Ann Mil Health Sci Res. 2022 June; 20(2):e119122. https://doi.org/10.5812/amh-119122.

Published online 2022 June 29. **Letter**

Mitochondrial Biogenesis in Continuous vs High-intensity Interval Swimming

Fatemeh Heiat [1], Mohsen Ghanbarzadeh [1,*], Rouhollah Ranjbar [1] and Manzar Banoo Shojaeifard [2]

[1] Department of Exercise Physiology, Faculty of Sport Sciences, Shahid Chamran University of Ahvaz, Ahvaz, Iran
[2] Ionizing and Non-Ionizing Radiation Protection Research Center (INIRPRC), School of Paramedical Sciences, Shiraz University of Medical Sciences, Shiraz, Iran

[*] *Corresponding author*: Department of Exercise Physiology, Faculty of Sport Sciences, Shahid Chamran University of Ahvaz, Ahvaz, Iran. Email: ghanbarzadeh213@gmail.com

Received 2021 September 06; **Revised** 2021 October 20; **Accepted** 2021 November 01.

Keywords: Continuous Training, High-intensity Interval Training, PGC-1α, SIRT3, Oxidative Stress Index

Dear Editor,

The PGC-1α protein is strongly affected by changes in SIRT3, and upregulation of SIRT3 increases the mitochondrial biogenesis. Due to the role of the mitochondria as the main organelles in energy production, its dysfunction (decrease in energy storage and mitochondrial-mediated apoptosis) may be involved in the development of degenerative diseases such as s arcopenia (severe loss of muscle mass). Therefore, mitochondrial dysfunction is closely related to cell death and consequently reduced life expectancy. Affecting PGC-1α and SIRT3, exercise and calorie restriction increase the processes related to mitochondrial biogenesis and decrease reactive oxygen species (ROS) production (1).

SIRT3 is a member of NAD^+-dependent deacetylase family proteins (2), regulating several cellular activities such as metabolic homeostasis (3) and principal cellular responses (3). SIRT3 increases cellular respiration while reducing the production of ROS (4). Ahn et al. indicated that SIRT3 regulated mitochondrial oxidative capacity (1), which is associated with mitochondrial-mediated protection against apoptosis (5). These results support the possibility of exercise-induced mitochondrial oxidative capacity and mitochondrial-mediated apoptosis in skeletal muscle (6), suggesting that SIRT3 is associated with cell longevity.

On the other side, PGC1α regulates genes involved in determining the type of muscle fiber (7). It also protects muscles against atrophy (8). Calorie restriction and exercise increase the expression of PGC1-α and SIRT3 (9). They also reduce cellular energy levels and increase NAD^+ levels. Since SIRT3 is NAD^+-dependent, such conditions increase the activity of SIRT3 and its downstream targets (9).

This theorem proves that endurance exercises regularly create adaptation in the cardiovascular and muscular systems. The most important intracellular response to endurance exercises is an increase in the number and size of mitochondria. This situation increases the activity of oxidative enzymes in muscle cells (10).

Turning to the authors' previous research (11, 12), continuous swimming (CT) and high-intensity interval swimming (HIIT) significantly increase the amount of PGC-1α in slow-twitch skeletal muscles soleus (SOL); however, the consequences of upregulation in PGC-1α are not totally understood and calls for more molecular research.

The authors also showed that CT and HIIT significantly increased the levels of the SIRT3 protein in slow-twitch muscle (SOL) (11, 12).

In our previous studies, a non-significant increase in reduced glutathione/oxidized glutathione (GSH: GSS) was observed in SOL muscles following HIIT exercise (11, 12). It can be related to various factors, including ROS produced by exercise and its measurement time. This phenomenon indicates the ability of the antioxidant system in SOL to maintain the balance of intracellular oxidative stress (13). This ability could be attributed to the greater compatibility of slow-twitch muscles with these two types of training, where the expression of the protein associated with the longevity and the antioxidant system of these muscles is further improved, and more free radicals produced by aerobic oxidation within the mitochondria are further neutralized.

Our previous findings (11, 12) suggest that 2 important proteins involved in mitochondrial biogenesis (PGC-1α and SIRT3) increase significantly following both HIIT and CT training in slow-twitch muscle tissue, which could potentially improve cell longevity. No significant increase in the GSH: GSSG level was also observed in SOL muscles fol-

lowing both exercises (CT and HIIT). This indicates the effect of both exercises on improving the oxidative capacity of SOL muscle fibers. Thus, HIIT exercise can be as effective as CT in improving mitochondrial biogenesis of muscle tissue, creating aerobic adaptations, increasing oxidative capacity, cell health, and ultimately longevity and preventing aging. Therefore, it can be a good alternative to traditional endurance training.

Footnotes

Authors' Contribution: Study concept and design and acquisition of data: F. H. and M. G; analysis and interpretation of data: F. H.; drafting of the manuscript: F. H.; critical revision of the manuscript for important intellectual content: M. G., M. B. S., and R. R.; statistical analysis: F. H.; administrative, technical, and material support: M. G., M. B. S., and R. R.; study supervision: M. G. and M. B. S.

Conflict of Interests: The authors have indicated that they have no conflicts of interest regarding the content of this article.

Funding/Support: The authors received no funding from any institution.

References

1. Ahn BH, Kim HS, Song S, Lee IH, Liu J, Vassilopoulos A, et al. A role for the mitochondrial deacetylase Sirt3 in regulating energy homeostasis. *Proc Natl Acad Sci U S A*. 2008;**105**(38):14447–52. [PubMed ID: 18794531]. [PubMed Central ID: PMC2567183]. https://doi.org/10.1073/pnas.0803790105.
2. Imai S, Armstrong CM, Kaeberlein M, Guarente L. Transcriptional silencing and longevity protein Sir2 is an NAD-dependent histone deacetylase. *Nature*. 2000;**403**(6771):795–800. [PubMed ID: 10693811]. https://doi.org/10.1038/35001622.
3. Finkel T, Deng CX, Mostoslavsky R. Recent progress in the biology and physiology of sirtuins. *Nature*. 2009;**460**(7255):587–91. [PubMed ID: 19641587]. [PubMed Central ID: PMC3727385]. https://doi.org/10.1038/nature08197.
4. Shi T, Wang F, Stieren E, Tong Q. SIRT3, a mitochondrial sirtuin deacetylase, regulates mitochondrial function and thermogenesis in brown adipocytes. *J Biol Chem*. 2005;**280**(14):13560–7. [PubMed ID: 15653680]. https://doi.org/10.1074/jbc.M414670200.
5. Sundaresan NR, Samant SA, Pillai VB, Rajamohan SB, Gupta MP. SIRT3 is a stress-responsive deacetylase in cardiomyocytes that protects cells from stress-mediated cell death by deacetylation of Ku70. *Mol Cell Biol*. 2008;**28**(20):6384–401. [PubMed ID: 18710944]. [PubMed Central ID: PMC2577434]. https://doi.org/10.1128/MCB.00426-08.
6. Hokari F, Kawasaki E, Sakai A, Koshinaka K, Sakuma K, Kawanaka K. Muscle contractile activity regulates Sirt3 protein expression in rat skeletal muscles. *J Appl Physiol (1985)*. 2010;**109**(2):332–40. [PubMed ID: 20413424]. https://doi.org/10.1152/japplphysiol.00335.2009.
7. Steinbacher P, Eckl P. Impact of oxidative stress on exercising skeletal muscle. *Biomolecules*. 2015;**5**(2):356–77. [PubMed ID: 25866921]. [PubMed Central ID: PMC4496677]. https://doi.org/10.3390/biom5020356.
8. Kang C, Ji LL. Role of PGC-1α in muscle function and aging. *J Sport Health Sci*. 2013;**2**(2):81–6. https://doi.org/10.1016/j.jshs.2013.03.005.
9. Palacios OM, Carmona JJ, Michan S, Chen KY, Manabe Y, Ward J3, et al. Diet and exercise signals regulate SIRT3 and activate AMPK and PGC-1alpha in skeletal muscle. *Aging (Albany NY)*. 2009;**1**(9):771–83. [PubMed ID: 20157566]. [PubMed Central ID: PMC2815736]. https://doi.org/10.18632/aging.100075.
10. Yan Z, Okutsu M, Akhtar YN, Lira VA. Regulation of exercise-induced fiber type transformation, mitochondrial biogenesis, and angiogenesis in skeletal muscle. *J Appl Physiol (1985)*. 2011;**110**(1):264–74. [PubMed ID: 21030673]. [PubMed Central ID: PMC3253006]. https://doi.org/10.1152/japplphysiol.00993.2010.
11. Heiat F, Ghanbarzadeh M, Ranjbar R, Shojaeifard M. Continuous swimming training arises a remarkable effect on some longevity biomarkers in rat skeletal muscles. *Ann Appl Sport Sci*. 2020;**8**(2):0.
12. Heiat F, Ghanbarzadeh M, Shojaeifard M, Ranjbar R. The effect of high-intensity interval training on the expression levels of PGC-1α and SIRT3 proteins and aging index of slow-twitch and fast-twitch of healthy male rats. *Science & Sports*. 2021;**36**(2):170–5. https://doi.org/10.1016/j.scispo.2020.06.002.
13. Michailidis Y, Jamurtas AZ, Nikolaidis MG, Fatouros IG, Koutedakis Y, Papassotiriou I, et al. Sampling time is crucial for measurement of aerobic exercise-induced oxidative stress. *Med Sci Sports Exerc*. 2007;**39**(7):1107–13. [PubMed ID: 17596778]. https://doi.org/10.1249/01.mss.0b013e318053e7ba.