**Associations between physical activity and thyroid function**

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**Abstract:**

Disorders related to thyroid hormone regulation are among Poland’s leading reasons for endocrinological consultations. The diagnosis and monitoring of thyroid dysfunction primarily rely on blood tests, including the measurement of TSH, fT3, and fT4 hormone levels, as well as antibodies specific to autoimmune thyroid diseases, such as anti-TPO, anti-Tg, and anti-TSHR. These tests are also useful in evaluating the impact of various factors on thyroid metabolism. In our study, we analyzed the effect of physical activity on thyroid function, taking into account specific population groups and particular disease entities.

**Methods:**

We conducted a comprehensive review using Google Scholar and PubMed, with a prioritizing on literature published within five to ten years. The search terms included “thyroid function”, “thyroid disorders”, “hypothyroidism”, “physical activity”, “exercise” and the names of its components as search terms to retrieve relevant articles. Additionally, references cited in the selected articles were also included in the analysis.

**Results:**

Physical activity affects thyroid metabolism and the functioning of the hypothalamic-pituitary-thyroid axis, but its effect may vary significantly depending on the initial thyroid function, the type and duration of physical activity and individual characteristics. The relationship between exercise and thyroid hormone metabolism is complex and requires further investigation to fully elucidate the physiological mechanisms involved.

**Conclusions:** While acute and chronic physical activity can influence thyroid hormone production, the effects are variable and depend on multiple factors including exercise intensity, duration, and individual baseline thyroid function. Further research is needed to fully understand these interactions and their implications for health and exercise recommendations.

Keywords

thyroid function, thyroid disorders, hypothyroidism, physical activity, exercise

**1.Introduction**

The thyroid gland is an endocrine organ, unpaired, located in the anterior region of the neck. It is composed of two lateral lobes, adjacent to the vascular and nerve bundles, the prevertebral fascia, and the esophagus, connected by an isthmus, as well as a variable pyramidal lobe, which is a remnant of the thyroglossal duct. This gland is characterized by a high blood flow. It is supplied by the paired superior, inferior thyroid arteries and sometimes the thyroid ima artery (an anatomical variant occurring in approximately 10% of cases) [1,2]. Its volume is dependent on blood flow through the organ, with a physiological volume of up to 20 ml in women and 25 ml in men [3]. The thyroid parenchyma is divided by connective tissue septa into lobules, which consist of the basic functional and morphological unit of the gland – the follicles. The follicles, formed by a single layer of cuboidal epithelium (thyrocytes) secreting thyroid hormones (TH) and fewer C cells, are filled with a hormone-rich colloid [1,2,4].

The thyroid gland's function and the hormones it secretes are highly multifaceted. The primary hormone involved in metabolic processes is 3,5,3’-triiodothyronine (T3), which constitutes a minor portion of the thyroid’s hormonal output. Due to its short half-life, the majority of T3 is synthesized in peripheral tissues through the conversion of 3,5,3’,5’-tetraiodothyronine (T4) by the enzyme deiodinase. T4, being the predominant secretion of the thyroid follicular cells, has a lower biological activity and a prolonged half-life, thus serving as a prohormone. Three distinct types of deiodinases are present in the body: types 1 and 2 facilitate the conversion of T4 to T3, whereas type 3 inactivates both hormones [2,5,6].

Thyroid hormone (TH) activity is pleiotropic, regulating homeostatic processes and influencing all body systems, including the cardiovascular, respiratory, nervous, and gastrointestinal systems. TH modulates gene expression of target proteins and ex-genomic actions, increasing the basal metabolic rate by enhancing cellular protein turnover, carbohydrate utilization, and ATP synthesis. This results in increased oxygen consumption, subsequently leading to an elevation in heart rate and respiratory rate.

The secretion of thyroid hormones under physiological conditions is regulated by a negative feedback loop within the hypothalamus-pituitary-thyroid axis. Thyroid hormones are released by the gland in response to stimulation by thyroid-stimulating hormone (TSH) produced by the anterior pituitary. The release of TSH is regulated by the hypothalamus, which promotes its secretion by releasing thyrotropin-releasing hormone (TRH). TH, in turn, feedback inhibits the synthesis of both TSH and TRH at higher regulatory levels [2,7].

2. Epidemiology

Thyroid diseases constitute a diverse group of conditions, predominantly involving dysregulation of hormone secretion. They are typically categorized into those associated with hypothyroidism and hyperthyroidism [2,8]. The thyroid gland has one of the highest incidences of autoimmune diseases among human tissues [9]. The overall prevalence of autoimmune thyroid disorders is estimated at approximately 5% of the population [10,11]. The most common clinical presentations include Graves’ disease and chronic autoimmune thyroiditis (Hashimoto’s disease) [12].

Hypothyroidism affects up to 6% of the population under 60 years of age, with Hashimoto's disease being the leading cause. It is significantly more frequent in women but can occur regardless of age or gender. The overall prevalence of hypothyroidism is estimated at 1-2%. The underlying mechanisms of autoimmunity are not fully understood, likely involving both humoral and cellular immune responses. The condition is characterized by lymphocytic infiltration of the thyroid gland and the presence of anti-thyroid peroxidase antibodies (anti-TPO) in up to 95% of patients. Thyroid peroxidase is an enzyme critical for the oxidation of iodide and synthesis of thyroid hormones. Anti-thyroglobulin antibodies (anti-Tg), which are less specific, are observed in 60-80% of affected individuals, likely indicating early stages of the disease. In the initial phase, mild hyperthyroid features may occur due to the presence of TSH receptor antibodies (TRAb), which bind to the TSH receptor—an unusual feature for Hashimoto's thyroiditis [2,9,13,14].

Hyperthyroidism, like hypothyroidism, predominantly affects women, with a prevalence of ~1.6%, while men are diagnosed 10 times less frequently. In iodine-sufficient areas, Graves’ disease is the most common cause of hyperthyroidism. This condition arises from the production of TRAb antibodies due to a multifactorial autoimmune process disrupting immune tolerance to TSH receptors. These antibodies exhibit stimulatory, neutral, or inhibitory effects, correlating with thyroid and extrathyroidal symptoms, such as thyroid-associated orbitopathy in Graves’ disease [15].

Another critical aspect of thyroid dysfunction involves iodine deficiency. According to WHO estimates from 2007, iodine deficiency affects approximately 2 billion people, including one in three school-aged children. Iodine deficiency can lead to compensatory proliferation of thyroid cells, resulting in endemic goiter. In Poland, due to iodine deficiency persisting until the late 20th century, up to 40% of hyperthyroidism cases were attributed to toxic nodular goiter [2,16].

1. Physical activity

As previously mentioned, the thyroid gland, despite its small size, is essential for the proper functioning of every system in the human body. Disruptions in the production or action of thyroid hormones can therefore cause a wide range of symptoms and abnormalities, depending on the etiology of the disorder. In clinical practice, the diagnosis and monitoring of thyroid diseases involve measuring TSH, fT3, and fT4 levels, as well as antibodies specific to autoimmune thyroid diseases, such as anti-TPO, anti-Tg, and anti-TSHR antibodies [17, 18]. These tests are also employed in assessing the impact of various factors on thyroid function. One such factor with a proven influence on thyroid regulation is physical activity.

Exercise has a notable impact on thyroid metabolism and development of thyroid diseases [19, 20], though the effects can vary based on its intensity and duration of, as well as the individual's baseline thyroid function, their comorbidities [21] and their physical activity advancement [22].

Enhanced thyroid metabolism could be linked to greater efficiency in the mechanical work executed by exercising muscles. In professional athletes changes in thyroid function may be considered an adaptive mechanism aimed at improving performance, potentially facilitating a more efficient balance between energy consumption and expenditure [5]. According to a study conducted by Ciloglu et al., acute aerobic exercise causes changes in circulating thyroid hormone values, with the most distinguished effects during moderate intensity training. The greatest increase of thyroid hormones concentrations (besides TSH) was observed during the exercise at the anaerobic threshold level (with 70% of maximum heart rate and 4.59 ± 1.75 mmol/l lactate level) [23]. Exercise-induced changes in thyroid hormones levels can be considered not only in the context of thyroid diseases but also in relation to other systems and organs.  Researchers from Xiamen University in China investigated the effect of aerobic exercises on liver injury in NASH related to hepatic thyroid hormone signaling. Their study conducted on mice showed the temporary rise in circulating thyroid hormones (FT3 and FT4) following aerobic exercise, in relation to the expression of deiodinase type 1 (Dio1), one of the most key genes in the T3 response signature. Dio1 is one of  the iodothyronine deiodinases responsible for converting T4 to biologically active T3 [24]. Serum FT3 and FT4 levels increased immediately after treadmill exercise in mice, accompanied by a significant upregulation of Dio1 expression in the liver following aerobic treadmill exercise. The study proves that physical activity, through T3 intrahepatic response, has a relevant role in improvement of hepatic lipid accumulation as well as reducing inflammatory infiltration and fibrosis [25]. Physical activity has also been proven to improve symptoms of depression and sleep quality in women with controlled hypothyroidism [26]. In a randomised control trial conducted by Ahmad et al on women with hypothyroidism on levothyroxine treatment, it was observed that physical activity including aerobic, resistance and combined training improved thyroid hormone levels but also lipid profile and quality of life of the participants [27].

 There are conflicting reports on the effect of chronic physical activity on thyroid hormone levels. A cohort study from 2021 found no significant association between TSH or fT4 levels and physical activity over a five-year period. Researchers used LASA Physical Activity Questionnaire to assess the type and duration of physical activity of the participants together with MET (metabolic equivalent of task) to establish the intensity of each activity. The aim of the study was to find any links between physical activity and thyroid metabolism in individuals from the general population, not in professional trained athletes. Although the researchers' work did not provide the evidence for this kind of links, they did underline that there were certain limitations to their study (weaknesses of the questionnaire, the possibility of reverse causation, misclassification of physical activity) which justifies that more research is needed in this area to establish the existence of a clear correlation [28]. A study by Tian et al based on National Health and Nutrition Examination Survey database showed however the significance of sustaining a balanced level of physical activity to support optimal thyroid function and reduce the risk of thyroid diseases. Importantly, the authors also noted that high-intensity physical activity can cause thyroid dysfunction, which is why the ideal thyroid metabolism can be supported through balanced, not excessive physical activity [14]. The crucial factor determining the impact of physical activity on thyroid metabolism is therefore the level of exercise intensity. It has been proven in a work of Vuletić et al conducted on patients with hypothyroidism that occupational physical activity is associated with reduced thyroid function and heightened thyroid autoimmunity, whereas recreational exercise correlates with enhancements in thyroid function [22].

3.1 Special groups of the population

Some of the researchers studying the associations between physical activity and thyroid function focused on specified groups of the population to investigate if results shown in studies involving general cohorts apply also to restricted populations.

Patients with hyperthyroidism

Changes in the body observed in individuals with hyperthyroidism are associated with an increase in metabolic rate and heightened heat energy production due to intensified oxidative metabolism. Additionally, there is a reduction in muscle strength (as a result of a deficiency in high-energy compounds) and a decrease in skeletal muscle mass (due to functional impairments and increased turnover of structural proteins), which affect especially big proximal groups of muscles [30]. Zhou et al. investigated the effect that thyroid hormones status has on exercise response in muscles. They conducted a study using animal model (rabbits with externally induced hypothyroidism and hyperthyroidism). Chronic Motor Nerve Stimulation (CMNS) was a substitute for exercise. Each rabbit underwent stimulation of the left peroneal nerve and dissection of the stimulated and unstimulated contralateral limb. The analysis of muscle samples revealed that in hyperthyroid rabbits, in comparison to hypothyroid ones, CMNS did not cause the increase of markers of muscle fiber type, autophagy, nutrient- or energy-sensing proteins and metabolic intermediates [31]. Another study focusing on muscle changes in hyperthyroidism conducted by Bousquet-Santos et al. found that resistance training enhances the recovery of skeletal muscle function and supports weight gain by improving muscle mass in patients undergoing medical treatment for hyperthyroidism compared with patients with only medical treatment (antithyroid or radioactive iodine therapy) [32].

Elderly people

A study by Di Blasio et al showed that in a group of euthyroid nonagenarians there is a negative correlation between thyroid function and physical activity. In their work by measuring the levels of serum TSH and fT4 researchers found that more daily movement is associated with less active thyroid function. Higher TSH and lower fT4 concentrations are associated with reduced mortality in older individuals [33]. This may be one of the components of the adaptive mechanisms of the aging organism, aimed at mitigating the basal metabolic rate. Similar conclusions were drawn by Simonsick et al. Their findings revealed that subjects with low fT4 level presented better values on all physical activity related parameters measured in the study in comparison to the individuals with high fT4 level. It was shown in their study that a mildly down-regulated thyroid function may contribute to better health in elderly people [34].

Patients with cancer

Physical activity is one of the preventive factors in the development of many cancers [35, 36, 37]. Although low levels of physical activity are not listed in the literature as a risk factor for thyroid cancer, studies indicate that obesity contributes to the occurrence of cancers affecting this organ [38]. It can therefore be concluded that reducing the prevalence of obesity, among other means through regular physical activity, may help lower the incidence of thyroid cancer. This is supported by studies conducted, among others, in Italy. Researchers from Catania studied the influence of daily walking duration on risk of thyroid cancer. Cases enrolled to this study were patients from Catania or neighboring municipalities with diagnosed thyroid cancer. The Lifestyle Assessment Questionnaire of the Italian Health Institute was used to obtain data on daily physical activity of the participants. The findings demonstrate that both engaging in physical activity (yes/no) at least twice a week for a minimum duration of one hour as well as daily walking for no less than 30 minutes can be protective factors in thyroid cancer [39]. The reduced risk of thyroid cancer among patients with higher levels of physical activity was also presented in the study conducted by researchers from Korea [19].

The study conducted by Zhang et al based on retrospective analysis and focused on papillary thyroid cancer (PTC) compared the effect of daily walking steps on development and progression of this type of thyroid cancer in individuals in sedentary and physical occupation who were diagnosed with PTC. Their findings show that in a group of construction workers thyroid-related hormones and antibodies levels were reduced, which is in correlation with improved thyroid function - as shown in instances mentioned above - and, consequently, reduced risk and progression of PTC [40].

Professional athletes

Thyroid hormones play a crucial role in the functioning of the entire body and also contribute to the development of adaptive mechanisms in response to the intense physical exertion experienced by professional athletes. One of the primary systems of the body in which adaptive changes to occupational physical exercise can be observed is the cardiovascular system. Regular physical activity has a multidimensional impact on this system, leading to molecular, cellular and metabolic changes as well as exercise-induced cardiac remodeling [41, 42]. Di Gioia et al. in their retrospective cross-sectional study investigated the role that thyroid hormones play in development of adaptive cardiovascular mechanisms in Olympic athletes. Elite athletes with thyroid function within euthyroid levels were included in the study. The findings show that there is a significant association between exercise induced changes in the cardiovascular system and variations in thyroid hormones levels which was observed in cardiac hypertrophy and heart rate. The researchers found a positive correlation between fT3 levels and resting and peak HR as well as left ventricle wall thickness. It was also shown that among all types of sporting disciplines, endurance athletes presented the lowest levels of TSH, fT3 and fT4 [43]. Similar conclusions regarding thyroid function in endurance sportspersons were drawn in the study by Nicoll et al. It was conducted on female track runners to evaluate different factors contributing to development of the overtraining syndrome. Researchers did not find changes in pre- and postseason TSH, T3 and T4 levels but it was shown that, in correlation with other factors studied (such as dietary intake and fatigue), thyroid hormones concentrations changes in endurance athletes can be associated with indicators of reduced performance [44].

Women

Thyroid dysfunction is more commonly observed in women than in men [30, 45, 46]. For this reason, it seems essential to identify women as a specific population when analyzing the impact of physical activity on thyroid metabolism. Hanke et al. compared the effect of endurance training on thyroid function in pre- and postmenopausal women. Although the study was conducted on a small sample and did not provide significant evidence, it gave an initial suggestion that  endurance training decreases the thyroid response to acute exercise in postmenopausal women [47]. In pregnant women with hypothyroidism on thyroxine replacement therapy aerobic exercise improved thyroid function by decreasing the level of TSH and increasing the level of fT4. It helped to maintain euthyroidism state crucial for the healthy course of pregnancy as well as mother’s health [48].  As far as the younger female population is concerned, in girls with hypothyroidism concurrent aerobic-resistance physical activity improved blood glucose level, insulin resistance and body composition.

3.**Conclusions**

Regular physical activity is recommended by specialists not only to prevent the development of diseases affecting various organs and systems but also as an integral component of their treatment. In some cases, it serves as the sole therapeutic approach, often accompanied by dietary habit modifications, or as a supplement to pharmacotherapy. This also applies to thyroid diseases, both malignant and non-malignant. Physical activity influences thyroid hormone metabolism through changes occurring at the molecular and cellular levels. The effects of thyroid hormones during exercise are primarily linked to their impact on the cardiovascular and respiratory systems, as well as the function of skeletal muscles. These effects include an increase in heart rate and force of heart contraction, a rise in stroke volume, enhanced ATP production in mitochondria, increased oxygen consumption in tissues, and elevated metabolism of amino acids, lipids, and carbohydrates. The type of physical activity, its duration, baseline physical fitness, overall health status, and other individual parameters significantly influence the effects of exercise on thyroid metabolism. For this reason, the studies published so far on this topic differ in the findings obtained. However, certain general conclusions can be drawn, with which most studies agree. Regular recreational physical activity improves thyroid function parameters and overall health, whereas intensive and chronic exercise is associated with reduced thyroid function. Further research is still required to better understand the relationship between exercise and thyroid metabolism, enabling healthcare professionals to provide more informed lifestyle recommendations for individuals with thyroid dysfunction.

**Disclosure**

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All authors have read and agreed with the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

Funding statement: No external funding was received to perform this review.

Statement of institutional review committee: not applicable.

Statement of informed consent: not applicable.

Statement of data availability: not applicable.

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