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Hybrid Exercise Rehabilitation in Persons with Spinal Cord Injuries: A Brief Review

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ABSTRACT

Background Individuals with spinal cord injury (SCI) have been shown to be at a higher risk for cardiovascular disease. Exercise rehabilitation is effective in reducing the risk for cardiovascular disease. Traditional exercise rehabilitation often involves arm ergometry. However, hybrid exercise (involving the concurrent exercise of the arms and legs) has been hypothesized to lead to greater cardiorespiratory responses to exercise than traditional arm ergometry.

Purpose The purpose of this paper was to examine briefly the health benefits of hybrid exercise and the key mechanisms responsible.

Methods A narrative review of the literature was conducted.

Results Hybrid exercise allows individuals with SCI to elicit greater cardiorespiratory response in comparison to arm exercise alone. This appears to be in part due to the ability to passively utilize the skeletal muscle pump during exercise facilitating venous return and augmenting the performance of the heart.

Conclusions Exercise incorporating both the upper and lower limbs is a viable means to promote enhancements in aerobic performance in comparison to arm exercise alone. This has important implications for persons with SCI since physical activity is a major independent risk factor for cardiovascular disease and premature mortality. **Health & Fitness Journal of Canada 2008;1(1):30-35.**

Keywords: Hybrid exercise, spinal cord injury, exercise rehabilitation.

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INTRODUCTION

An estimated 36,000 Canadians live with spinal cord injury (SCI)(BCPA 2006) and profound advances in medical treatment within the last few decades have contributed to making the life expectancy of these individuals similar to that of the general population (Hicks et al. 2003;). Persons with SCI are limited in their ability to exercise and complete activities of daily living. As a result, they are prone to leading a sedentary lifestyle, which leads to varying degrees of physical deconditioning (Washburn and Figoni 1998; Jacobs and Mahoney 2002). Marked deconditioning increases the risk of secondary health complications including, but not limited to, cardiovascular and pulmonary diseases, and muscle atrophy (Brenes et al. 1986; Dallmeijer et al. 1997; Dearwater et al. 1986; Demirel et al. 2001; Janssen et al. 1997; Bravo et al. 2004).

Cardiovascular disease (CVD) is the leading cause of death not only in able-bodied individuals (Health Canada 1999), but in persons with SCI as well (Whiteneck et al. 1992). Historically, respiratory and renal conditions have been the most prevalent comorbidities (Myers et al. 2007), but CVD has emerged recently as the leading cause of mortality in chronic SCI (Garshick et al. 2005).

Individuals with SCI may be at increased risk for CVD in comparison to their able-bodied counterparts because certain risk factors, including hyperlipidemia, obesity, and diabetes, have been found to be higher in the population with SCI than in the able-bodied population (Yekuteil et al. 1989).

Evidence demonstrates that physical inactivity is a major independent risk factor for CVD and premature mortality (Katzmarzyk et al. 2000). Another contributing factor to the higher cardiovascular morbidity and mortality in people with SCI is the sedentary lifestyle and reduced physical function associated with a loss of motor function (Washburn and Figoni 1998). Inactivity is common among individuals with SCI, and accordingly, they exhibit low levels of cardiovascular fitness and suffer more from inactivity related illnesses in comparison to the general population (Mohr et al. 2001). Additionally, ordinary activities of daily living are not sufficient to maintain cardiovascular health in this population (Vidal et al. 2003). Thus, it is imperative to highlight the importance of improving cardiovascular health and function through physical activity in persons with SCI.

Previous studies have demonstrated that participation in physical activity in people with SCI is able to help improve fitness levels and exercise capacity (Tordi et al. 2001). Recent studies have shown that endurance training with upper extremity exercise, lower extremity exercise, or their combination is able to reverse some of the metabolic and skeletal muscle abnormalities associated with SCI (Phillips 1998). Improvements such as reversing muscle atrophy, and increasing muscle mass, and improving endurance have been found following training of the lower extremities (Petrofsky et al. 2000). It is likely that exercise rehabilitation will improve the capacity for work and employment, increase functional independence, and reduce the risk for chronic disease (e.g., CVD) (Noreau and Shephard 1995), and promote an active lifestyle (Hicks et al. 2003; Figoni et al. 1990).

Furthermore, a decline in functional capacity following injury has been found to negatively affect the Quality of Life (QOL)(Noreau and Shephard 1995). Research consistently demonstrates that long-term participation in exercise has beneficial effects on several subjective outcomes such as depression, self-concept, and QOL (Hicks et al. 2003). In parallel with the able-bodied population (Warburton et al. 2006), regular physical activity promotes numerous health benefits that help attenuate the risk for several chronic conditions (e.g., CVD), and premature mortality in persons with SCI.

Various exercise modalities have been employed to improve the health status of persons with SCI. Common modalities such as arm ergometry and functional electrical stimulation have been effective in reducing the risk for secondary complications, and improving the overall QOL of persons with SCI. Hybrid exercise involves concurrent exercise of the arms and legs and has been proposed to be an effective means of rehabilitating persons with SCI. However, relatively little information exists regarding the health benefits of this form of exercise. Therefore, the purpose of this narrative review of the literature is to examine briefly the health benefits of hybrid exercise and the key mechanisms responsible.

Exercise Rehabilitation in SCI

Upper Extremity Exercise

Exercise participation has been shown to help improve functional capacity in persons with SCI, but they are limited in the types of exercise they can perform. Due to lower limb paralysis subsequent to SCI, individuals commonly perform upper body exercise in the form of arm cycling (Jacobs and Mahoney 2002).

During upper body exercise, it is generally observed in the able-bodied population that their ability to activate the skeletal muscle pump enhances aerobic capacity and overall exercise performance. The skeletal muscle pump helps maintain venous return, which produces sufficient cardiac output, and thus, oxygen uptake (VO_2), which will be discussed later on.

However, even for able-bodied individuals, upper extremity activity is very physically demanding and elicits unique cardiovascular adaptations in comparison with leg exercise at equivalent power outputs (Davis et al. 1990) such as decreases in ventricular filling and stroke volume (Sawka 1986), and increases in total peripheral resistance (Davis et al. 1990), heart rate and blood pressure (Davis and Shephard 1984; Miles et al. 1982). Persons with SCI also experience problems that arise from circulatory hypokinesis, a cardiac output that is lower than expected for a given VO_2, which is subsequent to insufficient venous return as a result of inactivity of the skeletal muscle pump (Freschuss and Knutsson 1970), leading to blood pooling in the paralyzed lower limbs (Davis et al. 1990).

Persons with tetraplegia and paraplegia elicit attenuated stroke volumes and cardiac outputs when they perform similar upper extremity exercises as their able-bodied counterparts (Glaser and Davis. 1989). This is problematic as it limits the ability to maximize health benefits; whole-body exercise has been shown to enhance cardiorespiratory response to a greater extent then arm exercise alone in population with SCI (Hooker et al. 1992a; Raymond et al.1999).

Furthermore, voluntary arm exercise elicits only small increases in maximal aerobic power (VO_2max) and is thought to be insufficient to enable maintenance of a high level of fitness in the population with SCI (Mohr et al. 2001). Upper extremity exercise capacity is limited since venous return and, subsequently, cardiac output, are compromised, leading to insufficient blood flow to the active muscles during exercise (Davis et al. 1990).

Skeletal Muscle Pump

The skeletal muscle pump has an important function during exercise. In able-bodied individuals, an increase in venous return is elicited by contraction of the leg muscles, which provide pressure against the veins and help the venous valves return blood to the heart and central circulation (Alimi et al. 1994). As demonstrated in the literature (Kinzer and Convertino 1989), leg muscle contractions significantly augment cardiovascular dynamics in able-bodied participants in comparison to participants with SCI. Studies have found that activation of the skeletal muscle pump augments venous return, ventricular filling, and oxygen uptake (Hooker et al. 1992a; Hopman et al. 1998). That is, the ability to activate the leg muscle pump during exercise helps enhance venous return, which leads to an increase in cardiac filling and preload, and ultimately, an increase in stroke volume (Raymond et al. 1999; Figoni et al. 1990), and all of these things help to enhance cardiorespiratory response and exercise performance.

Lower Extremity Exercise
Active Muscle Contraction

Exercise involving the lower extremities incorporates the ability to utilize the skeletal muscle pump which helps to ensure adequate redistribution of blood during activity. However, in individuals with SCI, the ability to contract the muscles of the legs independently is often lost as a result lower limb paralysis following injury, in turn, limiting the cardiorespiratory response to exercise. It has been established that the inability to use the leg muscle pump arises when the leg muscles are no longer contracting, producing a concomitant reduction in venous return that ultimately causes a decline in stroke volume (Rowell 1997). Fortunately, in persons with SCI, active contraction of the lower limbs via the application of electrical stimulation has the potential to elicit the activation of the skeletal muscle pump. Muscle contractions are induced through microprocessor-controlled electrical stimulation that is delivered via skin surface electrodes placed over motor points of the quadriceps, hamstring, and gluteal muscle groups (Figoni et al. 1990). Leg exercise training that involves stimulating the lower extremities with electrical stimulation has been found to promote improvements in cardiorespiratory measures including oxygen uptake, heart rate, and cardiac output in individuals with SCI (Mohr et al. 2001).

Passive Leg Exercise

Previous investigations that have examined the effects of passive inclusion of the legs during exercise for persons with SCI have demonstrated that this enhances cardiorespiratory response (Figoni et al. 1990; Muraki et al. 2000). It has been found that passive cycling movements are an effective means of increasing venous return in persons with SCI (Morikawa et al. 1989; Thomas et al. 1997), and similar results have been found for able-bodied individuals (Muraki et al. 2000). Increases in stroke volume and cardiac output have been found during exercise in both populations (Muraki et al. 2000). This suggests that passive cycling movements are effective in promoting circulation in passively moved muscles. Individuals with SCI have no afferent reflexes from their paralyzed lower limbs, since the afferent pathway is disrupted following injury (Muraki et al 2000). Accordingly, improvements in cardiorespiratory response during passive exercise have been attributed to rhythmic lengthening and shortening of the leg muscles, specifically the paralyzed leg muscles in individuals with SCI, which promotes venous return during activity (Muraki et al. 2000).

Hybrid Exercise

Since the ability to utilize the leg muscle pump during exercise has been shown to help improve performance (Hopman et al. 1998), it is logical that recent research examines cardiorespiratory measures during simultaneous activity of the upper and lower extremities. Hybrid exercise involves concurrent exercise of the arms and legs and facilitates activation of a larger muscles mass in comparison to upper or lower body exercise alone. As expected, findings from several studies comparing hybrid exercise to arm ergometry illustrate that there is greater cardiorespiratory response to whole-body exercise in individuals with SCI (Hooker et al. 1992a, Raymond et al. 1999). Hybrid exercise elicits increases in oxygen uptake (Mutton et al. 1997; Wong et al. 2008) and stroke volume (Raymond et al. 1999; Wong et al. 2008). The increase in stroke volume may imply that exercise involving the legs promotes reductions in venous pooling, and subsequently, augmentations in venous return (Raymond et al. 1999).

CONCLUSIONS

Cardiorespiratory response to arm ergometry and hybrid exercise is different. It is evident that exercise incorporating the upper and lower limbs into hybrid exercise is an effective means to promote enhancements in aerobic performance in comparison to arm exercise alone. Another important finding has been that passive inclusion of the lower limbs into hybrid exercise is an effective way of improving exercise performance and capacity. This suggests that active muscle contraction is not necessary to enhance exercise capacity, which is beneficial for individuals with SCI, who commonly experience lower limb paralysis following injury.

Since the life expectancy of people with SCI is approaching that of the general population, managing health issues to promote long and healthy lifestyles in this population of paramount importance. Accordingly, hybrid exercise, since it may help to promote greater benefits to health than arm exercise alone, should be considered as a form of physical activity to help improve functional independence and Quality of Life of persons with SCI.

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