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Review & Commentary

Response to Aerobic Exercise Training in Humans with Neuromuscular Disease

ABSTRACT

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There have been few studies examining the response of persons with neuromuscular disease and postpolio syndrome to cardiopulmonary testing and aerobic exercise training. In persons with neuromuscular disease that directly involves the cardiac and respiratory systems, deficits in performance may be primarily due to these limitations, along with loss of functional muscle tissue from the disease process. In the more slowly progressive disorders, deconditioning may play an important role in limiting aerobic exercise performance and may be amenable to training. Recommendations are provided for future exercise studies with these populations.

Key Words: Cardiopulmonary Training, Deconditioning, Exercise Intolerance

Although symptoms of poor endurance and fatigue are common in persons with neuromuscular disease (NMD), there is a paucity of research investigating the aerobic capacity of these individuals and their ability to respond to aerobic exercise training. This review highlights available literature related to aerobic exercise testing and training in NMD, including postpolio syndrome (but excluding metabolic myopathies, beyond the scope of this review), and provides recommendations for future studies in this area.

One of the primary questions for researchers and clinicians is whether reduced exercise performance is directly due to the muscle or nerve disease through loss of muscle tissue or to the effects of physical deconditioning. If it is primarily the latter, endurance exercise training may be helpful to reverse untoward effects of the deconditioned state.[1] It is known that in the general population, an inactive lifestyle increases the risk of coronary heart disease, hypertension, osteoporosis, obesity, and adult-onset diabetes mellitus.[2] If per-

sons with NMD are able to obtain a training effect from increasing physical activity through aerobic exercise, it may reduce the risk of chronic medical conditions and improve functional ability and personal independence.

CARDIOPULMONARY RESPONSES TO EXERCISE TESTING

Studies investigating the results of exercise testing have not been performed in any standard fashion. There are differences regarding the use of constant *vs.* incremental testing, maximal or submaximal workloads, steady-state periods, and utilization of control groups or predicted values for comparison.

Despite differences in testing protocols and the nature of the NMD studied, there is a consistent reduction of maximal or peak oxygen uptake (VO_{2max}),[3–11] pulmonary ventilation,[3,11] work capacity or rate, and endurance[3–6,11] in both rapidly and slowly progressive disorders. Some studies also report a higher heart rate at rest, which is attributed to a lack of physical conditioning.[3,10] In Duchenne muscular dystrophy, one investigation also found 32% lower stroke volume and 53% lower cardiac output during maximal exercise.[3] A recent study of patients with chronic polymyositis or dermatomyositis demonstrated a nearly 50% reduction in peak VO_2 compared with able-bodied controls.[12]

In the few studies in which leg strength was measured, there was a correlation between leg strength and maximal or peak VO_2 in three investigations[3,11,12] and no relationship in other studies.[13,14]

The etiologies for impaired exercise capacity in persons with NMDs are probably dependent on the specific disorder. In some diseases such as Duchenne muscular dystrophy, cardiomyopathy or pulmonary restrictive lung disease may be primary underlying factors. In diseases without apparent cardiopulmonary involvement, muscle fiber degeneration from the disease process, along with a sedentary lifestyle associated with physical deconditioning, are of primary importance.

AEROBIC EXERCISE TRAINING

With the exception of a single case report,[6] there are no studies examining aerobic exercise training in the more rapidly progressive NMDs of amyotrophic lateral sclerosis and Duchenne muscular dystrophy. One study of patients with inflammatory myopathy demonstrated improved cardiorespiratory fitness without any significant change of serum muscle enzymes after 6 wk of bicycle ergometry and step aerobics.[15]

In slowly progressive hereditary NMDs, three studies exist that combine multiple types of NMD into a group. In Florence and Hagberg,[8] subjects performed 12 wk of cycle ergometry training for 30 min, three times per week, for 12 wk, at 70% VO_{2max}. This resulted in a 25% increase in maximal oxygen uptake, similar to control subjects. However, there was significant variability between individual subjects. Conversely, Wright et al.[11] used a 12-wk home walking program, 3–4 times/wk, for 12 wk, at 50–60% heart rate reserve and found no change in peak VO_2, but a reduced heart rate at the same submaximal workload supported a training response. In an 8-wk study of treadmill exercise in subjects with various dystrophies at 70–85% estimated maximal heart rate reserve, Taivassalo et al.[16] demonstrated similar improvements in estimated aerobic capacity in both myopathic (15.7%) and control (10.1%) groups. Heart rate was significantly reduced at a comparable submaximal workload in the myopathic group.

In polio survivors, improved movement economy and walking duration in a aerobic treadmill training program 3 times/wk for 8 wk was consistent with improved biomechanical efficiency, but there was no change in VO_{2max}.[9,17] However, a longer training period of 16 wk was associated with improved VO_{2max} and increased exercise time using either cycle ergometry[18] or an upper limb training program.[19] A decreased heart rate at a given submaximal workload has also been demonstrated in polio survivors after 22 wk of low-resistance, high-repetition exercises[20] and 5 mo of activities in water.[21] The latter program involved 40 min of resistance and endurance activities two times/wk paced to avoid fatigue for the next 24 hr. No untoward effects of training were noted in these studies.

In summary, a small number of NMD investigations to date support these conclusions: (1) Most studies demonstrate positive response to aerobic exercise training, although VO_{2max} may not be affected; (2) cardiorespiratory adaptations to submaximal aerobic exercise training are qualitatively similar to adaptations in able-bodied persons; (3) although short-term adaptations may be demonstrated, the effect of long-term aerobic training is unclear and may ultimately be limited by the loss of muscle mass; and (4) individuals have a variable response to aerobic training, probably due to effects of the individual disease and level of conditioning at the time the study began.

Individuals with NMD generally represent a very sedentary and deconditioned population. Their responses to exercise testing are similar to deconditioned able-bodied subjects: lower VO_2, minute ventilation, stroke volume, cardiac output, work capacity, peripheral blood flow, and strength.[22] The age-related rate of decline in VO_{2max} seems to be greater in sedentary compared with active individuals,[23] which may also be relevant for the NMD population.

The reduction in maximal or VO_{2max} capacity in the NMD popula-

tion is at least partially due to loss of functional muscle mass directly related to the NMD. Without significant associated cardiac disease, reduced oxygen delivery to the muscle tissue is not an important limitation to performance.[24] Thus, it is likely that the reduction in functional muscle mass in individuals with NMD is the result of both atrophy of disuse from a sedentary lifestyle along with muscle fiber degeneration secondary to the NMD. In an individual patient, it may be difficult to separate the two processes.

CONSIDERATIONS FOR FUTURE EXERCISE STUDIES

The relative importance of improving aerobic capacity *vs.* muscular strength to enhance performance of daily tasks for persons with NMDs is unclear. It can be argued that maximal or peak aerobic capacity is less critical than muscle endurance, strength, and power because this seldom limits a person's ability to perform routine daily activities.[25]

Based on this review, future studies should focus on the following points:

1. Subjects with different diseases should be grouped separately because previous investigations demonstrate widely disparate responses between the different NMDs.
2. Baseline activity levels should be obtained to determine the level of physical inactivity for individual subjects. This may be performed with step activity monitoring, heart rate monitoring, or other techniques.
3. Specific training efforts should be focused on those activities that potentially yield the greatest effect on performance of work tasks and forestalling fatigue, possibly through a combination of strength and aerobic activities.
4. Measured outcome variables should include indicators of chronic disease risk such as blood pressure, resting heart rate, body mass and adiposity, glucose tolerance, and bone density.

REFERENCES

1. Neufer PD: The effect of detraining and reduced training on the physiological adaptations to aerobic exercise training. *Sports Med* 1989;8:302–21

2. Heath GW, Fentem PH: Physical activity among persons with disabilities: A public health perspective, in Holloszy JO (ed): *Exercise and Sports Science Reviews*. Baltimore, Williams and Wilkins, 1997, vol 25, pp 195–234

3. Sockolov R, Irwin B, Dressendorfer RH, et al: Exercise performance in 6–11-year old boys with Duchenne muscular dystrophy. *Arch Phys Med Rehabil* 1977; 58:195–201

4. Carroll JE, Hagberg JM, Brooke MH, et al: Bicycle ergometry and gas exchange measurements in neuromuscular diseases. *Arch Neurol* 1979;36:457–61

5. Sanjak M, Reddan W, Brooks BR: Role of muscular exercise in amyotrophic lateral sclerosis. *Neurol Clin* 1987;5:251–68

6. Sanjak M, Paulson D, Sufit R, et al: Physiologic and metabolic response to progressive and prolonged exercise in amyotrophic lateral sclerosis. *Neurol* 1987;37:1217–20

7. Haller RG, Lewis SF, Cook JD, et al: Hyperkinetic circulation during exercise in neuromuscular disease. *Neurol* 1983; 33:1283–7

8. Florence JM, Hagberg JM: Effect of training on the exercise responses of neuromuscular disease patients. *Med Sci Sports Exercise* 1984;16:460–5

9. Dean E, Ross J: Effect of modified aerobic training on movement energetics on polio survivors. *Orthopedics* 1991;14: 1243–6

10. Dean E, Ross J: Movement energetics of individuals with a history of poliomyelitis. *Arch Phys Med Rehabil* 1993;74: 478–83

11. Wright NC, Kilmer DD, McCrory MA, et al: Aerobic walking in slowly progressive neuromuscular disease: Effect of a 12-week program. *Arch Phys Med Rehabil* 1996;77:64–9

12. Wiesinger GF, Quittan M, Nuhr M, et al: Aerobic capacity in adult dematomyositis/polymyositis patients and healthy controls. *Arch Phys Med Rehabil* 2000;81: 1–5

13. Silva AC, Russo AK, Picarro IC, et al: Breathing pattern during exercise in myopathic subjects. *Braz J Med Biol Res* 1987;20:561–4

14. Silva AC, Russo AK, Picarro IC, et al: Cardiorespiratory responses to exercise in patients with spinal muscular atrophy and limb-girdle dystrophy. *Braz J Med Biol Res* 1987;20:565–8

15. Wiesinger GF, Quittan M, Aringer M, et al: Improvement of physical fitness and muscle strength in polymyositis/dermatomyositis patients by a training programme. *Br J Rheumatol* 1998;37:196–200

16. Taivassalo T, De Stafano N, Chen J, et al: Short-term aerobic training response in chronic myopathies. *Muscle Nerve* 1999;22:1239–43

17. Dean E, Ross J: Modified aerobic walking program: Effect on patients with post-polio syndrome symptoms. *Arch Phys Med Rehabil* 1988;69:1033–8

18. Jones DR, Speir J, Canine K, et al: Cardiorespiratory responses to aerobic training by patients with postpoliomyelitis sequelae. *JAMA* 1989;261:3255–8

19. Kriz JL, Jones DR, Speier JL, et al: Cardiorespiratory responses to upper extremity aerobic training by post-polio subjects. *Arch Phys Med Rehabil* 1992;73:49–54

20. Ernstoff B, Wetterqvist H, Kvist H, et al: Endurance training effect on individuals with postpoliomyelitis. *Arch Phys Med Rehabil* 1996;77:843–8

21. Willen C, Sunnerhagen KS, Grimby G: Dynamic water exercise in individuals with late poliomyelitis. *Arch Phys Med Rehabil* 2001;82:66–72

22. Greenleaf JE: Physiological consequences of reduced physical activity during bed rest, in Terjung RL (ed): *Exercise and Sport Sciences Reviews*. Lexington, MA, Collamore Press, 1982, vol 10, pp 84–119

23. Rogers MA, Hagberg JM, Martin WH III, et al: Decline in VO_{2max} with aging in master athletes and sedentary men. *J Appl Physiol* 1990;68:2195–9

24. Haller RG, Lewis SF: Pathophysiology of exercise performance in muscle disease. *Med Sci Sports Exerc* 1984;5: 456–9

25. Bar-Or O: Role of exercise in the assessment and management of neuromuscular disease in children. *Med Sci Sports Exerc* 1996;28:421–7