SF), (4) bodily pain (BP), (5) general mental health (MH), (6) role emotional (RE) , (7) vitality (VT), and (8) general health perceptions (GH).[43] **Table 1** lists each domain with a corresponding acronym and description. The terms in the physical function section of the SF-36v2 were changed to be more appropriate for individuals with tetraplegia as suggested by previous research reviewers of the SF-36v2.[2,44-46] For example, "climbing stairs or walking more than a mile" was changed to "propelling up a steep ramp or pushing more than a mile." Items from each dimension were summed and rescaled with a standard scale range of 0 to 100, with a higher score indicating a better perception of health.[43]

Data screening and analysis

Data collected from the study during pretesting were screened for missing data and outliers and to evaluate the fulfillment of test assumptions such as linearity and normality. The results from the data screening revealed mixed findings for the 8 HRQoL

Table 2. Pre- and posttest changes for measures of SF-36v2 eight domains

SF-36 domains	CON (n = 7)		CPTR (n = 4)			CFR (n = 5)		
	Pre	Post	Pre	Post	NIE[a]	Pre	Post	NIE
PF	53.42±3.36	53.41±3.57	48.08±9.77	45.66±10.52	-4.98%	48.19±7.49	49.45±9.47	2.62%
RP	51.46±8.49	53.32±5.71	51.10±6.67	50.04±8.40	-5.7%	52.95±5.34	52.54±6.02	-4.4%
BP	54.94±8.34	46.9±13.42	44.58±12.91	51.45±12.73	29.9%	51.05±8.06	51.98±8.33	16%*
GH	57.02±3.29	57.77±4.53	56.03±2.74	52.46±4.21	-7.7%	55.13±6.41	59.13±2.72	6%
VT	56.55±7.40	54.62±4.19	55.99±3.93	57.58±1.50	6.2%	53.34±3.56	58.43±5.74	12.8%*
SF	52.95±5.19	53.73±5.26	52.76±5.22	57±0	6.5%	52.49±9.76	54.67±4.88	2.7%
RE	54.76±1.91	55.28±1.59	53.93±3.90	52.97±5.83	-2.7%	53.94±4.76	53.55±5.22	-1.6%
MH	48.8±7.06	54.03±3.94	50.01±7.62	58.46±2.30	6.2%	53.39±10.04	57.33±5.84	-18.1%

Note: BP = bodily pain; CFR = concurrent flow resistance treatment group; CON = control group; CPTR = concurrent pressure threshold resistance treatment group; GH = General Health; MH = Mental Health; NIE = net intervention effect; PF = Physical Functioning; RE = Role-Emotional; RP = Role-Physical; SF = Social Functioning; VT = Vitality.

[a]A negative % change indicates a decrease from pre- to posttest measures.

*$P < .05$.

domains. The assumptions of normality, linearity, and homogeneity of variance were violated for 3 of the SF-36v2 domain variables: VT, SF, and RE. Yet, the same assumptions were not violated for the other 5 SF-36v2 domain variables: MH, PF, RP, BP, and GH. Due to some variations of normality and linearity and the reduction in sample size prior to posttesting (n = 24 to n = 16), nonparametric test Mann-Whitney *U* rank order was performed to compare between group differences for VT, SF, RE, MH, PF, RP BP, and GH. Finally, to characterize the effects of the intervention, the net intervention effect (NIE) was calculated using the following formula:

$$\text{NIE} = [(I_{post} - I_{pre})/ I_{pre}] - [(C_{post} - C_{pre})/ C_{pre}] \text{ x } 100$$

where *I* is equal to CPTR or CFR and *C* is equal to CON.[47]

SF-36 scoring

In accordance to standardized methods, the individual SF-36v2 items were coded, summed, and transformed for all 8 domains. Each of the transformed scores were then converted to *z* scores and finally to norm-based scores. The transformed scores are standardized to a mean score of 50 and a standard deviation of 10. Because the standard deviation is 10 for all 8 domains, each 1 point difference or change in scores also has a direct interpretation. A 1 point difference or change is one-tenth of a standard deviation unit or an effect size of .10.[41] To reduce error and verify tabulation of all scores throughout each step in transformation, they were calculated separately by hand and then compared for accuracy by 2 trained research assistants. The primary investigator performed random scoring checks recommended in the SF-36v2 manual that included cross-calculation of several respondents' scores. In addition, correlations were computed between each scale to verify that they are positive in direction and of substantial magnitude (.3 or higher).[41]

Results

The group means, standard deviations, and NIE for subject characteristics, as well as the pre- and posttest measures, are presented in **Table 2**. The Kruskal-Wallis test revealed no group differences in the pretest values for (a) rugby classification *(P* = .274), (b) time since injury *(P* = .621), and (c) time playing rugby *(P* = .507). Furthermore, chi-square analysis revealed no group differences in lesion level (*P* = .304) and completeness of injury *(P* = .258). **Table 3** represents the results of the Mann-Whitney *U* test, which revealed significant group differences in change from pretest to posttest between CFR when compared to the CON group for a significant reduction in BP (*Z* = -2.07, *P* = .038), as well as a significant increase in VT (*Z* = -2.19, *P* = .028). In addition, the effect sizes were

Table 3. Comparison of change in the quality of life between CFR and the CON group

	Physical Function	Role Physical	Bodily Pain	General Health	Vitality	Social Functioning	Role Emotional	Mental Health
Z	-.99	-.78	-2.07	-.89	-2.19	.08	-.75	-.24
p	.320	.435	.038*	.371	.028*	.933	.456	.807
η^2	.127	.048	.304	.191	.326	.022	.071	.053
ES	Large	Medium	Large	Large	Large	Small	Medium	Medium

Note: CON = control; CFR = concurrent flow device; ES = effect size.
* $P < .05$.

calculated for all 8 domains on the SF-36v2 for all 3 groups. The effect sizes for the quality of life dimensions ranged from small to large and are as follows: PF = .127, RP =.048, BP = .304, GH =.191, VT =.326, SF =.022, RE = .071, and MH = .053. The eta-squared estimate of effect size was interpreted as follows: .01 = small effect, .06 = medium effect, and .14= large effect.[48]

With regard to BP following training with a CFR device, 2 athletes reported decreased pain, 2 reported no change in their pain status, and 1 reported worse pain. Both athletes who experienced less pain improved approximately 9 points, reportedly going from mild to very mild with regard to degree of pain experienced during the previous 4 weeks. Furthermore, these same athletes reported that little or no pain interfered with their daily lives. Last, comments from these athletes indicated that after practice, one athlete was not as sore and the other stated his congestion cleared.

For VT scores, 4 of the 5 individuals reported an increase in energy, while 1 remained unchanged. The VT scores for 2 athletes increased by 9 points, another by 4 points, and another by 3. The 2 athletes who improved the most noted feeling less fatigued and more energetic.

Discussion

This pilot study evaluated the effects of 2 types of CRRT devices on HRQoL in a small sample of WR athletes. Based on previous research[20-22] and data collected in our laboratory, [23] we expected that 9 weeks of training with a CRRT device, especially in the CFR group, would positively impact all dimensions of HRQoL. However, our expectations were only partially met, as the CFR device had an impact on only 2 of the 8 dimensions and the CPTR had no impact on any dimension. We observed that 9 weeks of training with a CFR device significantly enhanced VT and reduced BP when compared to a CON group. However, training with either a CPTR or CFR device did not improve any other dimension of HRQoL, including PF, RP, RE, SF, MH and GH.

Notably, the CFR group's 5-point increase in VT scores was found to be statistically different than the 2-point decrease reported in the CON group but not statistically different than the 2-point increase reported in the CPTR group. The NIE for VT in the CFR group was 13% and only 6% in the CPTR group. Interviews following the interventions with the athletes reinforced these findings, as one athlete in the CFR group reported experiencing fewer limitations due to breathing on the court while another stated, "I have an easier time breathing and getting up in the morning." Likewise, the CFR group's 1-point decrease in BP was found to be statistically different than the 8-point increase reported in the CON group but not statistically different than the 7-point decrease reported in the CPTR group. Counterintuitively, the NIE for BP was 16% in the CFR group versus 30% in the CPTR group. Though the NIE was large, the lack of significant differences between the CPTR and CON groups might be attributable to the rather large variation in BP scores reported within the CPTR group. In light of this, the large NIE found in both treatment groups suggests that

a larger sample might show whether BP changes as a result of training with either CPTR device.

The improvements observed in VT may be due, in part, to the respiratory adaptations that resulted from CFR training. In a previous report focusing on the physiological changes observed in these WR players, we showed that significantly greater improvements in overall respiratory function (as measured by maximum voluntary ventilation [MVV]) were observed in the CFR versus CPTR group.[23] Postintervention interviews supported this finding, in that 2 athletes who trained with the CFR device agreed that it was easier to take deeper breaths, while another stated that he felt more comfortable and his lungs felt stronger. These results are consistent with a previous study that we conducted in our laboratory involving a different group of wheelchair athletes training with a CFR device for 10 weeks.[22] Collectively, our quantitative and qualitative results on training with the CFR device in 2 different samples of wheelchair athletes suggest that improvements in lung function and attenuation of respiratory muscle fatigue may contribute to the increase in vitality. Indeed, this apparent association between lung function and vitality has been previously documented in individuals with compromised respiratory function due to a physiological condition.[49] Specifically, de Freitas Fregonezi and colleagues [49] observed a significant relationship between forced vital capacity (FVC) and vitality in individuals with myasthenia gravis, a neuromuscular disorder that impacts the respiratory muscles. They reported that subjects had low FVC and vitality scores compared to referenced values. In that same study, a similar, though not statistically significant, relationship appeared between MVV and vitality. As is the case with the present study, the lack of significance was attributed to a small sample size, individual variability, and between-group variability.

Relationships between performance on pulmonary function tests and several dimensions of HRQoL have been observed in patients with pulmonary impairments.[50,51] Previous studies demonstrated a reduction in HRQoL[51,52] and lung function[52] in individuals with acute respiratory distress syndrome (ARDS). Schelling et al,[51] in particular, recommended that an association between HRQoL and pulmonary function existed by demonstrating that the lowest HRQoL scores occurred among ARDS survivors who experienced multiple pulmonary function impairments. Furthermore, Jain et al[16] observed that the physical functioning domain for HRQoL was lower in persons with SCI with a reduced FVC and percent of predicted forced expiratory volume in 1 second (FEV_1). Therefore, based on this relationship, Jain et al[16] suggested that interventions designed to improve pulmonary function would improve HRQoL. Our findings support this postulation in that the current research demonstrated that an improvement in MVV among the CFR group resulted in concomitant improvement in vitality.

Another important finding in this present study is that BP improved for those who trained with a CFR device. Although there was an even larger NIE in the CPTR group, it was not significant. One athlete from the CPTR group reported experiencing a urinary tract infection (UTI) that resolved itself by the end of the study. This, perhaps, impacted the group's rather large average reduction in BP scores and large standard deviation. Nevertheless, BP is oftentimes experienced by persons with SCI. For instance, using follow-up questions to the SF-36v2, Dudley-Javorski and Shields[2] identified 5 secondary complications of SCI that were related to pain, including leg spasms, leg joint stiffness, difficulty coughing, back pain, and shoulder pain. In line with these results, Post[15] found respiratory problems and UTI were related to poor physical health. The prevalence of respiratory problems, pain, and UTI were also related to psychological functioning. In addition, respiratory problems and pain were also related to poor life satisfaction. More specifically, persons with tetraplegia in Post's[15] study reported having difficulty breathing during the past 4 weeks that significantly impacted physical, psychological, and social functioning with regard to health status and life satisfaction scores.

The adverse effect pain has on the overall quality of life (QOL) of persons with tetraplegia is clear.[2,14,35,36,38,52-54] Furthermore, the intensity of the pain worsens the QOL in persons with tetraplegia and interferes with their integration

back into community life.[53] Likewise, the negative thoughts about pain adversely affect QOL in this population.[38] Specific to persons with tetraplegia, Middleton[35] found significantly lower QOL in the domain of physical functioning and greater limitation due to bodily pain. In short, because tetraplegia is associated with multiple physical impairments (eg, decreased motor and neurological function that impacts respiratory muscle function), the additional burden of persistent pain can substantially decrease QOL.[54] For example, results of a study that involved more than 1,000 persons with SCI in 4 countries revealed that pain relief was determined to be one of the highest priorities for this population.[9] In light of the negative effects of pain on QOL, any effect that a training device may have on reducing bodily pain in persons with SCI is worthy of consideration.

A thorough review of the literature on this population resulted in no substantiated indications as to why pain reduction occurred. Researchers investigating the effects of regular aerobic and resistance training exercises on persons with SCI have also reported reductions in bodily pain,[8] but did not propose a mechanism. However, it is widely accepted that pain tolerance increases as a result of training in able-bodied individuals.[55,56] The most commonly cited explanation for this is that exercise stimulates the release of beta-endorphins, which blocks pain by acting on opiate receptors in the brain. Though yet to be investigated, perhaps regular CFR training is a potent inducer of the release of this hormone.

There were some limitations to this study. Indeed, it is possible that some participants underutilized these devices and may not have been compliant with the training protocol. The protocols prescribed in this study require a large degree of motivation. Lesser motivated participants may not have (a) completed the required number of sets and repetitions each day, (b) performed each repetition with maximum effort; (c) increased the level of resistance at an optimal rate of progression; or (d) performed any combination of these. We can only rely on what was stated in the training logs and communicated to us by the participants and assume that the participants were truthful when they indicated that they complied with the training instructions. In light of this limitation, it is indeed possible that some did not train with enough intensity with their CFFR device to experience improvements in every domain of HRQoL.

Conclusion

The results of this pilot study suggest that training with a CFR device improves vitality and reduces bodily pain in WR athletes. These positive findings may be explained, at least in part, by the effects that training with a CFR device has on pulmonary function. Findings from this pilot study should be interpreted with caution, however, due to the small sample size, rate of attrition, and population investigated. While the sample size used in this study is not too dissimilar from the sample sizes reported in other studies involving persons with SCI,[2,7,8,11,28] the statistical power is low. However, most of the effect sizes were large, which indicates that the power of the study may have been too small to detect statistical significance. Future research involving CRRT should include a larger sample size and address the ideal level of intensity to achieve long-lasting improvement in HRQoL and cardiopulmonary variables. Determining whether certain patient conditions have a more favorable response to CRRT needs to be addressed as well.

REFERENCES

1. Anneken V, Hannssen-Doose A, Hirschfeld S, Scheuer T, Thietje R. Influence of physical exercise on quality of life in individuals with spinal cord injury. *Spinal Cord.* 2010;48:393-399.
2. Dudley-Javoroski S, Shields RK. Assessment of physical function and secondary complications after complete spinal cord injury. *Disabil Rehabil.* 2006;28(2):103-110.
3. Kennedy P, Lude P, Taylor N. Quality of life, social participation, appraisals and coping post spinal cord injury: a review of four community samples. *Spinal Cord.* 2006;44:95-105.
4. Murray RF, Asghari A, Egorov DD, et al. Impact of spinal cord injury on self-perceived pre- and postmorbid cognitive, emotional and physical functioning. *Spinal Cord.* 2007;45:429-436.

5. Center for Disease Control and Prevention. Health-related quality of life. June 3, 2010. http://www.cdc.gov/hrqol/.
6. Bassett RL Martin Ginis KA. More than looking good: impact on quality of life moderates the relationship between functional body image and physical activity in men with SCI. *Spinal Cord.* 2009;47:252-256.
7. Dallmeijer AJ, van der Woude HHV. Health related functional status in men with spinal cord injury: relationship with lesion level and endurance capacity. *Spinal Cord.* 2001;39:577-583.
8. Hicks AL, Martin KA, Ditor DS, et al. Long-term exercise training in persons with spinal cord injury: effects on strength, arm ergometry performance and psychological well-being. *Spinal Cord.* 2003;41:34-43.
9. Kennedy P, Lude P, Taylor N. A pilot investigation of a psychosocial activity course for people with spinal cord injury. *Psychol Health Med.* 2006;11(1):91-99.
10. McVeigh SA, Hitzig SL, Craven D. Influence of sport participation on community integration and quality of life: a comparison between sport participants and non-sport participants with spinal cord injury. *J Spinal Cord Med.* 2009;32(2):115-124.
11. O'Neill SB, Maguire S. Patient perception of the impact of sporting activity on rehabilitation in a spinal cord injuries unit. *Spinal Cord.* 2004;42:627-630.
12. Stevens SL, Caputo JL, Fuller DK, Morgan DW. Physical activity and quality of life in adults with spinal cord injury. *J Spinal Cord Med.* 2008;3:373-378.
13. Tasiemski T, Kennedy P, Gardner P, Taylor N. The association of sports and physical recreation with life satisfaction in a community sample of people with spinal cord injuries. *NeuroRehabil.* 2005;20:253-265.
14. Tawashy AE, Eng JJ, Lin K H, Tang PF, Hung C. Physical activity is related to lower levels of pain, fatigue and depression in individuals with spinal-cord injury: a correlational study. *Spinal Cord.* 2009;47:301-306.
15. Post MWM, de Witte LP, van Asbeck FWA, van Dikjk AJ, I Schrijvers AJP. Predictors of health status and life satisfaction in spinal cord injury. *Arch Phys Med Rehabil.* 1998;79:395-402.
16. Jain NB, Sullivan M, Kazis LE, Tun CG, Garshick E. Factors associated with health-related quality of life in chronic spinal cord injury. *Am J Phys Med Rehabil.* 2007;86(5):387-396.
17. Smith BM, LaVela SL, Weaver FM. Health-related quality of life for veterans with spinal cord injury. *Spinal Cord.* 2008;46:507-512.
18. Zimmer MB, Nantwi K, Goshgarian HG. Effect of spinal cord injury on the respiratory system: basic research and current clinical treatment options. *J Spinal Cord Med.* 2007;30:319-330.
19. United States Quad Rugby Association. Quad rugby: What is it all about? June 23, 2010. http://www.quadrugby.com/qr-brief.htm.
20. Fugl-Meyer AR. A model for treatment of impaired ventilatory function in tetraplegic patients. *Scand J Rehabil Med.* 1971;3:168-177.
21. Huldtgren AC, Fugl-Meyer AR, Jonason E, Bake B. Ventilatory dysfunction and respiratory rehabilitation in post-traumatic tetraplegia. *Euro J Respir Dis.* 1980;61:347-356.
22. Litchke LG, Russian CJ, Lloyd LK, Schmidt EA, Price LP, Walker JL. Effects of respiratory resistance training with a concurrent flow device on wheelchair athletes. *J Spinal Cord Med.* 2008;31(1):7-13.
23. Litchke LG, Russian CJ, Lloyd LK, Schmidt EA, Reardon R. The effects of two types of concurrent respiratory resistance training devices on measures of physiological performance in wheelchair rugby athletes. *Ther Rec J.* 2010;44(1):51-62.
24. Wells GD, Plyley M, Thomas S, Goodman L, Dufflin J. Effects of concurrent inspiratory and expiratory muscle training on respiratory and exercise performance in competitive swimmers. *Euro J Appl Phys.* 2005;94:527-540.
25. Barker RN, Kendall MD, Amsters EI, Pershouse KJ, Haines TP, Kuipers P. The relationship between quality of life and disability across the lifespan for people with spinal cord injury. *Spinal Cord.* 2009;47:149-155.
26. Elfstrom ML, Ryden A, Kreuter M, Taft C, Sullivan M. Relations between coping strategies and health-related quality of life in patients with spinal cord lesion. *J Rehabil Med.* 2005;37:9-16.
27. Franceschini M, Di Clemente B, Rampello A, Nora M, Spizzichino L. Longitudinal outcome 6 years after spinal cord injury. *Spinal Cord.* 2003;41:280-285.
28. Hammell WK. Quality of life among people with high spinal cord injury living in the community. *Spinal Cord.* 2004;42:607-620.
29. Haran MJ, Lee BB, King MT, Marial O, Stockler MR. Health status rated with the medical outcomes study 36-item short-form health survey after spinal cord injury. *Arch Phys Med Rehabil.* 2005;86;2290-2295.
30. Krahn GL, Suzuki R, Horner-Johnson W. Self-related health in persons with spinal cord injury: relationship of secondary conditions, function and health status. *Qual Life Res.* 2009;18:575-584.
31. Krause JS. Aging, life satisfaction, and self-reported problems among participants with spinal cord injury. *Top Spinal Cord Inj Rehabil.* 2010;15(3):34-40.
32. Kreuter M, Siosteen A, Erkholm B, Bystrom U, Brown DJ. Health and quality of life of persons with spinal cord lesion in Australia and Sweden. *Spinal Cord.* 2005;4:123-129.
33. Leduc BE, Lepage Y. Health-related quality of life after spinal cord injury. *Disabil Rehabil.* 2002;24(4):196-202.
34. Lidal IB, Veenstra M, Hjeltnes N, Biering-Sorensen F. Health-related quality of life in persons with long-standing spinal cord injury. *Spinal Cord.* 2008;46:710-715.
35. Middleton J, Tran Y, Craig A. Relationship between quality of life and self-efficacy in persons with spinal cord injuries. *Arch Phys Med Rehabil.* 2007;88:1643-1648.
36. Murray RF, Asghari A, Egorov DD, et al. Impact of spinal cord injury on self-perceived and pre- and

postmorbid cognitive, emotional, and physical functioning. *Spinal Cord.* 2007;45:429-436.
37. Saadat S, Javadi M, Divshali BS, et al. Health-related quality of life among individuals with long-standing spinal cord injury: a comparative study of veterans and non-veterans. *BioMed Cent Pub Health.*2010;10(6):1-7. http://www.biomedcentral.com/1471-2458/10/6
38. Wollaars MM, Post MWM, van Asbeck FWA, Brand N. Spinal cord injury pain: the influence of psychologic factors and impact on quality of life. *Clin J Pain.* 2007;23(5):383-391.
39. Zabriskie RB, Lundbeg NR, Groff DG. Quality of life and identity: the benefits of a community–based therapeutic recreation and adaptive sports program. *Ther Rec J.* 2005;39(3):176-171.
40. United States Quad Rugby Association. Quad rugby classification. June 23, 2010. http://www.quadrugby.com/class.htm.
41. Ware JE, Kosinski MA, Dewey JE. *How to Score Version 2 of the SF-36™ Health Survey: Standard & Acute Forms.* Lincoln, RI: QualityMetric, Inc; 2002.
42. deRoon-Cassini TA, St. Aubin ED, Valvano A, Hastings J, Horn P. Psychological well-being after spinal cord injury: perception of loss and meaning making. *Rehabil Psychol.* 2009;54(3):306-314.
43. Forchheimer M, McAweeney M, Tate DG. Use of the SF-36 among persons with spinal cord injury. *Am J Phys Med Rehabil.* 2004; 83(5):390-395.
44. Luther SL, Kromrey J, Powell-Cope G, et al. A pilot study to modify the SF-36v physical functioning scale for use with veterans with spinal cord injury. *Arch Phys Med Rehabil.* 2006;87:1059-1066.
45. Meyers AR, Andresen EM. Enabling our instruments: accommodation, universal design, and access to participation in research. *Arch Phys Med Rehabil.* 2000;81(12):S5-9.
46. Tate D. Medical outcome study SF-36 and SF 12. In: Tulsky D, Chair. *Quality of Life.* Symposium conducted at the meeting of the Global Spinal Cord Injury Conference; June 2006; Boston, MA.
47. Kahn EB, Ramsey LT, Brownson RC, et al. The effectiveness of intervention to increase physical activity: a systematic review. *Am J Prev Med.* 2002;22(4S):73-107.
48. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences.* 2nd ed. Hillsdale, NJ: Lawrence Erlbaum; 1988.
49. de Freitas Fregonezi GA, Regiane-Resqueti V, Pradas J, Vigil L, Casan P. The relationship between lung function and health-related quality of life in patients with generalized myasthenia gravis. *Archivos de Bronconeumología.* 2006;42(5):218-224.
50. Davidson TA, Caldwell ES, Curtis JR, Hudson LD, Steinberg KP. Reduced quality of life in survivors of acute respiratory distress syndrome compared with critically ill control patients. *J Am Med Assoc.* 1999;281(4):354-360.
51. Schelling G, Stoll C, Vogelmeier C, et al. Pulmonary function and health-related quality of life in a sample of long-term survivors of the acute respiratory distress syndrome. *Intens Care Med.* 2000;26:1304-1311.
52. Budh CN, Osteraker AL. Life satisfaction in individuals with spinal cord injury and pain. *Clin Rehabil.* 2007;21:89-96.
53. Donnelly C, Eng JJ. Pain following spinal cord injury: the impact on community integration. *Spinal Cord.* 2005;43 278-282.
54. Widerstrom-Noga EG, Cruz-Almeida Y, Felix ER, Adcock JP. Relationship between pain characteristics and pain adaptation type in persons with SCI. *J Rehabil Res Dev.* 2009;46(1):43-56.
55. Thoren P, Floras JS, Hoffmann P, Seals DR. Endorphins and exercise: physiological mechanisms and clinical implications. *Med Sci Sports Exer.* 1990;22(4):417-428.
56. Powers SK, Howley ET. *Exercise Physiology: Theory and Application to Fitness and Performance.* 6th ed. New York: McGraw Hill Higher Education; 2007.