The role of adapted/therapeutic exercise for paraplegic patients

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ABSTRACT

Paraplegia is a severe condition leading to paralysis and significant limitations to individuals' lives. Secondary health complications, psychological disorders and social difficulties, make persons with spinal injuries susceptible to serious hazards in various aspects. Considering the fact individuals with SCI are one of the most inactive parts of society, the objective of this overview is to present the role and benefits of adapted exercise for SCI population. The outcome of studies yield credible evidence that becoming physically active post SCI, is a critical factor for preserving overall health and health-related quality of life. Systematic physical activity and/or sport have important positive impact upon physical and psychosocial well-being by improving fitness, physical conditioning and health, helping in medical risks prevention, affecting the psychological status, promoting social participation and facilitating functional independence and quality of life of individuals. Exercise recommendations, guidelines and special considerations for the spinal injured people –with emphasis in paraplegia- are also discussed, since it must be specialized and adapted to the demands and restrictions of this condition. Acknowledging this multidimensional role of physical activity, future research is needed to further determine health outcomes in specific domains and the optimal elements and guidelines for physical activity.

KEYWORDS: adapted exercise, physical activity, paraplegia, Spinal Cord Injury

Introduction

Paraplegia, and Spinal Cord Injury in general, is a severe lesion, caused usually by a great force imposed on the spinal cord, which interrupts completely or partially its function, i.e. the transferring of neural signals from the brain to the various body systems and vice versa. This results in various types of motor and sensory disabilities and may also interrupt the autonomic function below the point of lesion, depending on the level and structure of the lesion [1-3]. This severe neurological deficit affects dramatically the lives of people who suffer it in all possible ways [1,4]. Individuals with SCI are physically deconditioned and susceptible to serious health complications, dysfunctions and psychosocial difficulties [3,5-9].

Thousands of people suffer every year SCI. It is estimated that there are 15-40 new cases per million of population every year [3,10]. The estimated global in-

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cidence rate is 23 per million, resulting in almost 18.000 new cases every year, mainly young people [1,11]. Although SCI remains an incurable condition, the survival has increased over the last years due to successful therapies for life threatening complications, early intervention and rehabilitation processes following SCI [12].

The preservation of fitness and physical wellness is a key factor in coping with spinal injuries and preventing secondary complications. Systematic physical activity seems to function in a beneficial way in order to adapt and overcome barriers in daily activities and protect health and well-being [7,13-17]. Adapted exercise has the potential to improve fitness, biological functions and provide the prerequisites for psychological adaptation, independence, social participation [5,18]. Nevertheless, the majority of the SCI population is physically inactive –maybe the most inactive part of society- or not active enough in order to gain the positive effects of exercise [19,20]. Thus, it is of great importance to facilitate and encourage the participation of this population in a systematic physical activity program and to promote the prescription of exercise.

Method –Material: This narrative review was conducted through searches in PubMedC and Google Scholar databases, using the keywords *adapted exercise, physical activity, paraplegia, Spinal Cord Injury.* Non English publications and articles before 2000 were excluded. This resulted in 672 publications. After removing duplicates and scanning irrelevant publications 119 articles remained. A second scanning of the abstracts excluded another 27 publications, as their main research referred to animals, exclusively quadriplegia or did not focus on the role of physical activity (e.g. purely medical issues). Three highly relevant Greek publications were also added. All the above resulted in 95 articles which were fully read. Well known and recognized scientific reports (e.g. WHO reports) that focus on exercise prescription and guidelines for adapted exercise have been also included.

Health risks and consequences after SCI

Individuals with paraplegia -and SCI in general- face a variety of health problems, even years after the injury. Some are immediate related to the injury, whereas others are secondary complications. Multisystem dysfunctions of various degrees accompany SCI, depending on the degree and level of lesion [3].

The most important threat, a common cause of death for people with SCI, are cardiovascular diseases (CVD) [20,21]. The lack of physical activity, the sedentary way of life, in combination with metabolic disorders, contribute to a higher risk of cardiovascular complications [22,23]. Metabolic diseases, as impaired glucose tolerance or diabetes mellitus, are common in people with SCI. Astorino points out that they have double percentages of suffering from CVD, mainly due to lack of physical activity, adiposity, glycemic and lipemic dysregulations, hypertension, adverse lipid profiles disorders of carbohydrate metabolism [24]. Moreover, body fat increases after the SCI leading to prevalent obesity, more burden in everyday life, but also CVD [3,21,25]. Insulin resistance and sarcopenic obesity constitute great hazard for cardiometabolic syndrome, which affects 60-80% of persons with chronic SCI [26,27] and may lead to serious coronary artery disease or myocardiac infraction[7,28].

Dysfunctions of the autonomous nervous system lead to severe neurological deficit. Orthostatic hypotension and autonomic dysreflexia are dangerous complications in high level lesions [8]. Moreover, autonomic dysfunctions negatively affect genitourary organs, thermoregulation and blood pressure regulation mechanism [3]. They also lead in neuropathic bladder and bowel and sexual dysfunctions, considered as priority by paraplegics [29]. The loss of urogenital and bowel control leads to infections, but also limits the person's willingness to be socially active and is critically linked with quality of life (QoL) [30,31].

SCI affects negatively the vascular characteristics and the sufficiency of the arterial circulation [21]. Blood pooling in the lower extremities increases the risk of thrombosis [3,24]**.** In addition, respiratory complications often accompany SCI, especially at high level lesions, as it decreases the elasticity of the lungs, reduces the vital capacity and lead to insufficient function of the respiratory muscles [8,32].

The musculoskeletal system is also highly affected. The paralyzed muscles and muscle fibers below the lesion loose gradually their properties, distribution and volume and undergo morphological and contractile changes [24,25]. Lack of activity and loading result

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in deteriorating muscle atrophy below the lesion [21]. Bone and joint deterioration are often experienced, even by young individuals [3]. Bone demineralization and osteoporosis manifests rapidly after the injury and continues to climax some years after [14,33]. Bone fractures are common, particularly after falls [34,35]. Other complications are spasticity, affecting approximately 70% of the individuals [36], and fatigue, a physical tiredness, hindering mobility and function [37].

Chronic pain, a devastating problem, affects heavily their QoL [5,38]. It can be neuropathic pain, nociceptive, visceral or musculoskeletal [38-40]. The most prevalent is shoulder pain, as the hands must do the work of both, hands and legs [2]. Poor circulation and sensory loss are the main causes of pressure ulcers development, which can lead to dangerous infections [31].

All these complications are not mere medical conditions. They have psychosocial effects. After the injury, the person usually loses the ability to live independently, has many medical problems, must adapt to a sedentary-passive life, experience fear about the future, feels isolated. The feeling of helplessness, depression, anger, stress, isolation, affect dramatically their QoL [41].

Adapted exercise - Barriers and facilitators

Individuals with paraplegia and spinal injuries face many constrictions in physical activities, due to limited exercise options, reduction in exercise capacity, but also health complications stemming from the injury. Exercise should be designed carefully and personalized-adapted to the individuals' condition, needs and personal characteristics.

Systematic training is a non-invasive, but effective way to improve and maintain physical fitness, overall health and wellness for persons sustained SCI [2,20,40]. The majority, although inactive [43], acknowledge the benefits of exercise and are willing to begin some kind of physical activity, but encounter many barriers, internal and resource impediments [43-47].

Exercise for persons with disabilities is determined by many factors, as special training opportunities, appropriate infrastructure, social interaction, policies and public services [46]. Experts need to take into account barriers and facilitators affecting participation and adherence [19]. Typical barriers recognized by individuals are physical health factors (e.g. impairment, pain), psychological factors (e.g. depression), social support, accessibility (transport, equipment), financial cost, lack of information-awareness and experts [14,19,45-48].

Thus, physical activity counseling, accessibility solutions, support organizations, evidence-based resources and experts, are very important in planning those programs [48-50]. Specialized activities and equipment, instruction/supervision by exercise professionals, accessible facilities, and community-based programs facilitate exercise [7,14,45,51-52]. Psychological factors also play an important role [53]. Gaining fitness and avoiding health problems is the most important motivation [54]. Strategies as action planning, goal setting, social support and self-regulation also act as strong facilitators [49].

Physical activity for adults with paraplegia should have long term fitness targets [14,49], as the benefits tend to diminish after a non-active period [55-56], starting from rehabilitation and the transitional period after discharge [6,57].

The beneficial role of exercise intervention in health and physical fitness

It is well documented that systematic exercise plays an important role in physical fitness, strength and functional aspects in SCI. It also seems to have positive effect on various health systems and improve psychosocial factors and QoL [2,10,14,49,58].

Physical fitness has great impact on the person's level of autonomy and overall heath [10,60-61]. Nevertheless, all aspects of physical fitness deteriorate after the spinal lesion. Physical capacity, an important fitness component, indicating the work one is able to perform, decreases post injury, resulting in the decline of two important factors: aerobic capacity (AC) and power output (PO).

Systematic training has a direct effect on AC, by increasing peak oxygen consumption (VO2peak)[14-15, 61-62]. It is associated with cardiovascular and cardiorespiratory health, endurance and functioning [8,16,20,26]. There is credible evidence that systematic aerobic or circuit training has positive cardiorespiratory responses, even if restricted in the upper part of the body [2,15,63]. The same result is observed with resist-

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ance training in paraplegics [64]. Moreover, exercise targeting at the accessory respiratory muscles, leads to ventilation efficiency [61] and improved fatigue resistance [15].

Aerobic and mixed training result in significant improvements in PO too, confirmed by many studies [15,61-61,65-67]. PO is an indirect indication of muscle strength and has great impact on the individuals' functional efficiency in daily activities, e.g. wheelchair propulsion [14,15].

Muscle strength, associated with muscle mass is a key factor for paraplegics, but decreases rapidly post injury. There is strong evidence that systematic endurance and resistance training leads to improvements in muscle strength and physical capacity, which are closely related to everyday tasks e.g. self-care, transfer [68-71]. Muscle strength also reduces risk factors associated with pain and injuries, mainly due to overuse [72]. Studies report better pain management options and pain decrease during exercise participation [38-39,45]. Shoulder pain, typical for manual wheelchair users, decreases as shoulder muscular strength increases after training, which optimizes the joint mobility and activates upper muscles, especially in paraplegics [73-75]. Thus muscle strength exercise has great impact on physical/functional efficiency and biomechanical economy [15,49,76]. This is of great importance considering that only 25 % of healthy young paraplegics are in the position to maintain their independence [14]. A meta-analysis of exercise benefits for wheelchair users found positive correlation between exercise and functionality, everyday activities, balance, movement, depression, sleep and spasticity [77]. Body composition is another indicator of fitness status [15,34,78]. Regular participation in exercise showed favorable results, mainly in muscle mass, which is related to muscle strength [15,70,73].

Considering the great risk of CVD complications, indications that exercise or sports elicit positive cardiovascular and cardiometabolic outcomes, must be seriously considered [2,10,72,79-80]. Blood glucose and body fat percentage decrease through increased caloric energy expenditure [13,69,72]. The lipid profile shows improvements, mainly due to increase in cardioprotective HDL-cholesterol, which tend to be proportionate to the exercise intensity and amount [14,21,42,62]. The same holds for insulin sensitivity [73]. Systematic intense exercise, in combination with nutritional management, are critical factors for attenuating cardiometabolic syndrome risk, as sarcopenic obesity and insulin resistance, and preserving health [26].

Apart from the traditional exercise modes, involuntary training of paralyzed limbs with the assistance of electrical stimulation methods, body weight support equipment and passive exercise, are also effective options in order to improve overall fitness, physical capacity, muscular strength and elicit health outcomes of different systems [14,15].

Beyond potential improvements in ambulation, studies have found evidence that Body Weight Supported Treadmill Training (BWSTT) results in reduced hazard for health complications and cardiovascular gains via favorable metabolic alteration, blood pressure, heart rate, body and muscle composition [14,21,78]. Locomotor training with BWST seems to have positive impact on the neural control of the urogenital and bower function and improvements in bladder capacity, voiding pressure, nocturia and time required for defecation [29]. This implies benefits not only for motor rehabilitation, but also in the neural circuitries of autonomic functions. Reduction of pain has also been documented [81].

Functional Electrical Stimulation (FES) training also results in positive outcomes. Regular intense FES exercise at the lower extremities, facilitates bone metabolism and formation, due to activation and mechanical loading imposed to the lower limbs and improvements in bone vasculature circulation [34]. Thus in chronic SCI, FES training seems to have effect on bone mineral density [21]. A current systematic review about the role of FES cycling reported improvements in aerobic fitness, PO and muscle health, particularly in fiber composition and muscle mass of the lower part of the body [82].

Another mode for training paralyzed limbs is passive exercise, as passive leg cycling. A systematic review examining the musculoskeletal, cardiovascular and neurological outcome of this method, concluded that multiple sessions have indeed positive impact on reflex excitability, spasticity, blood flow in the lower extremities, and range of motion [83].

Not only the physical but also the psychological and

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social well-being improved significantly from systematic training programs [84-85]. The beneficial effect is linked with psychological balance, achieved through the promotion of functional independence, perceived health status, reduced stress and pain levels [7,53-56]. Psychological health is closely related to autonomy. Every intervention that improves fitness, strength and physical capacity, enhances the individual's functional performance, the ability to be socially active and personally autonomous, and thus has a critical impact on psychosocial status [86-87].

The above findings are confirmed by systematic reviews and studies demonstrating positive impact of training on mental health, and psychological factors. Indices like depression feelings, anger, stress and satisfaction from functioning and life, were significantly associated with participation in sports and exercise [14]. Studies revealed that life satisfaction measures, improved significantly after participation in a systematic training program [14,84]. Koppenhagen et al found a significant association between wheelchair exercise capacity and life satisfaction, defined as the persons' subjective well-being [88].

Bonnell et al studied the social relations of people with disability and showed that exercise programs were a key factor [46]. Social contact, reintegration and participation post injury is a complex procedure, but crucial to ones' perception of satisfaction and QoL [87]. Participation in team sports and training programs enhances social skills, interpersonal relations between co-athletes and peers and generates socialization and life satisfaction [87,89]. Particularly community-based programs post rehabilitation seem to function as a stable basis for SCI people to sustain participation in social and physical activities [20].

Quality of life is a multidimensional concept [89]. Individuals with SCI are reported to have a dramatic deterioration in their perceived QoL in comparison with non-disabled peers [90]. Leisure time physical activity is a strong predictive factor of QoL and many studies have shown their positive relation [9-10,53,56,59,87]. Exercise affects the objective and subjective QoL in the physical, psychological and social domain [85].

Generally, physical and emotional well-being, self-determination and integration are higher in physically active SCI persons [87]. A great promoting factor of physical activity is the realization of the exercise participation benefits, which include control over their lives, enhanced self- esteem and autonomy [15,54,72].

Exercise prescription

Special considerations: All the above make the prescription of exercise an important but complicated task, which must be carefully designed, personalized and adapted to special characteristics. Experts should begin with a thorough description/evaluation of the individual's condition, based on the medical status, the exact type and extend of paralysis, personal factors, way of life, time since injury, age, comorbidities [2,91].

The completeness and level of the lesion play a very important role in the exercise capacity and prescription. Dysfunctions of the sympathetic system in higher level lesions, may reduce maximal heart rate to 110-130 beats/min [3,42,92]. Thus, maintenance or cardiac output in maximal exercise due to compensatory HR increase, is hardly possible.

The active muscle mass reduces post injury, leading to reduction in oxygen uptake. Impairments in venous return is also affected by the lesion level and completeness [2,92]. Researchers stress the fact that VO2peak, PO, and consequently the exercise capacity, are inversely related to the level of the lesion [3.92]. Muscle mass, respiratory function, blood redistribution capacity, cardiovascular adaptation during exercise, have also an inverse relation with the injury level. Individuals with paraplegia have elevated HR responses and lower stroke volume [3], but may achieve high VO2peak in arm ergometry, depending on the lesion level[2].

Orthostatic or exercise-induced hypotension, due to circulation dysfunctions, may lead in nausea or syncope and need blood pressure monitoring, slow position alteration and progressive exercise introduction [2,20,55]. The same manipulation decreases the possibility of painful spasticity incidents. Sensory impairments may lead to ulcers and professionals should monitor skin areas frequently, adapt material and equipment and relief pressure regularly [2,63]. There is also increased hazard of bone fractures after falls or stretching of paralyzed limbs, especially in team sport, due to osteoporosis and lack of sensation, leading in delayed detection [2]. Musculoskeletal injuries must be prevented, mainly by gradual exercise introduc-

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tion and pain self-report [42]. Thermoregulation and sweating dysfunctions may cause overheating and need cooling strategies [2,63]. Nevertheless, there is no doubt that beneficial outcomes outweigh the dangers and the adverse incidents are rare and usually not severe [2,68].

Onset time: Individuals should be motivated by experts from the early stages of the injury to gain body control and everyday functionality [14]. Mobilization should begin as soon as the medical condition allows it, initially with passive activation of musculature with stretching and joint mobilization, and then with energetic exercise. During the subacute phase a strength and aerobic program should be implemented, followed by a systematic program afterwards [71].

The initial period after the injury, is considered to be crucial for better rehabilitation results and adoption of positive behavior towards physical activity. Immediate exercise participation, which continues after discharge, optimizes recovery and reduces health complication risks. Rimmer and Lai propose the transformative exercise model which begins in the acute phase. It presuppose the cooperation of the therapist and the training specialist in order to transform the patient to a life-long physical activity participant [6].

Exercise recommendations: Activity recommendations have to address all elements of exercise, type, frequency, intensity and duration [42], depending on cardiovascular responses and oxygen uptake measures. The ergometer is a safe way to determine cardiovascular capacity. The intensity threshold according to researchers should not exceed the 70% of the HRmax and last 20min at least [71]. On the other hand studies support that in higher level lesions, HR is not a reliable marker due to autonomic dysregulations which distort the data, although it could be a secure measure in most paraplegias. Measures of VO2peak are more complex, but precise, and exercise should aim at 60-80% [42]. A more practical measure is the Rate of Perceived Exertion of Borg [93], applicable for all ages. Generally, the training programs should develop conservatively and gradually.

In paraplegia, most types of exercise mainly rely on the upper part of the body, which demands more physiological strain than exercise involving legs. This modality restriction seems to yield lower PO and VO2peak values and higher HR during arm cranking than leg cycling [92]. Thus the exercise capacity is limited and the intensity level difficult to determine. Nevertheless, cardiovascular endurance and strength improve with systematic exercise. Pelletier et al found no difference in energy demand between arm only and arm and leg training in incomplete lesions, where persons were able to perform leg activation [20]. Hybrid exercise types show a metabolic advantage in complete lesions, where FES or BWSTT can be utilized in order to activate large inactive/paralyzed muscle groups of the lower extremities. FES has been reported to provoke physical, functional and psychological benefits for person with paraplegia [94]. Depending on the lesion level, a combination of arm aerobic exercise and passive leg cycling or FES leg training might be needed for improving aerobic capacity. Torhaug et al found that aerobic training -with arm crank ergometry only- elicits increased VO2peak in individuals with lesion below T6, but did not enhance cardiovascular fitness in persons with higher level lesion, unless an additional passive leg cycling or FES hybrid cycling was used[69].

Exercise guidelines: Experts and international organizations have developed guidelines in order to define the elements of physical activity, appropriate and effective for the SCI population. Exercise guidelines show a rising tendency over the last decade, as far as frequency, intensity or duration is concerned [2,55,95-96].

World Health Organization introduced in 2020 the first evidence-based Global Physical Activity and Sedentary Behavior Guidelines for People Living with Disabilities [97]. SCI was one of the conditions described. Recommendations were based on the general population fitness guidelines [68]. 150-300 min of moderate aerobic exercise per week is considered to be the minimum in order to achieve health gains, combined with strengthening exercise for all major muscle groups and balance training to enhance functional capacity.

A multidisciplinary panel developed in 2011 the first SCI-specific, evidence-based Physical Activity Guidelines [55]. The goal of it was to improve fitness and determine elements of exercise in a feasible way. The recommended frequency was 2 times/week of aerobic and strength training in a moderate-vigorous intensity for at least 20min, but 30min would elicit better results. An update of 2018, emphasizing on cardiometabolic

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health, recommended aerobic exercise, performed 3 times/week for at least 30min in a moderate-intense mode [95].

The Consortium for Spinal Cord Medicine (USA) focusing on the high cardiometabolic risk for spinal injured persons, proposes at least 150min/week of physical exercise, even from the acute phase, stratified during the weekdays [79].

Another approach designed for professionals and targeting in cardiometabolic health and fitness, is the Exercise and Sports Science Australia (ESSA) Position Statement [2], which proposes a program based on the able bodied population, with SCI evidence-based adaptations and international organizations recommendations [98-100]. Arm aerobic or circuit training are recommended and resistance training, especially for paraplegics. Moderate (HRR 40-59%) aerobic exercise should be performed 5 times/week for at least 30min or vigorous exercise (HRR 60-89%) 3 times/week for at least 20min. Strength and flexibility exercise at least 2 times/week with no pain or internal shoulder rotation are also important.

Nevertheless other studies report that Moderate Intensity Continuous Training (60-70% intensity) is not enough to yield positive outcomes, especially cardiometabolic [26,96]. An alternative is High Intensity Interval Training (80-100% HRmax with 1-3 min intervals), which has shown greater physiological outcomes in able-bodied population and seems to have the potential to reduce cardiorespiratory, vascular and cardiometabolic risks [1,96]. A systematic review of the results of HIIT concluded that, despite the benefits in VO2max and PO in SCI population, it is premature to recommend this mode, as more studies must confirm its safety and effectiveness [1].

Conclusion

Individuals with paraplegia experience a dramatic change in their lives and are susceptible to a range of health complications, many of which are related with inactivity, due to paralysis. Moreover, their general fitness level deteriorates rapidly, the exercise options decrease greatly, leaving less space for physical activity interventions. Nevertheless emphasis should be given in accessible, adapted exercise programs and early education of the these population about the benefits of systematic training in disease prevention and coping, but also in fitness level, functional aspects and psychosocial gains, related to exercise. Acknowledging the beneficial role of exercise, experts propose special exercise recommendations and guidelines for persons with SCI in general. The ultimate goal is to reverse the sedentary way of life consequences, prevent secondary complications and achieve the most of functional independence and quality of life. More research is needed to further determine the benefits of exercise in specific body functions, as well as the optimal exercise adaptations, physical activity elements and interventions, needed to accomplish this goal.

Conflict of interest

The authors declared no conflict of interest

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