

Experience the unique benefits of eccentric cycling!

High intensity work with lower metabolic cost
to increase concentric and eccentric muscle strength
for more power production.



Highlighted features

- Bidirectional 10 to 100 RPM
- Maximum power output up to 1000 watts from 40 to 100 RPM
- Low cadences with high workloads
- Smooth accelerations
- Eccentric exercises in isokinetic and constant power mode
- Concentric exercises in isokinetic mode
- Mixed load profiles backward/forward, eccentric/concentric and isokinetic/power
- Feedback display
- Export feature for research

Typical applications

- Strength training
- Coordination training and fall protection
- COPD and cardiac rehabilitation
- Cruciate ligament rupture and replacement rehabilitation
- Post Covid rehabilitation

CYCLUS 2

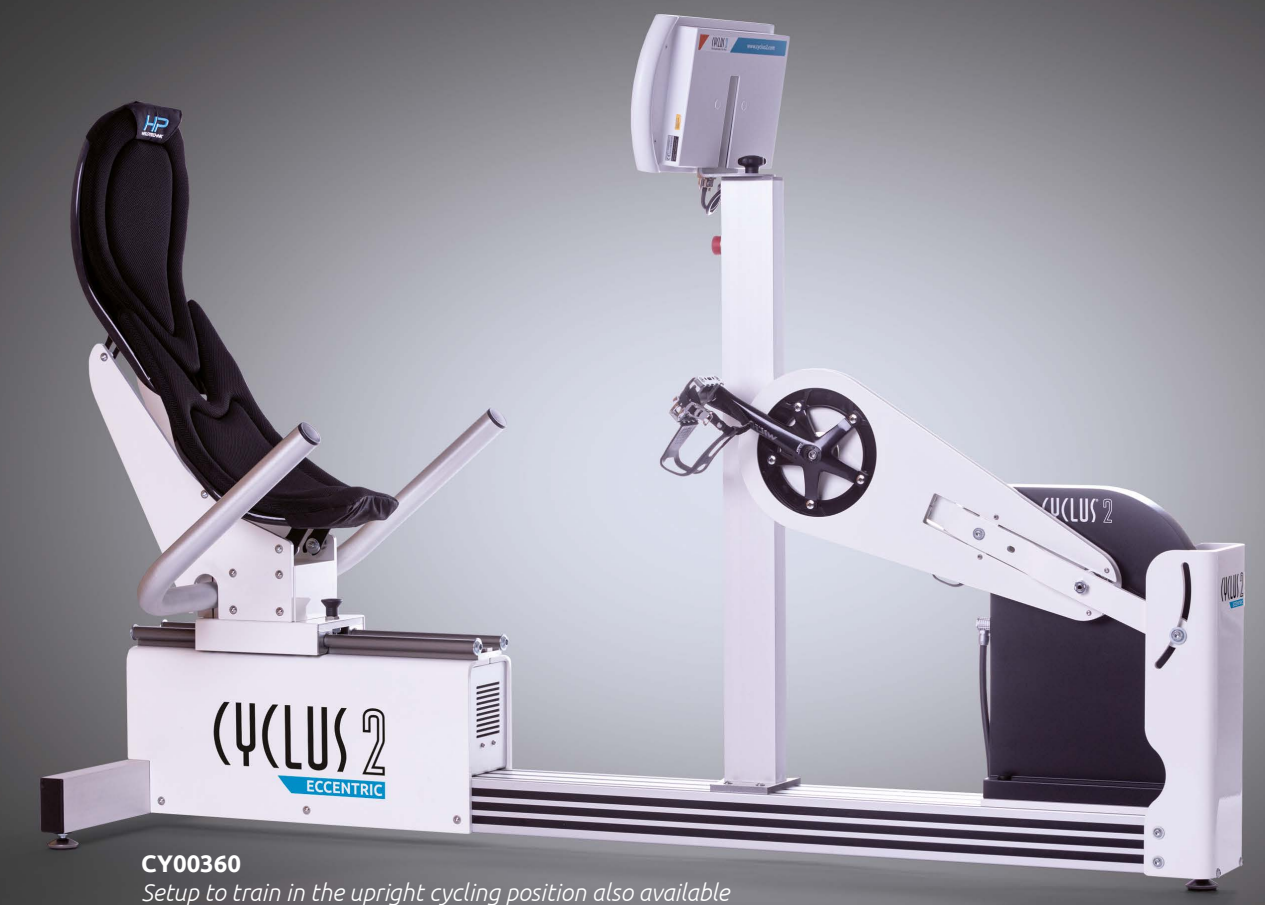
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Eccentric cycle ergometry: an old concept turned into a novel training modality

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In concentric (CON) muscle work, the muscle shortens during activation and performs motor actions, whereas in eccentric (ECC) muscle work, the muscle undergoes a forced lengthening while bearing an external load and performs braking actions. The last 25 years have seen a renewed interest for ECC cycle ergometry^{1,2}.

The very first ECC cycle ergometer for the lower limbs was described by Abbott et al.³ (Fig. 1) and was subsequently adapted as new technologies became available for both lower⁴ and upper limbs⁵. Nowadays, an eccentric cycle ergometer has been made commercially available offering the possibility to use a normal bike to generate both CON and ECC muscle work on the same apparatus (Cyclus2 Eccentric Trainer®).

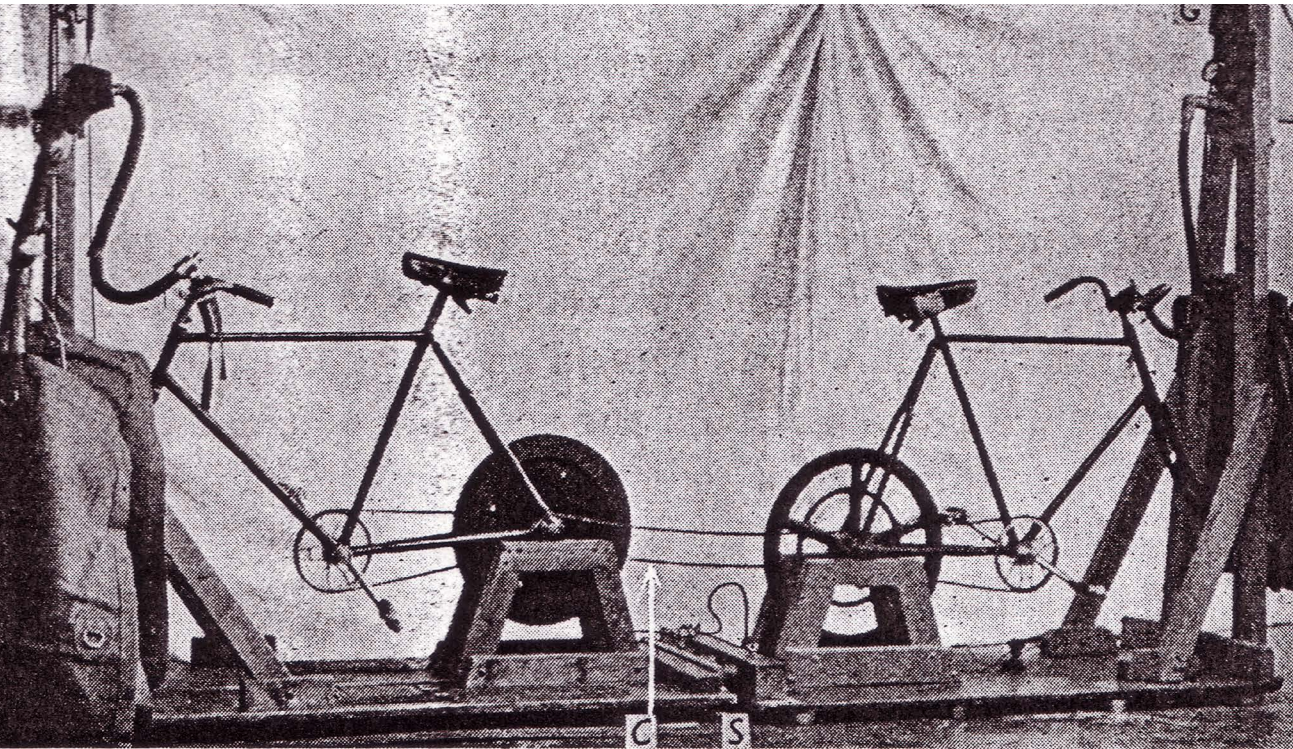


Figure 1: The first eccentric cycle ergometer. Two bicycle ergometers were placed back to back and coupled by a chain; when one cyclist pedaled concentrically in the conventional forward direction, the legs of the other cyclist were driven backwards allowing eccentric muscle work to be performed (reproduced from Abbott et al.³)

1. Major physiological properties of eccentric muscle work

Eccentric muscle actions can produce greater force than CON or isometric muscle actions⁶⁻⁸ and maximal power can be much higher in eccentric than in conventional concentric cycling^{9,10}. The greater force produced during ECC muscle actions arise from a combination of specific, although not yet fully identified, molecular events involved in the cross-bridge cycle¹¹ and of specific neural control strategies¹². At similar mechanical power output, ECC cycling elicits a lower oxygen consumption (VO_2)^{13,14}, and reduced ventilatory¹⁵ and cardiocirculatory responses (Figure 2).^{16,17}

The lower oxygen cost of ECC cycling might be due to a combination of non-adenosine triphosphate (ATP)-dependent “mechanical” rupture of the actin-myosin crossbridges^{18,19}, a greater distance covered by each individual actin-myosin crossbridge^{20,21} and a lower recruitment of motor units²².

Therefore, the general feeling of subjects cycling eccentrically is that exercise is much easier compared to the CON cycling, as attested by lower levels of perceived exertion. Also of particular interest are several reports which suggest that despite being “energy efficient”, ECC muscle work might increase post-exercise resting energy expenditure for up to 72 h^{22,23}.

ECC cycling can also be performed at a similar VO_2 as CON cycling provided that the mechanical power output in the ECC mode is high enough (i.e., ~5-fold higher in ECC than CON cycling). In this specific condition, Q and HR are higher during ECC cycling²⁵.

This observation has important repercussions for the management of exercise intensity and training load as exercising at a similar VO_2 actually requires a higher HR in ECC than in CON cycling.¹³

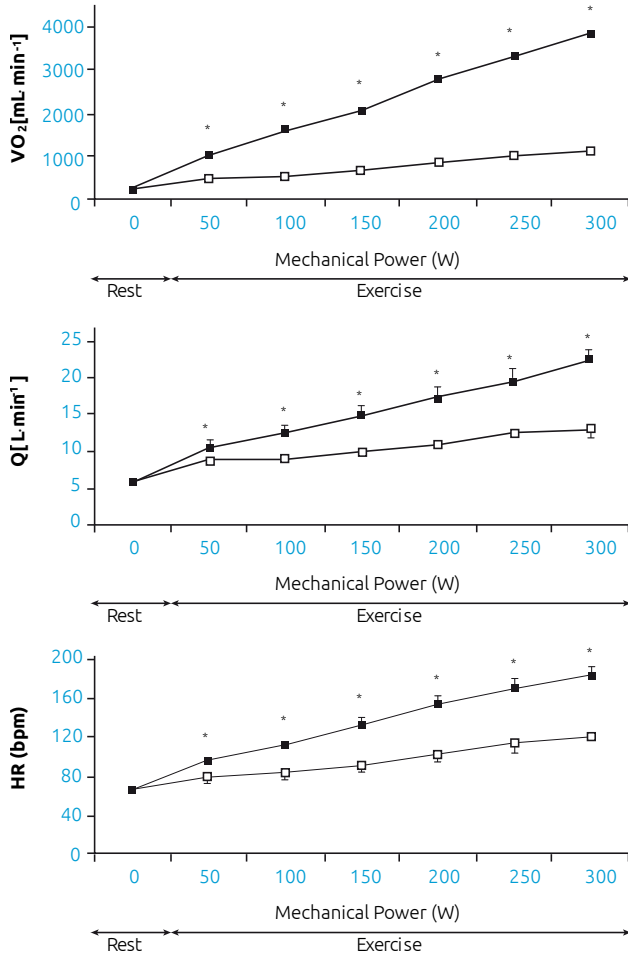


Figure 2: VO_2 , cardiac output (Q) and heart rate (HR) as a function of the mechanical power during CON and ECC cycling. (adapted from Dufour et al.¹³). bpm beats per min, ECC: white symbols; CON: black symbols, *p < 0.05: significant difference CON vs ECC.

2. Eccentric cycle exercise does not necessarily generate muscle damage

ECC muscle work can lead to marked exercise-induced muscle damage (EIMD), especially when high muscle forces are generated^{26,27} and/or if the ECC muscle actions are performed at high velocity²⁸ or short/long muscle length²⁹. However, the magnitude of EIMD is progressively reduced after repetition of the same ECC exercise (i.e repeated bout effect)³⁰ and subjects engaged in regular

ECC training become less susceptible to EIMD³⁰. Therefore, if ECC cycling intensity is increased gradually, young^{31,32} and older^{33,34} healthy subjects as well as patients with various chronic diseases (i.e cancer, cardiac, respiratory disorders,...) can adapt to high-force ECC cycling sessions without muscle damage but improved locomotor abilities and health outcomes³⁵.

3. Training Response After ECC Exercise Training Programmes

A major advantage of ECC cycling is the possibility to achieve very high mechanical load (up to 900W over 30min continuous training session³⁶) with limited energy expenditure. ECC cycling as a training strategy was shown to improve isometric strength (+33 %) and induce greater hypertrophy of the quadriceps muscle (+52%) than CON cycling training in healthy subjects^{37,38}. In high-school basketball players and top level junior alpine skiers, ECC cycle training improved jump height by 6-8% compared with weight-training³⁹. Increased jumping power and leg spring stiffness were also documented after ECC compared to CON cycle training⁴⁰, suggesting that ECC cycle training might improve muscle ability to store and restore elastic strain energy. The interest of ECC cycling is also appearing for rehabilitation purposes in athletes as elevated quadriceps strength and volume were observed after ECC compared to CON cycle training after ligamentoplasty of the anterior cruciate ligament of the knee^{41,42}.

In elderly people³³ or in patients suffering from cardio-respiratory diseases⁴³⁻⁴⁶, metabolic disorders and obesi-

ty^{47,48}, neurological pathologies^{49,50} and some types of cancers (i.e breast, prostate, lung, colon and lymphoma)^{51,52}, ECC cycle training demonstrated its feasibility even at very advanced ages (i.e >80 yr old) with virtually no EIMD nor other side effects. Common to these different conditions, ECC cycle training has demonstrated encouraging results in increasing muscle mass and force ultimately improving patients' exercise capacity and quality of life. Recent findings also indicate that ECC cycling might prevent bone fragility⁵³ and favor neuroplasticity⁵⁴. Altogether, these findings suggest that ECC training might be particularly suitable for improving body composition and muscle strength even in the more frail subjects, possibly via the specific expression of transcripts encoding factors involved in muscle growth, repair and remodeling⁵⁵.

Although its specific mechanical, metabolic and cardiovascular responses deserve particular attention for optimal monitoring of training load, ECC cycle ergometry currently emerges as a promising training strategy not only for athletes but also in the elderly and many diseased states.

1. Hoppeler, H., Eccentric exercise: physiology and application in sport and rehabilitation. 2015, New York: Routledge.

2. Isner-Horobeti, M.E., et al., Eccentric exercise training: modalities, applications and perspectives. Sports Med, 2013. 43(6): p. 483-512.

3. Abbott, B.C., B. Bigland, and J.J. Ritchie, The physiological cost of negative work. J Physiol, 1952. 117(3): p. 380-90.

4. Elmer, S.J., and J.C. Martin, Construction of an isokinetic eccentric cycle ergometer for research and training. J Appl Biomech, 2013. 29(4): p. 490-5.

5. Elmer, S.J., J. Danvind, and H.C. Holmberg, Development of a novel eccentric arm cycle ergometer for training the upper body. Med Sci Sports Exerc, 2013. 45(1): p. 206-11.

6. Westing, S.H. and J.Y. Seger, Eccentric and concentric torque-velocity characteristics, torque output comparisons, and gravity effect torque corrections for the quadriceps and hamstrings muscles in females. Int J Sports Med, 1989. 10(3): p. 175-80.

7. Westing, S.H., A.G. Cresswell, and A. Thorstensson, Muscle activation during maximal voluntary eccentric and concentric knee extension. Eur J Appl Physiol Occup Physiol, 1991. 62(2): p. 104-8.

8. Crenshaw, A.G., et al., Knee extension torque and intramuscular pressure of the vastus lateralis muscle during eccentric and concentric activities. Eur J Appl Physiol Occup Physiol, 1995. 70(1): p. 13-9.

9. Lipski, M., C.R. Abbiss, and K. Nosaka, Cardio-pulmonary responses to incremental eccentric and concentric cycling tests to task failure. Eur J Appl Physiol, 2018. 118(5): p. 947-957.

10. Green, D.J., et al., Torque, power and muscle activation of eccentric and concentric isokinetic cycling. J Electromyogr Kinesiol, 2018. 40: p. 56-63.

11. Hessel, A.L., S.L. Lindstedt, and K.C. Nishikawa, Physiological Mechanisms of Eccentric Contraction and Its Applications: A Role for the Giant Titin Protein. Front Physiol, 2017. 8: p. 70.

12. Enoka, R.M., Eccentric contractions require unique activation strategies by the nervous system. J Appl Physiol, 1996. 81(6): p. 2339-46.

13. Dufour, S.P., et al., Eccentric cycle exercise: training application of specific circulatory adjustments. Med Sci Sports Exerc, 2004. 36(11): p. 1900-6.

14. Perrey, S., et al., Comparison of oxygen uptake kinetics during concentric and eccentric cycle exercise. J Appl Physiol, 2001. 91(5): p. 2135-42.

15. Lechaume, J.B., et al., Breathing patterns during eccentric exercise. Respir Physiol Neurobiol, 2014. 202: p. 53-8.

16. Bonde-Petersen, F., H.G. Knuttgen, and J. Henriksson, Muscle metabolism during exercise with concentric and eccentric contractions. J Appl Physiol, 1972. 33(6): p. 792-5.

17. Knuttgen, H.G. and K. Klausen, Oxygen debt in short-term exercise with concentric and eccentric muscle contractions. J Appl Physiol, 1971. 30(5): p. 632-5.

18. Piazzesi, G., et al., Tension transients during steady lengthening of tetanized muscle fibres of the frog. J Physiol, 1992. 445: p. 659-711.

19. Huxley, A.F., Biological motors: energy storage in myosin molecules. Curr Biol, 1998. 8(14): p. R485-8.

20. Ryschon, T.W., et al., Efficiency of human skeletal muscle in vivo: comparison of isometric, concentric, and eccentric muscle action. J Appl Physiol, 1997. 83(3): p. 867-74.

21. Kitamura, K., et al., A single myosin head moves along an actin filament with regular steps of 5.3 nanometres. Nature, 1999. 397(6715): p. 129-34.

22. Bigland-Ritchie, B. and J.J. Woods, Integrated electromyogram and oxygen uptake during positive and negative work. J Physiol, 1976. 260(2): p. 267-77.

23. Paschalis, V., et al., Beneficial changes in energy expenditure and lipid profile after eccentric exercise in overweight and lean women. Scand J Med Sci Sports, 2010. 20(1): p. e103-11.

24. Hackney, K.J., H.J. Engels, and R.J. Gretebeck, Resting energy expenditure and delayed-onset muscle soreness after full-body resistance training with an eccentric concentration. J Strength Cond Res, 2008. 22(5): p. 1602-9.

25. Dufour, S.P., et al., Deciphering the metabolic and mechanical contributions to the exercise-induced circulatory response: insights from eccentric cycling. Am J Physiol Regul Integr Comp Physiol, 2007. 292: p. R1641-R1648.

26. Coffey, V.G., et al., Early signaling responses to divergent exercise stimuli in skeletal muscle from well-trained humans. FASEB J, 2006. 20(1): p. 190-2.

27. Krentz, J.R. and J.P. Farthing, Neural and morphological changes in response to a 20-day intense eccentric training protocol. Eur J Appl Physiol, 2010. 110(2): p. 333-40.

28. Chapman, D., et al., Greater muscle damage induced by fast versus slow velocity eccentric exercise. Int J Sports Med, 2006. 27(8): p. 591-8.

29. Paschalis, V., et al., Short vs. long length of rectus femoris during eccentric exercise in relation to muscle damage in healthy males. Clin Biomech (Bristol, Avon), 2005. 20(6): p. 617-22.

30. Hydahl, R.D., T.C. Chen, and K. Nosaka, Mechanisms and Mediators of the Skeletal Muscle Repeated Bout Effect. Exerc Sport Sci Rev, 2017. 45(1): p. 24-33.

31. Lastayo, P.C., et al., Chronic eccentric exercise: improvements in muscle strength can occur with little demand for oxygen. Am J Physiol, 1999. 276(2 Pt 2): p. R611-5.

32. Lastayo, P.C., et al., Eccentric ergometry: increases in locomotor muscle size and strength at low training intensities. Am J Physiol Regul Integr Comp Physiol, 2000. 278(5): p. R1282-8.

33. Lastayo, P.C., et al., The positive effects of negative work: increased muscle strength and decreased fall risk in a frail elderly population. J Gerontol A Biol Sci Med Sci, 2003. 58(5): p. M419-24.

34. Lastayo, P.C., et al., Reversing muscle and mobility deficits 1 to 4 years after TKA: a pilot study. Clin Orthop Relat Res, 2009. 467(6): p. 1493-500.

35. Barreto, R.V., L.C.R. de Lima, and B.S. Denadai, Moving forward with backward pedaling: a review on eccentric cycling. Eur J Appl Physiol, 2021. 121(2): p. 381-407.

36. Gross, M., et al., Effects of eccentric cycle ergometry in alpine skiers. Int J Sports Med, 2010. 31(8): p. 572-6.

37. Lastayo, P.C., et al., Chronic eccentric exercise: improvements in muscle strength can occur with little demand for oxygen. Am J Physiol, 1999. 276(2 Pt 2): p. R611-R615.

38. Lastayo, P.C., et al., Eccentric ergometry: increases in locomotor muscle size and strength at low training intensities. Am J Physiol Regul Integr Comp Physiol, 2000. 278(5): p. R1282-R1288.

39. Lindstedt, S.L., et al., Do muscles function as adaptable locomotor springs? J Exp Biol, 2002. 205(Pt 15): p. 2211-6.

40. Elmer, S., et al., Improvements in multi-joint leg function following chronic eccentric exercise. Scand J Med Sci Sports, 2011.

41. Gerber, J.P., et al., Effects of early progressive eccentric exercise on muscle structure after anterior cruciate ligament reconstruction. J Bone Joint Surg Am, 2007. 89(3): p. 559-70.

42. Gerber, J.P., et al., Safety, feasibility, and efficacy of negative work exercise via eccentric muscle activity following anterior cruciate ligament reconstruction. J Orthop Sports Phys Ther, 2007. 37(1): p. 10-8.

43. MacMillan, N.J., et al., Eccentric Ergometer Training Promotes Locomotor Muscle Strength but Not Mitochondrial Adaptation in Patients with Severe Chronic Obstructive Pulmonary Disease. Front Physiol, 2017. 8: p. 114.

44. Chasland, L.C., et al., Eccentric Cycling: A Promising Modality for Patients with Chronic Heart Failure. Med Sci Sports Exerc, 2017. 49(4): p. 646-651.

45. Inostroza, M., et al., Effects of eccentric vs concentric cycling training on patients with moderate COPD. Eur J Appl Physiol, 2022. 122(2): p. 489-502.

46. Bourbeau, J., et al., Eccentric versus conventional cycle training to improve muscle strength in advanced COPD: A randomized clinical trial. Respir Physiol Neurobiol, 2020. 276: p. 103414.

47. Marcus, R.L., et al., Comparison of combined aerobic and high-force eccentric resistance exercise with aerobic exercise only for people with type 2 diabetes mellitus. Phys Ther, 2008. 88(11): p. 1345-54.

48. Julian, V., et al., Eccentric cycling is more efficient in reducing fat mass than concentric cycling in adolescents with obesity. Scand J Med Sci Sports, 2019. 29(1): p. 4-15.

49. Dibble, L.E., et al., The safety and feasibility of high-force eccentric resistance exercise in persons with Parkinson's disease. Arch Phys Med Rehabil, 2006. 87(9): p. 1280-2.

50. Dibble, L.E., et al., High-intensity resistance training amplifies muscle hypertrophy and functional gains in persons with Parkinson's disease. Mov Disord, 2006. 21(9): p. 1444-52.

51. Lastayo, P.C., et al., Eccentric exercise versus usual-care with older cancer survivors: the impact on muscle and mobility—an exploratory pilot study. BMC Geriatr, 2011. 11: p. 5.

52. Lastayo, P.C., et al., The feasibility and efficacy of eccentric exercise with older cancer survivors: a preliminary study. J Geriatr Phys Ther, 2010. 33(3): p. 135-40.

53. Julian, V., et al., Bone response to eccentric versus concentric cycling in adolescents with obesity. Obes Res Clin Pract, 2020. 14(6): p. 554-560.

54. Clos, P., R. Lepers, and Y.M. Garnier, Locomotor activities as a way of inducing neuroplasticity: insights from conventional approaches and perspectives on eccentric exercises. Eur J Appl Physiol, 2021. 121(3): p. 697-706.

55. Mueller, M., et al., Different molecular and structural adaptations with eccentric and conventional strength training in elderly men and women. Gerontology, 2011. 57(6): p. 528-38.