

Exercise awareness and barriers after spinal cord injury

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Author contributions: Gorgey AS contributed solely to this editorial.

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Received: December 13, 2013 Revised: March 27, 2014

Accepted: May 14, 2014

Published online: July 18, 2014

Key words: Spinal cord injury; Rehabilitation; Exercise awareness; Barriers to exercise; Medical community

Core tip: Exercise is an essential component in managing persons with spinal cord injury (SCI). Knowledge of the barriers that encounters prescribing exercise routine is essential to ensure successful engagement in active lifestyle after SCI. Interdisciplinary approach may be the key of addressing some of these barriers after SCI.

Gorgey AS. Exercise awareness and barriers after spinal cord injury. *World J Orthop* 2014; 5(3): 158-162 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v5/i3/158.htm> DOI: <http://dx.doi.org/10.5312/wjo.v5.i3.158>

Abstract

Exercise is an essential element in managing several of the non-communicable diseases after spinal cord injury (SCI). Awareness of the importance of prescribing a customized exercise program that meets the goals of persons with SCI should be highly considered in the rehabilitation community. The barriers of implementing specific exercise program as well as the factors that may mask the outcomes of regular exercise regimen need to be continuously addressed as a part of patients' rehabilitation care. The focus of this editorial is to encourage the medical community to consider routine physical activity as one of the necessary vital signs that needs to be routinely checked in patients with SCI. Providing education tips, nutritional counseling and engaging in recreational programs may provide motivational route to the community of SCI. This may result in reinforcing active lifestyle in survivors with SCI as well as to reduce the impact of chronic life threatening medical disorders.

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INTRODUCTION

Spinal cord injury (SCI) is a devastating medical problem that may result from direct or indirect insult to the cord. The trauma may result from motor vehicle accidents, military or civilian gunshot wounds, wounded warriors in the combat fields or sports related injuries or non-traumatic causes such as infectious, inflammatory or tumor-related causes. It is estimated that there are more than 250000 survivors with SCI in the United States^[1]. The clinical care burdens of chronic SCI are extensive and can lead long-term disability with serious social and economic consequences.

Skeletal muscle atrophy and decline in lean mass are key features after SCI. Within few weeks post-SCI, there is more than 40% loss in skeletal muscle size in lower extremity^[2,3]. The process of continuous loss in muscle mass is magnified as the aging process continues; "baby boomers" with SCI may have profound muscle atrophy. The rapid loss in muscle mass following SCI leads to serious metabolic consequences similar to extensive decline in basal metabolic rate (BMR), insulin resistance and impaired glucose tolerance. The evidence suggests that

there is up to 22%-40% decline in BMR in person with SCI based on their level of injury and about 50%-75% suffers from impaired glucose tolerance or type II diabetes mellitus^[4-6]. The disruption in energy balance process predisposes these individuals to become a fat building machine. Body composition assessment studies reveal intriguing evidence that body mass individuals with chronic SCI composes of more than 30% fat mass, despite their normal and healthy body mass index^[3,7]. The process is further complicated with a decline in routine daily physical activity^[8].

The stacking of fat mass in non-fat sites leads to accumulation of depot of ectopic adipose tissue similar to muscle (intramuscular fat) or perineum (visceral fat)^[9,10]. Ectopic adipose tissue accumulation has serious health consequences on insulin signaling, glucose tolerance and may lead to disruption in lipid metabolism. The mechanistic links by which ectopic adipose tissue disrupts several of the key metabolic functions have yet to be determined. It is important to recognize that the prevalence of cardiovascular diseases, type 2 diabetes mellitus and amputation exceeds 200%, 50% and 30% in persons with SCI^[6,10,11]. The prevalence of these medical conditions escalates with aging. This leads to life threatening conditions, extensive economic burden, poor quality of life and shorten life span among those with SCI.

SCI leads to extreme physical inactivity. Sitting time has been identified as an independent health risk factor that may lead to all cause mortality. Reduction in the level of physical activity after SCI is a life a threatening condition and it is complicated by the prolonged sitting time in their wheelchairs. Recreational activities as well as rehabilitation strategies that help reverse this pattern of physical inactivity and prolonged lifetime sitting are highly recommended after SCI. The primary focus of the current editorial is to shed the light about the most common exercise strategies available to the SCI community and the main barriers which prevent implantation of these strategies. Previous publications have identified some of the challenges that involve conducting exercise research trials after SCI^[12,13]. The editorial offers few recommendations based on the current exercise research studies on how to address these barriers.

EXERCISE AWARENESS AFTER SCI

Exercise is a cornerstone that can ameliorate several of the aforementioned medical conditions after SCI. The American College of Sports Medicine (ACSM) refers to exercise as a type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve and/or maintain one or more components of physical fitness. This can be accomplished for variety of purposes including musculoskeletal strengthening, cardiovascular performance and weight reduction and weight maintenance. Exercise after SCI can be either target towards fitness (cardiovascular or muscular), compensatory (using assistive device) and restorative

(functional electrical stimulation and locomotor training). According to current guidelines, adults with SCI should engage in at least 20 min of aerobic exercise training twice weekly prescribed at moderate-vigorous intensity or 3 sets of 8-10 repetitions of resistance training to the major muscle groups^[14].

Cardiovascular or muscular fitness programs encourage individuals with SCI to engage their innervated upper extremity musculature in either aerobic type training using arm-crank ergometer or circuit-resistance type training to build major muscle groups above the level of injury. There is established evidence that twice to three times weekly for 30-60 min may be sufficient to achieve desirable cardiovascular and muscular fitness gains^[14]. In our facility, engagement of persons with paraplegia or tetraplegia in upper extremity circuit resistance training once weekly for 45-60 min resulted in a modest gain in muscular strength as measured by the number of plates lifted per session (clinical observation). Engagement in upper extremity training results in improvement in glucose/lipid profile; however, it is unclear if these rehabilitation interventions may lead to improvement in whole and regional body composition after SCI.

Functional electrical stimulation (FES) or neuromuscular electrical stimulation (NMES) training of the paralyzed lower extremity muscles have been targeted to offset for the rapid process of skeletal muscle atrophy, regional adiposity and improve metabolic profile. Long-term training with FES or NMES has also led to improvement in bone health parameters after SCI. Early engagement in NMES training immediately after SCI can offset for the negative effects on skeletal muscle size and prevent the development of other medical complications similar to pressure ulcer. Recent research work noted the significance of loading the paralyzed skeletal muscles to improve musculoskeletal, metabolic and cardiovascular features in persons with SCI^[15]. One interesting area for potential future study is the interaction between exercise and medical supplements to boost the outcomes of exercise. Similar to administration of Testosterone supplements which are likely to overcome the diminished anabolic profile and provide appropriate homeostatic environment for improving body composition by increasing lean mass and decreasing fat mass accumulation after SCI. Research in our laboratory is currently ongoing to investigate this interaction on body composition and metabolic profiles.

The compensatory strategy has been commonly used to exercise the paralyzed the lower extremity muscle as well as to provide loading to attenuate negative effects on musculoskeletal health after SCI. The knee, ankle, foot orthosis (KAFO) brace as well as reciprocal gait orthosis have been utilized by persons with SCI to allow them to walk with bilateral crutches or walker^[16]. However within few months, individuals with SCI are likely to give them up because of their bulkiness, difficulty to doff/don and reliance on caregivers to ambulate with these units. Advancement in electronics allows the availability of new

generation of functional neuromuscular units that may compensate for functional deficits after SCI. The Bioness unit (L300) allows stimulating of the ankle dorsiflexors to compensate for drop foot at heel strike of the gait cycle. These units although proven effective in improving gait cycle after SCI, however, they are not easily accessible because of their costs, the need of a qualified staff to train their patients and the need of a long-term training for patients to efficiently utilize them.

Manual and power wheelchairs may offer the possibility to stand up to ameliorate several of the negative effects of sitting and experiencing health benefits of loading the lower extremities. Exoskeletons or robotic suits offer a scientific breakthrough in walking rehabilitation after SCI. The efficacy of exoskeleton is yet to be established before it can be recommended for rehabilitation and exercise after SCI. Exoskeletons can be used in conjunction with a walker and can progress to be used with bilateral crutches. However, the cost of these units may preclude their practical use in rehabilitation settings.

Restorative type exercise has focused on providing afferent feedback to evoke spinal reflexes to regain motor recovery in the paralyzed muscles below the level of injury^[17-19]. The introduction of central pattern generator theory allows many researchers to utilize locomotor training in conjunction with other therapeutic modalities similar to electrical stimulation, magnetic stimulation and sensory transcutaneous electrical stimulation to encourage motor recovery. A recent breakthrough showed that epidural stimulation allows recovery of walking in persons with motor complete SCI^[20]. It should also be noted that locomotor training is not only about walking, but offers other metabolic and cardiovascular benefits after SCI^[18]. It is essential to maintain the integrity of musculoskeletal system below the level of injury to maximize the benefits of utilizing restorative interventions. The atrophic adaptations and weakening of bone after SCI may potentially limit the outcomes of these promising restorative trials. Finally, published evidence suggests that individuals with SCI who are participating in a regular wellness program or engaged in a regular physical activity routine are less likely to develop several of the aforementioned medical conditions^[19].

EXERCISE BARRIERS

We have to be aware of the barriers that interfere with long term commitments to persons with SCI. These barriers may include lack of access to exercise facility, lack of accessible public transportation, lack of background knowledge on dealing with persons with SCI, failure to provide the appropriate exercise routine based on the person's neurologic level and spared muscle function. For example, prescribing an exercise routine for a person with C6 SCI will be completely different than one for a person with T6 SCI. Clinicians should be aware of these factors to appropriately customize exercise programs which allow long-term engagement and prevent drop-out.

Spinal cord injury medicine requires special training and expertise to understand the consequences on physical, mental and psychological health in this population. Several programs in United States and other countries offer clinical program to train health care specialists to understand the major physiological and pathological adaptations after SCI. Prescribing exercise programs to improve cardiorespiratory fitness, muscular strength, and changes in body composition requires extensive training to understand medical issues that may arise similar to autonomic dysreflexia, pressure ulcers, urinary tract infection, heterotrophic ossifications, osteoporosis. Protecting participants with SCI who engage in specialized exercise programs is vital to ensure their safety. Exercise facilities should be equipped with ceiling or portable lifts to ensure safe transfer especially for those with high level of SCI.

The lack of appropriate guidelines on how to evaluate the effectiveness of specific exercise intervention in the SCI community is a considered a major hurdle for this population. Many clinicians/researchers are still utilizing body mass index (BMI) to evaluate the effectiveness of specific exercise protocols on weight management and body composition changes after SCI; although it is well established that the World Health Organization (WHO) BMI criteria cannot be adopted to this population because it underestimates the percentage fat mass after SCI. A clinical tool similar to waist/abdominal circumference needs to be validated to accurately evaluate the longitudinal changes in response to diet/exercise. At Miami project, Kressler *et al*^[21] validated a tool to evaluate the effectiveness of gauging exercise intensity compared to utilizing VO₂ peak that requires specific equipment or heart rate that may be limited by the level of injury. The study showed that Borg-rate of perceived exertion (RPE) scale can be used effectively to determine the intensity of the exercise intervention necessary to elicit the highest fat oxidation that is equivalent to approximately 50% of total energy expenditure^[21]. Another study utilized thigh circumference to determine the effects of different FES cadence on thigh muscle size after 6 wk of training^[22]. These studies are essential to bridge the gap between research and clinical community to provide simple tools to evaluate the effectiveness of exercise interventions after SCI.

Another important aspect is to identify the primary goal(s) for which the exercise program is being designed. Establishing the goal requires an interdisciplinary team of professionals to determine the appropriateness of these goals based on the person's level of injury, medical and psychological status and duration post-SCI. Several medical centers have adopted strategies such as locomotor training to restore motor function and facilitate recovery of walking following SCI^[17,18]. This goal requires daily intervention and frequent repetitions to reeducate the injured nervous system on the possibility of restoring walking. However, it is impractical to adopt the same exercise regimen to improve body composition or to restore muscle mass. A typical exercise physiology phenomenon is

that protein accretion is a cycle of protein synthesis and protein breakdown and providing a reasonable resting interval between exercise sessions facilitates the process of restoring or building muscle mass. Therefore, identifying appropriate goals is a key element that ensures successful rehabilitation intervention.

Exercise adherence is another common barrier that can be overcome by reducing the frequency of exercise to twice or thrice weekly workouts. Previous evidence suggests that twice weekly for 12 wk is adequate to increase muscle mass and reduce accumulation of ectopic adipose tissue as well as improving metabolic profile^[15]. A very important shift in the rehabilitation paradigm is the translation of clinical based laboratory studies or hospital based training protocols to home based environment. This can be easily monitored *via* advances in video conference communication taking advantages of the high speed internet. This allows safe monitoring and overcoming the hurdles of commuting to the rehabilitation centers. We have recently reported that exercise adherence was above 60% when exercise program using FES was administered as a home based routine twice or three times a week^[23]. Therefore, future clinical trials need to have translation plans that allow clinicians, caregivers and patients easy access to rehabilitation strategies without reliance on bulky or expensive equipments to exercise.

Awareness of the environmental and community barriers that may limit engagement in a long-term physical activity needs to be identified. Public transportation with reasonable wheelchair lifts, accessible doors and curbs need to be considered as a public health policy especially in the developing countries. Promoting exercise facilities that encourage individuals with SCI to engage in community programs are highly desirable. Improvement in the outcomes of exercise interventions can be translated into improvement in activities of daily living (*e.g.*, transfer, grasping, *etc.*). Moreover, the outcomes of any exercise program can be further complicated by several factors including dietary intake, smoking, mental health and family support. For example, excessive caloric intake can mask any metabolic benefits that may result from engaging in daily active routine. There is established evidence that persons with SCI are likely to consume high fat diet and they are low on daily protein intake^[24]. This observation is likely to disrupt several metabolic signaling and interferes with exercise protocols aiming to restore muscle mass. Therefore, dietary counseling is an essential component to the success of any exercise regimen. Several of the established SCI programs offer smoking cessation programs as well as recreation programs in the community to provide continuous motivation to survivors with SCI to engage in active life style as well as to reduce the factors that may lead life threatening medical conditions.

CONCLUSION

The medical community engaging in caring and rehabilitation of persons with SCI needs to consider adding

routine physical activity as one of the necessary vital signs. Moreover, continuous medical education needs to be provided to medical, physical therapy and occupational therapy students and clinicians about the necessity of identifying the suitable exercise regimen to their patients as well as to provide awareness of the factors which are essential to optimize the outcomes of any exercise interventions after SCI. Awareness in medical community about different exercise strategies as well as with the barriers of prescribing exercise protocols is a key to ensure successful outcomes for persons with SCI. A custom based exercise program that can balance both the goals and identify potential limitations for adherence may consider a gold-standard strategy that ensures engagement after SCI. Goals sharing and planning with SCI participants are crucial elements in designing a custom based exercise program that ensures long-term exercise commitment. Providing an appropriate long term exercise programs for persons with SCI which incorporates lifestyle and dietary modifications may enhance health, function and quality of life in this population.

ACKNOWLEDGEMENTS

The author would like to thank Drs. David Cifu and Lance Goetz for their positive feedback about the work. Ashraf S. Gorgey is a Career Development Award-2 recipient (B7867-W) and is currently supported by the Department of Veteran Affairs, Rehabilitation Research and Development Service.

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