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Editorial

Methodological issues in physical exercise and people with spinal cord injury: a multidisciplinary approach is needed

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This editorial presents some methodological issues that should be considered when performing physical exercise in people with spinal cord injury (SCI) and raises the need for specific knowledge to adjust the protocols and training programs used in this population.

SCI is a paradigmatic case of a population with special characteristics in which there is a multisystemic alteration like neuromuscular, cardiovascular, respiratory, endocrine and others (Perrouin-Verbe et al., 2021) that influences the ability to perform physical exercise and the physiological response to it (Hicks et al., 2011). The development of aerobic training programs requires accurate monitoring of exercise intensity and knowledge of the metabolic response in terms of energy substrates used as a function of exercise intensity and duration. It is therefore necessary to know the pathophysiological characteristics of people with SCI and their response to exercise in order to make interventions safe and provide, in turn, health results.

Cardiovascular impairment

People with SCI have an impaired neural function below the level of injury, that is, a determining factor in the heart and peripheral vascular function (Astorino et al., 2009). SCI above T6 has a significant alteration due to the affectation of the sympathetic innervation of the heart, that plays a key role in cardiac and hemodynamic response during exercise because of the decrease in heart rate (HR), blood pressure and catecholamine release (Dela 2003). In fact, HR and cardiac output are inversely related to the level of injury, so a lower peak cardiovascular response occurs with high injury levels (Bhambani 2002). People with tetraplegia rarely reach maximum HR of 110-130 beats per minute (Brizuela et al., 2016). Consequently, some authors propose to adjust the age-predicted maximum HR to 190 - Age (Lockette et al., 1994). However, there is great variability in the maximum HR in each SCI person, and there is a lack of knowledge not just about how the level, but also how the degree of injury (complete or incomplete) affects heart rate.

Therefore, the use of HR to determine exercise intensity, as well as to evaluate changes in physical fitness, does not seem to be appropriate in SCI, especially above T6 level. Instead, the use of field-based methods such as rate of perceived exertion and talk test may be more accurate. (Goosey-Tolfrey et al., 2022).

Energy metabolism and physical fitness

Studies in athletes with SCI have observed that the pattern of energy substrate utilization during prolonged exercise is consistent with that of able-bodied athletes (Bhambhani et al., 2002), where the intensity and duration of exercise are determinant in the relative contribution of carbohydrates and fats; with increased intensity, contribution of fat decreases with enhanced reliance on carbohydrates and when exercise duration is prolonged, and contribution of fat increases (Romijn et al., 1993). Nevertheless, in people with SCI it was thought that the relative exercise intensity at which the maximum rate of fat oxidation (MFO) occurs (Fat_{max}) was lower than in the able-bodied population and therefore a greater dependence on carbohydrates was present (Knechtle et al., 2003). This has been observed in studies comparing SCI athletes performing an arm cycle ergometer test with able-bodied athletes performing a leg cycle ergometer test, which makes the results not entirely comparable as different muscle groups are involved. Conversely, and despite a lower maximum oxygen consumption (VO_{2max}) in people with SCI, we found that when comparing both groups performing the same type of exercise, those with SCI showed better rates of MFO, also obtained at a higher relative exercise intensity (Martín-Manjarrés et al., 2021). Furthermore, these differences remain even after considering whole-body and upper-body lean mass, cardiorespiratory fitness and fat mass percentage (Martín-Manjarrés et al., 2021). Therefore, there seems to be some adaptation of metabolism (metabolic flexibility) and muscle function for greater efficiency in people with SCI (Martín-Manjarrés et al., 2021).

In relation to the physical fitness, the exercise performed with arms could reach a VO_{2max} of 70% compared to treadmill exercise (Berg et al., 1976). Considering this, the VO_{2max} values of people with SCI will be lower than those obtained in non-disabled people. This shows that sympathetic impairment, lower limb paralysis and inactivity lead to a loss of physical capacity in people with SCI (Haisma et al., 2006). However, physical fitness is especially associated to the lean mass of people with SCI, with even the arm lean mass acting as a partial mediator in the indirect relationship between cardiorespiratory fitness and bone mass (Rodríguez-Gómez et al., 2019).

In this respect, and continuing with this approach, it is necessary to determine the fat oxidation in this population to stablish normative values in different levels of injury and fitness. Thus, further studies are warranted in this field.

Neuromuscular impairment

SCI causes loss of muscle strength in all muscle groups below the lesion and atrophy with decreased cross-sectional area and increased intramuscular fat (Gorgey et al., 2007). But the involvement also affects other aspects such as tone or muscle fiber composition. Impaired tone can lead to the development of spasticity in more than 65% of cases (Sköld et al., 1999) and can hinder independence, produce pain and fatigue, but can also be a protective factor for loss of skeletal muscle mass due to induction of muscle contraction (Cha et al., 2019).

Another consequence of this injury is an increase in the proportion of type IIx (fast) fibers and a decrease in type I (oxidative) fibers in the musculature below the injury due to the lack of stimuli from denervation and sedentary lifestyles and physical inactivity (Grimby et al., 1976).

These muscular alterations should be considered when programming cardiovascular and muscle strengthening exercises, with the aim of improving the oxidative capacity of impaired muscle fibers in partially affected limbs of patients with incomplete SCI, reducing early fatigue and improving aerobic capacity.

Multidisciplinary approach

People with SCI present characteristics that are not present in other disabled populations, which requires that exercise programs include both clinical criteria and aspects related to exercise training.

The altered response to exercise, the decrease in active muscle groups and therefore, in the variety of available exercises, the lack of integrated knowledge on the part of professionals, in addition to problems of access to facilities and appropriate equipment, make difficult for people with SCI to incorporate physical exercise into their daily lives, which in fact promotes an increase in sedentary lifestyles in this population. As a consequence, rates of obesity, metabolic syndrome and cardiovascular disease are higher in people with SCI (Martín-Manjarrés et al., 2022).

Therefore, a multidisciplinary approach including professionals from both the clinical and non-clinical settings from different disciplines is needed. in order to ensure that people with SCI obtain the highest benefits for their health and train in the most optimal conditions.

Conflicts of Interest: The authors declare no conflict of interest.

References

Astorino, T. A., Harness, E. T. (2009). Substrate metabolism during exercise in the spinal cord injured. Eur J Appl Physiol., 106(2):187-93. doi: 10.1007/s00421-009-1005-x

Bergh, U., Kanstrup, I. L., Ekblom, B. (1976). Maximal oxygen uptake during exercise with various combinations of arm and leg work. J Appl Physiol., 41(2):191-6. doi: 10.1152/jappl.1976.41.2.191

Bhambhani, Y. (2002). Physiology of wheelchair racing in athletes with spinal cord injury.

Sports Med., 32(1):23-51. doi: 10.2165/00007256-200232010-00002.
Brizuela, G., Romero, J. L., Beltrán, J. (2016). Lesión medular y ejercicio físico: revisión desde una perspectiva deportiva. Revista Española de Discapacidad, 4 (2): 163-185. doi: 10.5569/2340-5104.04.02.09
Cha, S., Yun, J. H., Myong, Y., & Shin, H. I. (2019). Spasticity and preservation of skeletal muscle mass in people with spinal cord injury. Spinal Cord, 57(4), 317-323.
Dela, F., Mohr, T., Jensen, C. M., Haahr, H. L., Secher, N. H., Biering-Sørensen, F., Kjaer, M. (2003). Cardiovascular control during exercise: insights from spinal cord-injured humans. Circulation. 29;107(16):2127-33. doi: 10.1161/01.CIR.0000065225.18093.E4
Goosey-Tolfrey, V. L., Hutchinson, M., & Sharpe, L. (2022). Infographic. Field-based methods for assessing exercise intensity in adults with spinal cord injury. British Journal of Sports Medicine.
Gorgey, A. S., Dudley, G. A. (2007) Skeletal muscle atrophy and increased intramuscular fat after incomplete spinal cord injury. Spinal Cord, 45(4):304-9. doi: 10.1038/sj.sc.3101968
Grimby, G., Broberg, C., Krotkiewska, I., Krotkiewski, M. (1976). Muscle fiber composition in patients with traumatic cord lesion. Scandinavian journal of rehabilitation medicine, 8(1), 37-42.
Haisma, J. A., van der Woude, L. H., Stam, H. J., Bergen, M.P., Sluis, T.A., Bussmann, J.B. (2006). Physical capacity in wheelchair-dependent persons with a spinal cord injury: a critical review of the literature. Spinal Cord. 44(11):642-52. doi: 10.1038/sj.sc.3101915.
Hicks, A. L., Martin Ginis, K. A., Pelletier, C. A., Ditor, D. S., Foulon, B., Wolfe, D. L. (2011). The effects of exercise training on physical capacity, strength, body composition and functional performance among adults with spinal cord injury: a systematic review. Spinal Cord, 49(11):1103-27. doi: 10.1038/sc.2011.62
Knechtle, B., Müller, G., Willmann, F., Eser, P., & Knecht, H. (2003). Comparison of fat oxidation in arm cranking in spinal cord-injured people versus ergometry in cyclists. European Journal of Applied Physiology, 90(5–6), 614–619. doi.org/10.1007/s00421-003-0920-5
Lockette, K. F., Keyes, A. M. (1994). Conditioning with physical disabilities. Human Kinetics, Champaign, IL, pp 91–116
Martín-Manjarrés, S., Leal-Martín, J., Granados, C., Mata, E., Gil-Agudo, Á., Rodríguez-Gómez, I., & Ara, I. (2022, December). Fat Oxidation during Exercise in People with Spinal Cord Injury, and Protocols Used: A Systematic Review. In Healthcare (Vol. 10, No. 12, p. 2402). Multidisciplinary Digital Publishing Institute.
Martín-Manjarrés, S., Rodríguez-López, C., Martín-García, M., Vila-Maldonado, S., Granados, C., Mata, E., Gil-Agudo, Á., Rodríguez-Gómez, I., Ara, I. (2021) Increased fat oxidation during arm cycling exercise in adult men with spinal cord injury compared with noninjured controls. Int J Sport Nutr Exerc Metab., 1;32(1):30-40. doi: 10.1123/ijsnem.2021-0143
Perrouin-Verbe, B., Lefevre, C., Kieny, P., Gross, R., Reiss, B., Le Fort, M. (2021). Spinal cord injury: A multisystem physiological impairment/dysfunction. Rev Neurol (Paris), 177(5):594-605. doi: 10.1016/j.neurol.2021.02.385
Rodríguez-Gómez, I., Martín-Manjarrés, S., Martín-García, M., Vila-Maldonado, S., Gil-Agudo, Á., M. Alegre, L., & Ara, I. (2019). Cardiorespiratory fitness and arm bone mineral health in young males with spinal cord injury: the mediator role of lean mass. Journal of sports sciences, 37(7), 717-725.
Romijn, J. A., Coyle, E. F., Sidossis, L. S., Gastaldelli, A., Horowitz, J. F., Endert, E., Wolfe, R. R. (1993). Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration. Am J Physiol., 265(3 Pt 1):E380-91. doi: 10.1152/ajpendo.1993.265.3.E380.
Sköld, C., Levi, R., Seiger, (1999). A. Spasticity after traumatic spinal cord injury: nature, severity, and location. Arch Phys Med Rehabil., 80(12):1548-57. doi: 10.1016/s0003-9993(99)90329-5.