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Effects of Exercise on Testosterone Level, Heat Shock Protein, and Fertility Potential

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ABSTRACT

In recent years, professional exercise has been significantly expanded among the individuals, especially young ones. According to high-intensity exercise courses, which are necessary for professional exercise, we decided to investigate the effects of high-intensity exercise on testosterone levels, heat shock proteins, and fertility potentials. Findings have shown that the levels of testosterone increase in moderate exercise; however, there are findings about the decrease of testosterone in the athletes who exercise with high intensity. In addition, because the high-intensity training is considered as a stressful condition, the heat shock proteins are activated, and their expression levels are increased that shows the vital role of these essential proteins in eliminating or weakening of that stress. Besides, the parameters, such as sperm quantity, sperm motility, and morphology determine the fertility potential of a person, and studies have shown that high-intensity exercise has harmful effects on these parameters.

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Introduction

Exercise is a two-edged sword, so that if the individuals do exercise with a normal and appropriate level, it will have positive effects on the reproductive system; however, if the individuals do it in a higher level than normal, it will harmfully affect the reproductive system. It has been shown that the harmful effects of training are associated with the volume, type, and the style of training (1,2). The effects of aerobic training on the hormonal and reproductive system are different. In the individuals who exercise for a long time with high intensity, the levels of testosterone (testosterone is an important factor in regulating the hypothalamus-pituitary-testis axis) diminish and hypogonadism occurs (3). In these individuals, the parameters, such as sperm number, motility, and viability decrease and as a result, the fertility potential declines (1,3,4).

It has been reported that the high levels of training in young men lead to the increased concentration of immotile sperms, which is associated with age. Furthermore, it has been shown that in young men who exercise moderately, the concentration and total number of sperm increase (5). It has been reported that body mass index (BMI) in the range of 20-25 kg/m^2 is important for maintaining the health of the reproductive system and fertility potentials of men. Like the individuals with normal BMI, in overweight people who exercise with a moderate intensity, the levels of testosterone, luteinizing hormone (LH), and follicle-stimulating hormone (FSH) are decreased; however,

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along with an increase in the intensity of training, the positive effects are substituted by the adverse effects (6).

Infertility is a significant problem,which attracts considerable attention, and with regard to the increase of professional exercises, this issue is increasing, and that is why infertility specialists warn about it. There are several parameters, such as sperm quality, sperm quantity, sperm motility, sperm DNA integrity, and oxidative stress, which determine the fertility potential; nonetheless, one of the most important factors is the level of heat shock proteins (HSPs). According to the results of normal sperm analysis in some patients with unexplained infertility and due to the adverse effects of intense exercise on the fertility, HSPs can be considered as a factor causing infertility that by molecular methods, we can survey the expression rates of the HSPs in the organs. Furthermore, we can investigate the destructive effects of exercises with high intensity on the level of HSPs.

There is an absolute need for cells to repair their proteins. Chaperones are the factors which mend those proteins. Molecular chaperones and chaperonins are two groups that have different functions (7). Molecular chaperones are present in the complexes with other proteins, which regulate ATPase activity. In 1962, Ferrucio Ritossa discovered a cellular reaction that is called heat shock. It has been approved that the major feature of the heat shock response is the rapid or high induction of expression of genes, which encode HSPs, and these proteins diminish the harmful effects of environment or endogenous stress (8). The HSPs are divided into various classes, according to their molecular weights and amino acid sequences (9).

The overall function of HSPs as molecular chaperones is maintaining the intracellular homeostasis, primarily by controlling the folding. Many HSPs function as molecular partners for other special proteins, such as signal transporters and transcription factors. Also, HSPs show anti-apoptosis feature; furthermore, they can regulate several immune responses. These properties are applied in various medical fields as useful markers or for treatment (10,11).

It has been shown that the largest group of heat shock proteins is HSPA (HSP70), which has at least 13 members in humans. There are two genes in HSPA family, namely HSPA2 and HSPA1L, which are special for spermatogenesis (9). It has been shown that HSP70 acts as a molecular chaperone. It is associated with the hydrophobic domains of ribosomal polypeptides, which contribute to releasing cycles, ATP-dependent reattaching, folding, and transporting of proteins, as well as aggregating them in the complexes (12). In stressful conditions, HSP70s contribute to the reconstruction of degenerated proteins and allow the cells to be improved from sub-lethal stresses.

The testis in most mammals is out of the body in the scrotum, which is cooled by counter-current process and is kept at 5° to 7 °C lower than the body temperature. Spermatogenesis is impaired by high temperature or other environmental damages (13-16), so that these heat shock proteins have different roles in spermatogenic cells, compared to other cell types. It has been reported that the leptotene/zygotene spermatocytes, which have completed the transcription, synthesize the HSP70-2 protein. It has been shown that the concentration of HSP72 is decreased by training. It has been demonstrated that when the level of HSP72 in the serum increases, the expression of the muscle HSP72 gene or protein decreases.

Furthermore, the important point is that HSP72, which is found in blood, is not released just from contracting skeletal muscle (17,18). The acute periodic exercise increases the expression of HSP72 gene and protein in the organs, such as heart, liver, skeletal muscle, and brain. The exercise is associated with the stressor factors, such as temperature, oxidative stress/free-radical formation, the decreased levels of glucose/glycogen, Hypoxia/ischemia, pH alteration, and increased levels of calcium, which induce the response of HSP72.

After training, the expression levels of messenger RNA and protein change. Chronic exercise causes the increase of HSP72 in skeletal muscles, whereas high-intensity exercise increases the concentration of HSP72 and HSP27 in skeletal muscles (19). It has been shown that four weeks of aerobic exercise (three times a week) increases the levels of cortisol, free testosterone, and lactate dehydrogenase in young men. Heat stress interferes with mitochondrial function and stimulates the oxidative damage, which is manifested in lipid peroxidation (20). Also, heat stress has increased the levels of many reactive oxygen species-scavenging proteins (21). It has been shown that in heat stress, which is produced by periodic exercise, the level of HSP70 increases. Also, it has been shown that after 15 days of periodic exercising, the concentration of HSP70 inclines toward generating harmony to the heat.

Literature Review

Exercise and testosterone

Testosterone as a hormone has several functions, such as increasing the quality of erection and secondary sexual features; however, because of its effects on the metabolic pathways, it affects the cardiovascular, neuromuscular, and central nervous systems (22). Hypothalamic-pituitary-testicular axis controls the secretion level of testosterone by neuroendocrinological pathways. In general, the preoptic neurons of the hypothalamus produce gonadotropin-releasing hormone that induces the production of LH and FSH from the anterior pituitary. Testosterone is produced in Leydig cells by the LH stimulation (23).

The production of hormone in the endocrine tissues is affected by the stress, which is created by physical activity. Gonadotropins (i.e., LH and FSH) are one of those hormones, which are increased in the acute exercise. The reaction and response that are produced by exercise stress are affected by factors, such as age, sex, puberty, and the intensity of exercise (24,25). It has been shown that the level of testosterone is increased after exercise (F. Derbre et al., 2010), and the concentration of LH enhances during training (25). Therefore, as we mentioned the effect of LH on the leydig cells, the concentration of testosterone will increase. It has been observed that the concentrations of total and free testosterone are lower in high-mileage runners, compared to those in moderate-mileage runners and controls, which shows the effect of professional exercise on decreasing the level of testosterone.

Exercise and semen quality (Fertility Potential)

The quality of semen is determined by the parameters, such as the number, morphology, and motility of sperms. Studying the effects of the high-intensity exercise on the reproductive system is one of the important fields, due to the spreading of professional sports, which require endurance training. It has been reported that the morphology of sperm is more abnormal in cyclists.

Also, based on the evidence it was shown that 10% of the population of marathon runners displayed severe oligospermia. Furthermore, according to the results of a study, the triathletes who performed very high training volume had weaker seminal parameters compared to the physically active and water polo groups (26). There is information about the alterations in the semen parameters of runners, so that the sperm concentration and total motile sperm were low in high-mileage runners. Also, the total normal sperm was low in these runners that shows the effects of professional exercise on semen quality.

Exercise and heat shock protein

The high increase in various types of HSPs can be stimulated in several tissues, such as heart and skeletal muscle by exercise. The HSPs are chaperones and are considered as a part of cellular defense system. The HSPs play different roles inside and outside the cells by preventing or weakening the level of denaturation stress and aggregation of cell proteins. Also, HSPs have effects on the appropriate refolding of proteins after stress. In general, exercise increases the expression of HSPs in the striated muscles (27); the alterations in the expression depend on several factors, such as the type of exercise (28), intensity of exercise (29), involved muscles (30), sex (31), age (32), and conditions of exercise (33).

It seems that exercise causes partial changes in the small HSPs (HSP 25/27 and αβ-crystallin) unless this exercise produces significant damage in the skeletal muscles (33). In these cases, small HSPs are rapidly phosphorylated and their sizes are decreased to the oligomer. Then, they are transported to selective myofibril proteins and cell membrane to protect the skeletal muscle. Many oxidative muscles show the high level of HSPs, especially HSP70. The increased stress in oxidative fibers is the result of special localization of HSPs according to the type of muscle fiber. It has been shown that the chronic activation of muscle fibers can create intra-changes, such as the increase of temperature, metabolic disturbance, and stress oxidative, which may activate stress response (34).

It seems that HSP content is mostly associated with the myosin phenotype instead of alterations in activity, and high expression is observed in the fiber types I and IIa, whereas the expression level in the IIx and IIb fibers is low (35). So, in spite of the changes in HSPs that are the results of acute or chronic stresses, such as exercise, the expression level of HSP is related to the muscle phenotype and may be considered as a transcription regulator (36).

It has been reported that the increased level of HSP70 in different muscles of rat such as skeletal muscle is observed as the result of using treadmill, and the metabolic changes of exercise is like the stressor factors that are known in inducing the synthesis of stress protein (such as the production of lactic acid and pH change). The exercise may mediate the synthesis of HSP70 through a special way and there is a common mechanism between exercise and other metabolic stressors. The synthesis of HSP70 in the muscle tissue showed that the production of stress protein may be associated with energy production. It seemed that metabolic stress in the absence of hyperthermia could be enough for the synthesis of HSP70.

Conclusion

Testosterone has several functions that we mentioned; however, the interesting point is that the level of testosterone increases in the individuals who exercise with a moderate level. When individuals exercise with high intensity like professional athletes, the level of this hormone diminishes. One of the functions of this important hormone is the increase of erection quality, then we could conclude that aside from some impairment in the semen quality and fertility potential of professional athletes, the process of erection in these individuals occurred with low intensity. Also, due to the effect of testosterone on the appearing of secondary sexual features, we could conclude that the young people, who exercise with high intensity, mature with delay.

The most important point about professional exercise is the effect of high-intensity exercise on the semen quality and fertility potential of athletes. We mentioned that the parameters, such as morphology and motility, determined the quality of semen. In all the studies that we analyzed, the results have shown that high-intensity exercise has harmful effects on the morphology and fertility, so that for instance, the morphology of sperm in the cyclists and the number of motile sperms had decreased, then these athletes or their coaches should consider a plan to prevent this abnormality or their infertility in future.

Considering exercise as HSPs inducers has created a new research field. Available data show that various forms of acute and chronic exercise regulate several HSPs in the human skeletal muscles. For resistance to the damage of exercise, the expression of HSP may begin by mechanical damage to muscle proteins and its level may increase by the inflammation response, which occurs several days later. After the tolerance of aerobic activities, it is possible that the expression of HSPs is mediated with redox signaling, which induces the radicals. In general, as we mentioned before, HSP helps to the maintenance of organism health.

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Conflict of Interest

The authors declare no conflict of interest.

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