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The Impact of Physical Activity on Skin Health and Skin Aging

Paulina Hetnar

Medical Centre in Piekary Slaskie, Limited Liability Company

Szpitalna 11, Piekary Śląskie, Poland

phetnar3@gmail.com

ORCID: 0009-0005-2920-2575

Milena Fortuna

5th Military Clinical Hospital in Krakow

Wrocławska 1/3, 30-901 Kraków, Poland

milenafortuna1@gmail.com

ORCID: 0009-0009-5670-1926

Sebastian Kiper

5th Military Clinical Hospital in Krakow

Wrocławska 1/3, 30-901 Kraków, Poland

sebastiankiper02@gmail.com

ORCID: 0009-0006-4708-2121

Sławomir Toczek
105th Borderland Military Hospital with a Clinic, Independent Public Health Care Facility in Zary
Domańskiego 2, 68-200 Żary, Poland
slawektoczek@interia.pl
ORCID: 0009-0000-3936-7115

Magdalena Tomala
Military Institute of Aviation Medicine
Zygmunta Krasińskiego 54/56, 01-755 Warszawa, Poland
magda.tomala99@gmail.com
ORCID: 0009-0000-4236-4943

Katarzyna Jastrowicz-Chęć
5th Military Clinical Hospital in Krakow
Wrocławska 1/3, 30-901 Kraków, Poland
katarzyna.jastrowiczchec@gmail.com
ORCID: 0009-0001-4820-0373

Klaudia Koryszko
1st Military Clinical Hospital with Polyclinic of Independent Public Health Care Unit in Lublin
Al. Racławickie 23, 20-049 Lublin, Poland
klaudia.koryszko@wp.eu
ORCID: 0009-0005-6294-8694

Natalia Pokrywka
Medical University in Lublin
Al. Racławickie 1, 20-059 Lublin, Poland
pokrywkan@gmail.com
ORCID: 0009-0004-1593-8760

Dawid Suwała
Medical University in Lublin
Al. Racławickie 1, 20-059 Lublin, Poland
dawid.suwala22@gmail.com
ORCID: 0009-0004-7606-7065

Marcelina Polak
Medical University in Lublin
Al. Racławickie 1, 20-059 Lublin, Poland
marcelina0polak@gmail.com
ORCID: 0009-0008-5987-4948

Abstract

Purpose: The aim of this review is to synthesize current literature regarding skin structure and function, the mechanisms of intrinsic and extrinsic aging, and the potential benefits of physical activity for general health, as well as its specific effects on skin aging.

Materials and research methods: The article is based on an analysis of research available on PubMed and Google Scholar. A literature review was conducted using following keywords such as "skin aging", "skin health", "intrinsic aging", "extrinsic aging", "physical activity", "health", "exercise", and "the impact of physical activity on health".

Results: Skin aging results from both intrinsic factors such as genomic instability, epigenetics, telomere shortening, and mitochondrial dysfunction, and extrinsic factors including UV radiation, pollution, smoking, and poor lifestyle habits. Regular physical activity supports skin health by enhancing circulation, promoting collagen synthesis, reducing oxidative damage, modulating hormones, and improving mitochondrial function. Exercise also indirectly benefits the skin by supporting overall health and reducing lifestyle-related risk factors.

Conclusion: Physical activity is a promising non-pharmacological strategy for preserving skin integrity and slowing age-related changes. Its incorporation into preventive dermatological care may complement conventional treatments and promote healthy aging. However, further investigations are required to elucidate the underlying mechanisms by which exercise influences the skin aging process.

Keywords: skin aging, skin health, intrinsic aging, extrinsic aging, physical activity, health, exercise, the impact of physical activity on health

1. Introduction

The skin, as the largest organ of the human body, plays a significant role in maintaining physiological homeostasis and providing a mechanical barrier between internal systems and the external environment. The integumentary system is composed of different cell types and essential for thermoregulation, immune defense, sensory perception, and the synthesis of vitamin D. [1] As a complex organ, the skin is subject to multifactorial processes involving structural, functional, and molecular alterations that contribute to its aging. Skin aging is a physiological process influenced by intrinsic factors related to congenital mechanism and extrinsic factors depending on lifestyle or environment. [2] Understanding the mechanisms underlying skin aging is crucial for developing effective interventions to maintain skin health and appearance.

Intrinsic aging, also known as chronological aging, is a natural process gradually leading to structural and functional changes in the skin. Over time apoptosis dominates epidermal proliferation due to changes in gene expression. [3] Extrinsic aging reflects the cumulative effects of environmental factors such as UV radiation, air pollution, furthermore a way of life meaning spending time, exercise, nutrition, addictions, mental state. Together, these processes result in clinical manifestations including dryness, thinning, sagging, wrinkle formation, and pigmentation irregularities. [2]

In recent years, there has been growing interest in understanding how modifiable behaviors, particularly physical activity, may mitigate skin senescence. It is well-documented that regular physical exercise is a key factor in maintaining human body systems in good health. Exercise positively affects both physical and mental condition. Emerging studies suggest that lifestyle modifications, including regular physical activity may delay age-associated skin changes by improving microcirculation, reducing oxidative stress and modulating inflammatory response. [4]

This review explores the structure and function of the skin, explains the mechanisms underlying intrinsic and extrinsic aging, and examines the potential role of physical activity as a non-pharmacological strategy for preserving skin and body health as well as mitigating age-related dermatological changes.

2. Structure of the skin

The skin is the component of the integumentary system, with a surface area of approximately 1.7 m^2 in the average adult person. It serves as the primary barrier, protecting internal structures from the external environment. As the largest organ of the human body, it plays a crucial role in temperature regulation, vitamin D synthesis, immune function, and sensory perception. Structurally, the skin is divided into three distinct layers: the epidermis, dermis and hypodermis.

The outermost skin part, the epidermis, directly communicates with the external surrounding and consists of five layers: the stratum basale, stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum. It is predominantly composed of keratinocytes producing keratin, cytokines and other structural proteins. The epidermis forms a waterproof barrier providing a protection against pathogens and dehydration. The Merkel cells distributed in the epidermis are involved in touch sensation. In addition, the basal layer contains melanocytes synthesizing melanin, thereby providing skin pigmentation and protection against ultraviolet radiation. Langerhans cells located within the stratum spinosum are the integral components of the skin's immune defense.

Beneath the epidermis lies the dermis, which primarily consists of connective tissue cells such as fibroblasts, histiocytes, mast cells, and lymphoblasts. The dermis is subdivided into the superficial papillary layer and the deeper reticular layer. The papillary layer is made of thin collagen fibers, whereas the reticular dermis contains densely packed collagen fibers, that provide structural support. Furthermore, various skin appendages including hair follicles, sebaceous glands and sweat glands are placed in the stratum reticulare and contribute to providing essential features. Oil glands keep the skin hydrated and protect against microbial infections through sebum production. Sweat glands help regulate body temperature. Moreover, the dermis contains blood vessels and nerve endings, responsible for touch, temperature and pain sensation.

The innermost layer, the hypodermis, consists of adipose and connective tissue. The subcutaneous tissue serves multiple functions, including thermal insulation, energy storage, and mechanical cushioning to protect internal organs. Furthermore, the hypodermis exhibits hormonal activity. [5]

3. Skin aging

Skin aging is a natural process consisting of structural modifications and significant changes in functioning of this organ. This process results in diminished elasticity and thinning of the skin, which leads to dryness, sagging and the formation of wrinkles. Other visible symptoms are pigmented spots situated especially in sun-exposed areas. The mechanisms responsible for aging include collagen degradation, chronic inflammation, increased oxidative stress and reduced cellular regeneration. [2] The changes associated with getting older are influenced by both intrinsic (genetic) factors and extrinsic (environmental) exposures.

3.1 Intrinsic aging

Intrinsic aging is primarily driven by cellular and molecular changes that occur naturally with age. The process is dependent on numerous multifaceted aspects for example genetic predisposition, human race and an origin of a person. Even different areas of the body may age at varying rates. [6]

One of the fundamental processes involved in chronological aging is genomic instability, whereby the accumulation of DNA damage over time impairs cellular function. This damage can result from errors in DNA replication, spontaneous mutations, and oxidative stress generated by metabolic processes. As a result, skin cells lose their ability to divide and regenerate effectively, leading to slower skin renewal and impaired repair mechanisms.

Telomere shortening is another hallmark of intrinsic aging. Telomeres are repetitive nucleotide sequences at the ends of chromosomes that prevent DNA from deterioration during cell division. With each cycle of replication, telomeres gradually become shorter until they reach a critical length, then cells enter a state known as senescence, where they stop dividing altogether. This reduction in cell turnover contributes to the thinning of the skin and a decreased ability to repair damage, making aging skin more fragile and prone to injuries. [7]

In addition to telomere attrition, epigenetic changes play a crucial role in chronological aging. Epigenetics refers to modifications in gene expression that do not alter the underlying DNA sequence but can impact on the activation or suppression of specific genes. Over time, DNA methylation and histone modifications can lead to the downregulation of genes responsible for collagen production, skin hydration, and repair processes. These changes result in a gradual decline in skin elasticity and the formation of fine lines and wrinkles. [8]

Mitochondrial dysfunction represents another significant contributor to intrinsic aging. Mitochondria, often referred to as “the powerhouse of the cell”, are responsible for producing the energy required for cellular activities. As the skin ages, mitochondrial efficiency declines, leading to a reduction in energy production. [9] This, in turn, increases the generation of reactive oxygen species (ROS) - unstable molecules that induce oxidative damage to cellular components, including DNA, proteins, and lipids. Oxidative stress accelerates cellular aging and impairs the skin's ability to maintain its youthful structure. [10] Moreover, aging is accompanied by the progressive loss of collagen and elastin, two essential proteins that provide structural integrity and elasticity to the skin. Fibroblasts, the specialized cells responsible for producing collagen and elastin, experience a gradual decline in activity over time. The reduced synthesis of these proteins leads to skin laxity, the appearance of fine lines, and a diminished ability to bounce back from mechanical stress. [11]

3.2 Extrinsic aging

On the other hand, extrinsic aging results from environmental and lifestyle-related factors. The most studied is prolonged exposure to ultraviolet (UV) radiation but air pollution, smoking, poor nutrition, and other lifestyle choices can affect the acceleration of skin aging. The impact of these elements induce oxidative damage, inflammation, and cellular dysfunction. Oxidative stress develops when the balance between reactive oxygen species (ROS) and the body's antioxidant defense system is disrupted. Mitochondrial disfunction and even environmental factors can increase a level of ROS. [10]

Photoaging is a process caused by the most significant factor namely UV radiation. UV rays (UVR) are classified into UVA (315-400 nm) and UVB (290-315 nm), both of which penetrate the skin and induce molecular damage. [12] Prolonged exposure to UVR triggers the breakdown of essential skin components, leading to formation of deep wrinkles, hyperpigmentation, and loss of skin elasticity. Additionally, UV radiation increases the production of reactive oxygen species and activates matrix metalloproteinases (MMPs), which degrade collagen and elastin fibers. [13] Chronic exposure to UVR results in irreversible skin changes and a heightened risk of skin cancer. Preventative measures, including the daily application of sunscreen, antioxidant skincare, and the use of protective clothing, play a crucial role in mitigating UV-induced damage. By adopting these protective strategies, individuals can significantly delay the effects of photoaging and maintain healthier, more resilient skin. Emerging studies showed that infrared radiation (IRA), as well as UVR, may induce photoaging. It enhances generation of reactive oxygen species and downgrades the level of collagen in human skin, accelerating skin aging. [14]

Air pollution, particularly in urban environments, is a major contributor to extrinsic aging. Pollutants such as particulate matter (PM), nitrogen dioxide (NO_2), and polycyclic aromatic hydrocarbons (PAHs) penetrate the skin and generate reactive oxygen species, initiating oxidative damage. [12] This cascade of events results in lipid peroxidation, weakening the skin barrier and increasing trans-epidermal water loss. ROS-mediated inflammation stimulates the release of cytokines and accelerates collagen degradation. Pollutants induce melanocyte activity, leading to hyperpigmentation and dark spots. Shikowski and Hüls (2020) indicate that individuals exposed to high levels of pollution exhibit increased signs of aging, including fine lines, dullness, and a loss of skin firmness. [15]

Daily habits affect the appearance and health of our skin, as well as the entire body. Lifestyle definition is a broad concept and includes daily habits and behaviours. The factors such as the inadequate length of sleep, chronic stress, poor nutrition, addictions, and insufficient physical activity can play an important role in premature aging.

Cigarette smoke contains so many harmful chemicals, including nicotine, carbon monoxide, and free radicals. Smoking, as well as UV radiation, conduce to increased oxidative stress and matrix metalloproteinase (MMP-1) activity. This mechanism leads to degradation of collagen and elastin fibers which results in impaired skin barrier and loss of skin firmness. [12] Moreover, nicotine causes vasoconstriction, narrowing blood vessels and reducing oxygen delivery to skin cells, resulting in dullness and slow healing. Smokers often develop deep wrinkles around the eyes and mouth, known as smoker's lines, due to repeated facial muscle contractions combined with collagen breakdown. Furthermore, cigarette smoke triggers melanocyte activity and makes skin hyperpigmented. [16]

Nutritional habits significantly affect a skin health. A well-balanced diet, including appropriate amount of macro- and microelements, plays a crucial role in maintaining youthful, resilient skin. Diet rich in various fruits and vegetables, unsaturated fatty acids, provide antioxidants and vitamins, which boost collagen production, and enhance skin hydration. However, a diet high in processed foods, sugar, and saturated fats contributes to oxidative stress and glycation. Glycation, a process in which excess sugar molecules bind to proteins like collagen, forming advanced glycation end-products (AGEs), results in reduced skin elasticity by stiffening collagen fibers and increased inflammation. [16]

Sleep is regulated by hormones, including cortisol and melatonin. Chronic sleep deprivation and stress increase cortisol levels and then redound to premature aging. [16] The lack of sleep also reduces melatonin levels, an important antioxidant that protects against free radical damage and prevents apoptosis in UV-exposed fibroblasts and keratinocytes. [17]

4. The impact of physical activity on general health

According to the World Health Organization, physical activity is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure". [18] This broad definition encompasses various forms of movement, including structured exercise, occupational activities, and everyday movements such as walking or household chores.

Regular physical exercise is one of the most effective ways to maintain health and prevent chronic diseases. However, sedentary lifestyles have become increasingly common nowadays. The lack of adequate physical activity has severe consequences on physical health, mental well-being, cognitive functions, and overall life expectancy. [19]

Exercising positively influences multiple physiological systems, including cardiovascular, musculoskeletal, endocrine and nervous systems. The World Health Organization (WHO) recommends a minimum of 150–300 minutes of moderate-intensity or 75–150 minutes of vigorous-intensity exercise per week for optimal health benefits. [18]

Aerobic training reduces the risk of cardiovascular diseases such as hypertension, coronary heart disease or myocardial infarction by regulating blood pressure and improving lipid profiles. Moreover, exercising increases circulation and strengthens the heart muscle. [20] Regular physical activity is essential for maintaining metabolic homeostasis and a correct weight. During physical exertion, glucose and fatty acids are mobilized to meet increased energy demands. In contrast, inactivity leads to decreased glucose utilization, favoring storage as adipose tissue. [20] Aerobic and resistance training can effectively prevent and manage obesity-related metabolic dysfunction, reduce the risk of type 2 diabetes and metabolic syndrome by improving insulin sensitivity and regulating blood sugar levels. It is worth noting that the appropriate level of physical activity contributes to a reduced risk of developing certain cancers and decreases all-cause mortality. [21]

Moderate exercise also strengthens immune function, improving resistance to infections. In addition, it reduces inflammation and oxidative stress, thereby slowing the aging process. [22]

Beyond metabolic benefits, exercising strengthens muscles, improves flexibility, and enhances joint mobility. Heavy lifting promotes bone density which reduces the risk of osteoporosis. [22]

Daily physical activity exerts a positive effect on mental health and cognitive function by alleviating stress and anxiety. Moreover, exercising improves memory and lowers the risk of neurodegenerative diseases like Alzheimer’s disease. [23]

Regular physical activity is a key factor in maintaining physical, mental, and metabolic health. Incorporating exercise into our daily life, whether in the form of aerobic exercise such as running, resistance training or yoga, significantly improves well-being and longevity. Although the benefits of exercise are substantial, it is important to acknowledge the potential risks, particularly in terms of musculoskeletal injuries. Inadequate exertion, especially immoderate or high-intensity exercise may have the opposite effects than intended and leads to the occurrence of overtraining syndrome, which manifests in chronic fatigue, hormonal imbalances, and weakened immunity. [24]

5. The role of exercise in the skin aging process

Regular physical activity is widely recognized for its multiple health benefits, extending beyond cardiovascular and metabolic improvements to encompass significant impacts on skin health and the aging process. Engaging in consistent exercise modulates cellular and molecular pathways, improves skin hydration, mitigates oxidative stress, and affects overall skin appearance.

One of the primary mechanism through which exercise benefits skin health is improved circulation. During exercising, body temperature rises and the cutaneous blood vessels become dilated. Increased blood flow optimizes oxygen and nutrient delivery to skin cells, thereby supporting hydration of the skin. [25]

Sweat glands help to effectively dissipate heat through sweat excretion and perspiration. The sweat, which contains natural moisturizing factors, including lactate and urea, supports maintaining the stratum corneum's hydration levels. [26] Additionally, sweating promotes body detoxification by facilitating the excretion of heavy metals and other toxins. According to the Genuis et al. study, some xenobiotics are present in sweat in a greater concentration than in urine. [27] The getting rid of toxins may potentially reducing the occurrence of acne and other dermatological issues. The removal of metabolic waste products can resist premature aging. [28]

As we have already mentioned, the factor accelerating skin aging is the elevated level of oxidative damage, which is caused by mitochondrial dysfunction and the imbalance between antioxidants and reactive oxygen species. Despite the fact that intense exercising may transiently enhance a production of ROS, regular physical activity stimulates the DNA repair processes and bolsters antioxidant defense, conferring resilience against oxidative stress. [29]

Crane et al. found that exercise promotes secretion of interleukin 15 (IL-15), a cytokine implicated in immune and mitochondrial function. IL-15 may stimulate fibroblasts proliferation, thereby maintaining collagen and elastin synthesis and preventing skin aging. Additionally, physically active individuals have had higher level of mitochondrial DNA (mtDNA) copy than inactive controls. It is assumed that insufficient physical activity is associated with lower level of dermal fibroblasts leading to decreased production of collagen and elastin fibers. Moreover, researchers have observed that people leading a sedentary lifestyle had a thicker stratum corneum and thinner stratum spinosum than habitually active. [30]

Hormonal imbalances can significantly affect skin health, leading to conditions such as acne, dryness, and premature aging. Regular physical activity modulates levels of hormones, reduces stress-induced breakouts and promotes balanced sebum production. Structured exercise has also been linked to improved insulin sensitivity and increased sex hormone binding globulin (SHBG), which can be beneficial in managing conditions like polycystic ovary syndrome (PCOS) and its dermatological complications. [31] Furthermore, physical activity modulates cortisol levels, a stress hormone that, when chronically elevated, can impair skin barrier function and accelerate the occurrence of skin aging symptoms, for example, wrinkles and loose skin. [32]

Finally, exercising has an indirect impact on skin aging by mitigating the risk factors. Active people are more likely to adopt a healthy lifestyle by keeping a well-balanced diet, avoiding smoking and reducing alcohol consumption. Moreover, regular physical activity prevents from obesity and its dermatological complications including acanthosis nigricans, keratosis pilaris, stretch marks, cellulite. [33] Combining aerobic exercises, resistance training, and flexibility workouts can maximize these benefits for youthful, healthy skin.

6. Conclusion

The integumentary system, particularly the skin, represents a dynamic and multifaceted organ responsible for critical physiological functions. The process of skin aging, influenced by both intrinsic and extrinsic factors, encompasses a complex interplay of molecular, cellular, and structural alterations. Intrinsic aging is predominantly governed by genetically programmed mechanisms such as telomere attrition, mitochondrial dysfunction, epigenetic modifications, and oxidative stress, whereas extrinsic aging is largely attributable to environmental exposures including ultraviolet radiation, air pollutants, tobacco smoke, and nutritional imbalances.

Among the modifiable factors, physical activity emerges as a powerful intervention not only for general health maintenance but also for mitigating the aging process of the skin. Through enhancement of microcirculation, stimulation of mitochondrial biogenesis, reduction of systemic inflammation, and modulation of hormonal homeostasis, exercise confers both direct and indirect benefits to skin health. Furthermore, physical activity may influence dermal remodeling by supporting fibroblast function and promoting the synthesis of extracellular matrix components such as collagen and elastin.

To sum up, the integration of regular physical activity into clinical recommendations for skin health represents a promising adjunct to conventional dermatologic interventions. Given its systemic benefits and potential to modulate key aging-related pathways, exercise warrants further investigation as a non-pharmacological strategy for preserving skin integrity and delaying age-associated dermatologic changes. Future research should aim to elucidate the precise molecular mechanisms by which physical activity exerts its dermoprotective effects and to clarify its role as a non-invasive and accessible approach to healthy aging.

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Author's contributions:

Conceptualization: Paulina Hetnar. Methodology: Sebastian Kiper. Software: n/a. Check: Dawid Suwała, Sławomir Toczek. Formal analysis: Marcelina Polak, Natalia Pokrywka. Investigation: Katarzyna Jastrowicz-Chęć. Resources: Sławomir Toczek, Katarzyna Jastrowicz-Chęć. Data curation: Natalia Pokrywka, Dawid Suwała. Writing - rough preparation: Milena Fortuna, Klaudia Koryszko, Sebastian Kiper. Writing - review and editing: Paulina Hetnar, Milena Fortuna, Marcelina Polak. Visualisation: Klaudia Koryszko. Supervision: Paulina Hetnar. Project administration: Paulina Hetnar. Receiving funding: not-applicable.

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