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ROLE OF DIET, EXERCISE, AND AGING PROCESS ON THE HUMAN IMMUNE SYSTEM

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ABSTRACT

The immune system is a dynamic and intricate defense mechanism that can ward off pathogens, harmful substances, and illnesses. In addition, genetics, lifestyle, and external factors affect immune function. Based on this, nutrition, exercise, and natural aging can modulate immune responses. Moreover, a balanced diet high in vital minerals, vitamins, and antioxidants strengthens the immune system. In contrast, unnecessary processing and bad fats cause persistent inflammation and immunological suppression. Apart from that, consistent exercise can boost immune surveillance, increase blood circulation, and lower the infection risk rate. On the other hand, physical exertion without appropriate recovery might cause transient immunosuppression that increases the body's vulnerability to diseases. Moreover, aging naturally reduces the immune system by means of immunosenescence, a process regarded to be responsible for low T-cell production. It can thereby aggravate inflammation and cause a decline in vaccination effectiveness. However, assuming a healthy lifestyle including appropriate nutrition, even physical activity, and stress management can help to build long-term immunological resilience and help to slow down age-related immunity decrease. This study shows how nutrition, exercise, and aging interact in immune function to

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underline their cooperative effect on general health and illness prevention. Therefore, it can comprehend these issues, which is necessary for creating successful plans to boost immune systems and make life better.

KEYWORDS: Diet, Exercise, Aging, Immune System, Immunosenescence, Nutrition, Physical Activity, Immune Health, Chronic Inflammation, Disease Prevention.

INTRODUCTION

The human immune system is a compound and active defense system that protects the body from pathogens, including bacteria, viruses, fungi, and other harmful antagonists [1]. It comprises a cultivated interaction of compartments, materials, and biochemical growths composed of effort to maintain health. Without a properly functioning immune system, the body becomes exceptionally disposed to infections and diseases [2]. Numerous factors affect immune efficiency, as well as genetics, lifestyle, environmental exposure, and essential health circumstances. However, nourishment, corporeal activity, and the natural ageing process are among the most important promoters of immune function [3].

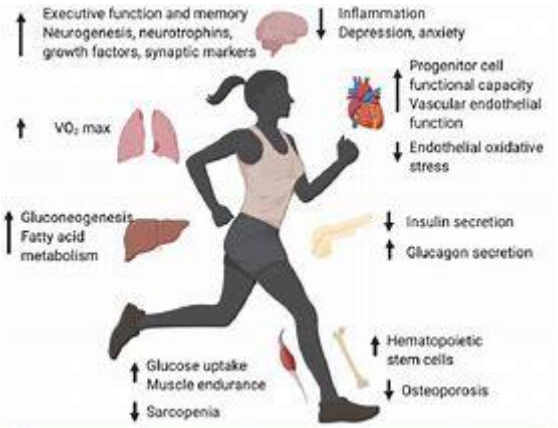

Figure 1: Exercise for healthy immune

The dual primary mechanisms involve the invulnerable arrangement, characteristics and adaptive immunity. The characteristic immune system provides an immediate but non-specific response to foreign aggressors, while the adaptive immune system develops targeted responses through specialised cells like T and B lymphocytes [4]. Over time, external and internal factors shape immune efficiency, establishing or weakening it. Proper nutrition supplies essential micronutrients that support immune cell function, while regular exercise

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improves circulation and immune function [5]. Equally, ageing presents a gradual decline in immune function, known as immunosenescence, which increases exposure to infections, chronic diseases, and inflammation-related conditions [6].

The role in either supporting or damaging the immune response. Dietary habits forcefully affect immune function, with certain nutrients playing an important role. Micronutrients such as vitamins A, C, D, and E and minerals like zinc and selenium are vital for maintaining immune cell activity, modulating inflammation, and preventing oxidative stress [7]. A well-adjusted food, amusing in entire nourishments, thin proteins, substantial body fat, and fibre, promotes overall immune resilience. On the other hand, excessive ingestion of managed nourishments, refined kinds of honey, and unnatural body fat can lead to chronic inflammation and a weakened immune response. Numerous nutritional patterns, such as the Mediterranean Sea diet, have been related to improved immune health. In contrast, Western-style diets have been related to increased risks of chronic diseases and immune dysfunction [8].

Table 1: Age-related variations in the innate immune system.

Category of cell	Age-related growth	Age-related reduction
Neutrophils		Oxidative eruption
		Phagocytic volume
		Bactericidal movement
Macrophages		Oxidative burst
		Phagocytic capacity
NK cells	Total number of cells	Proliferative response to IL2
		Cytotoxicity
Dendritic cells		Capacity to stimulate antigen-specific T cells
		Lymph node homing
Cytokines and Chemokines	serum levels of IL6, IL1β and TNFα	

The fundamental factor, exercise, is an additional factor in the immune parameter. Moderate physical activity has been shown to enhance immune function by endorsing the circulation of white blood cells, reducing stress hormones, and decreasing inflammation [9]. Helping to reduce the risk of infections, regular exercise supports a well-regulated immune system and

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refines vaccine responses. However, excessive or intense exercise without tolerable recovery can lead to immunosuppression, making the body more vulnerable to illnesses. The balance emphasising exercise's beneficial and damaging effects on the immune system is important for optimising overall health [10].

The process that the elderly is unavoidable affects the immune capability in several ways. As people age, their immune system experiences structural and functional changes, leading to reduced production of unexperienced T cells, reduced vaccine effectiveness, and increased levels of pro-inflammatory cytokines, known as "inflammation [11]." These changes contribute to higher susceptibility to infections, autoimmune diseases, and chronic conditions such as cardiovascular diseases and metabolic disorders. However, lifestyle interventions, including proper nutrition, regular physical activity, and stress management, can alleviate the impact of immunosenescence and endorse an improved immune response in ageing individuals [12].

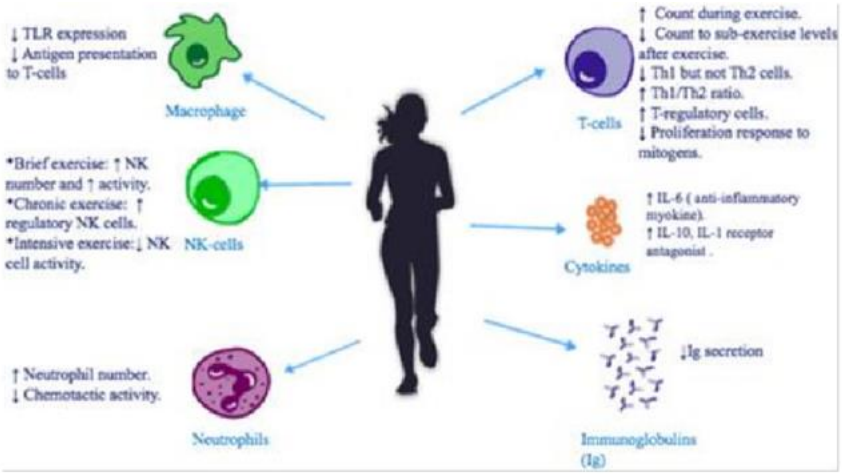

Figure 2: Physical activity enhances the immunity

This review aims to discover how diet, exercise, and ageing shape immune function. The important nutritional elements essential for immune health are examining the properties of physical activity on resistant resilience and then discussing methods to respond to age-related immune decline. Sympathetic, these factors are crucial for developing practical health approaches to enhance immune responses and improve overall well-being through life [13].

The Resistant Classification and Its Purpose

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The protected system is a vastly compound defence instrument that protects the body from damaging invaders like bacteria, viruses, fungi, and parasites. It contains a massive network of compartments, materials, and biochemical replies that notice and neutralise foreign substances, avoiding infections and preserving homeostasis [14]. The immune system functions through two primary mechanisms, the innate immune system and the adaptive resistant system, providing protection and ensuring long-term immunity.

The Distinctive Resistant System

The protected system is the body's first line of defence, replying rapidly and non-specifically to invasive pathogens. It contains physical barriers, biochemical defences, and specialised immune cells that try to identify and remove external substances [15].

Physical and Biochemical Barriers are the membrane and lubricated membranes, which appear as physical blockades that stop pathogens from toward the inside the body. In addition, secretions such as saliva, mucus, and stomach acid contain antimicrobial enzymes that help neutralise harmful mediators before they can cause harm [16].

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Figure 3: Exercise in the immune system

Inflammatory responses are when an infection or injury occurs. The immune system inductees an inflammatory response to contain and eliminate the threat. This includes the release of cytokines and chemokines, signalling molecules that attract immune cells to the exaggerated area, increasing blood flow, and enhancing immune activity [17].

Phagocytic Cells are Macrophages and neutrophils, important phagocytic cells that engulf and digest pathogens, eliminating them from the body. They recognise foreign invaders through pattern recognition receptors and initiate immune responses [18].

Natural Killer Cells are immune compartments that profoundly identify and destroy virus-infected and tumour cells. NK cells detect abnormal variations in cells and trigger programmed cell death to prevent the spread of infection [19].

Figure 4: Effect of exercise on Telemore

The Adaptive Immune System

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Dissimilar to the distinctive immune system, which affords immediate but non-specific defence, the adaptive resistant system responds precisely to pathogens. It is characterised by its ability to remember past infections and generate stronger and faster replies upon re-exposure to the same pathogen [20].

- **T Cells:** T lymphocytes are essential for adaptive immunity. They are divided into different subsets, counting assistant T cells (CD4+), which assist in organising immune responses, and cytotoxic T compartments (CD8+), which directly attack infected or irregular cells.
- **B Cells:** B lymph cells produce antibodies that target antigens on pathogens and pattern them for destruction by other immune cells. These antibodies provide long-term immunity and are the basis for vaccine-induced immunity.
- **Memory Cells:** T and B cells can develop into memory cells after an infection or vaccination, permitting the immune system to stand a rapid and efficient response if the same pathogen occurs again [21].

The Role of Cytokines and Immune Parameters

Cytokines are signalling molecules that normalise immune responses, inflammation, and communication between immune cells. Proinflammatory cytokines activate immune responses, while anti-inflammatory cytokines help control inflammation and avoid extreme tissue damage [22].

- The proteins are released in response to viral infections, attracting immune cell activity and inhibiting viral replication, called interferon.
- A broad group of cytokines that control immune cell differentiation, proliferation, and communication, known as Interleukins.
- A cytokine that plays a critical role in inflammation, immune cell activation, and apoptosis is the tumour necrosis Factor [23].

The Balance Between Immune Activation and Tolerance

An immune system must preserve a delicate balance between immune activation and broadmindedness. Intense immune responses can lead to autoimmune diseases, where the

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body incorrectly attacks its tissues, while hypoactive responses can result in augmented susceptibility to infections [24].

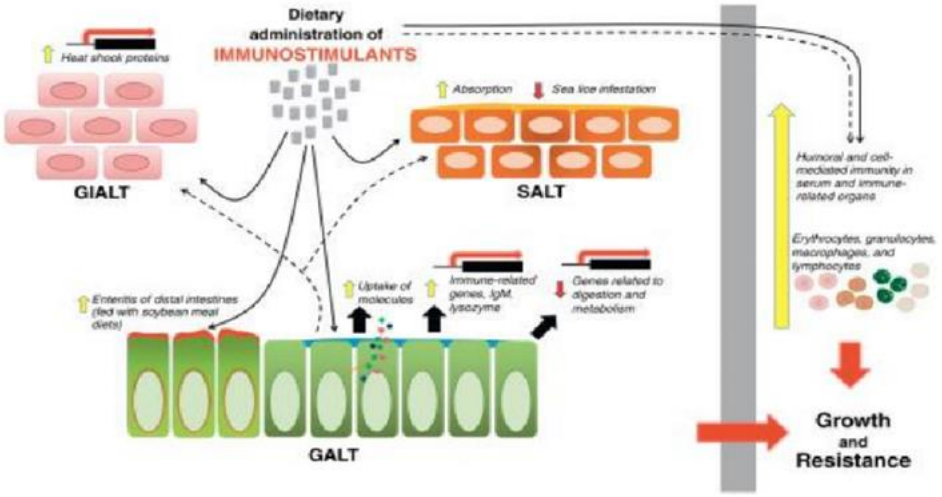

Figure 5: Dietary Immune stimulant

- **Autoimmunity:** Circumstances similar to rheumatoid arthritis, numerous cases of sclerosis, and lupus increase when the protected system imperfectly marks the body's cells.
- **Immunodeficiency:** Syndromes such as HIV/AIDS weaken immune function, making individuals more inclined to infections [25].

Table 2: Important Findings of the Similar studies

Study	Important Results	Conclusion
Giustina et al. (2020) [26]	Inspected the possession of vitamin D in resistant function and found that supplement enhances immune replies and reduces infection risk.	Vitamin D is life-threatening in supporting protection, particularly in elder adults.
Li (2019) [27]	Analysed the influence of Mediterranean diet patterns on inflammation and immune variation.	A diet rich in antioxidants and healthy fats improves immune flexibility.
Baker	Examined the part of even exercise on immune cell	Physical activity

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et al. (2021) [28]	activity. Reasonable exercise increases white blood cell circulation and summary inflammation.	strengthens the immune system, while extreme training can suppress it.
Thompson et al. (2018) [29]	The effects of ageing on immune function were considered, mainly by concentrating on immunosenescence. Found that ageing leads to a weakening in naïve T cells and increased inflammation.	Older adults weaken immune responses, making older individuals more prone to infections.
Garcia (2022) [30]	Studied the relationship between stress management and immune function. Chronic stress overpowers immune cell activity.	Stress reduction methods like meditation improve immune flexibility.

The Role of Diet in Immune Function

Nourishment is important in determining the body's immune system, operating its capacity to protect against infections and maintain overall health. A well-balanced regime provides essential nutrients that support the production and function of immune cells, adjust inflammation, and enhance the body's ability to fight off pathogens. Poor nutrition can deteriorate immune defences, making the body more susceptible to infections and chronic diseases [31].

Macronutrients and Immune Health

Macronutrients, proteins, adipose tissue, and cellulose are structural blocks for immune function. Protein is important, providing amino acids necessary for producing antibodies, immune cells, and signalling molecules. A protein deficiency can damage immune responses, increasing the risk of infections. Vigorous fats, predominantly omega-3 fatty acids found in flyfish, silly, and stones, have anti-inflammatory properties that help regulate immune function. On the other hand, extreme ingestion of unhealthy trans fats and treated foods can promote chronic inflammation and weaken immunity [32]. Carbohydrates, mainly from entire scraps, berries, and root vegetables, provide a stable energy source for immune cells. Different advanced carbohydrates can cause points in blood sugar and underwrite irritation, but complex carbohydrates support gut health and immune parameters.

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Micronutrients Essential for Immunity

Several vitamins and minerals play a dangerous role in supporting immune function. Vitamin C, found in citrus fruits, bell peppers, and leafy greens, enhances the production of white blood cells and acts as a powerful antioxidant to protect immune cells from damage. Vitamin D, often obtained from sunlight experience and foods like fatty fish and encouraged dairy products, helps regulate immune responses and reduce inflammation [33]. Deficiencies in vitamin D have been linked to increased vulnerability to infections. Zinc, present in nuts, seeds, meat, and legumes, is vital for immune cell function, wound healing, and reducing the severity of colds and respiratory infections. Selenium, found in Brazil nuts, seafood, and eggs, is an antioxidant that reinforces immune defences.

Instinctive Health and Immunity

An important serving of the immune system exists in the instinctive, making gut health important for strong immunity. The gut microbiome, composed of trillions of beneficial bacteria, modulates immune responses and protects against harmful pathogens. A fibre-rich diet, prebiotics, and probiotics support a varied and healthy gut microbiota [34]. Prebiotic foods, such as garlic, onions, bananas, and whole grains, fuel valuable gut bacteria, while probiotic foods like yoghurt, kefir, and agitated vegetables introduce beneficial bacteria that enhance immune function. An imbalance in gut bacteria, often caused by excessive sugar, processed foods, or antibiotic use, can lead to chronic inflammation and a debilitated immune system [35].

Dietary Approaches for a Strong Immune System

To optimise immune function, a diet should emphasise whole, nutrient-dense foods while minimising treated and inflammatory foods. Eating various fruits and vegetables confirms satisfactory intake of important vitamins, raw materials, and antioxidants. Thin protein sources, such as poultry, fish, beans, and tofu, provide the necessary building blocks for immune cells. Vigorous fats like emerald oil, silly, and avocados help regulate inflammation. In addition, staying hydrous and limiting excessive sugar and alcohol consumption can support immune flexibility [36].

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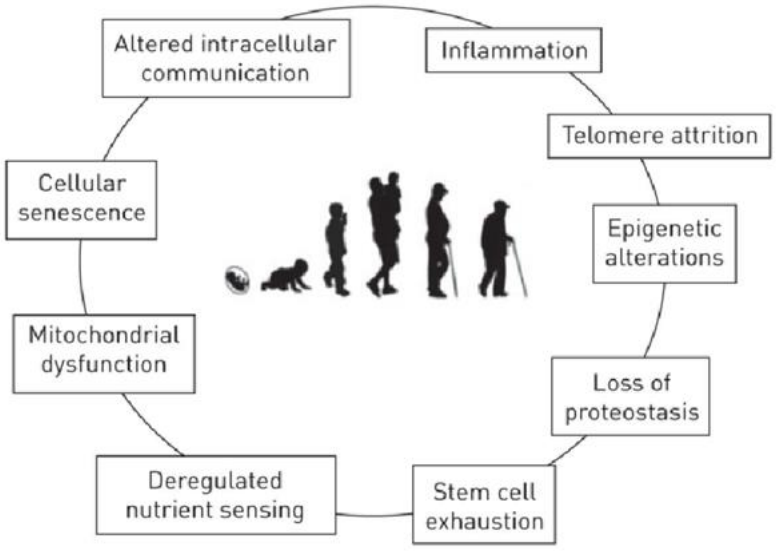

Figure 6: Ageing and the border between health and diseases

Important Nutrients for Immunity

- **Vitamins**: Vitamin C improves the manufacture of white blood cells, though vitamin D controls immune replies and reduces inflammation. Vitamins A and E act as antioxidants, protecting immune cells from oxidative stress.
- **Minerals:** Zinc is vital for T-cell function, and selenium has antioxidant properties that guard against infections.
- **Proteins and Fats**: Amino acids are the structure blocks for immune cells, and omega-3 fatty acids reduce irritation [37].

Dietary Patterns and Immunity

- **Mediterranean Diet:** Ridiculous in berries, root vegetables, whole grains, and healthy fats, this diet improves immune function by providing anti-inflammatory and antioxidant compounds.
- **Western Diet:** High in processed foods, sugars, and unhealthy fats, it can underwrite chronic inflammation and weaken immune replies [38].

Exercise and Immune Function

Exercise is vital in supporting immune function, with both short-term and long-term benefits. Regular moderate exercise improves immune investigation by endorsing the circulation of

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immune cells throughout the body, making it easier for the immune system to notice and rejoin to potential pressures. It also helps lower chronic inflammation by dropping the levels of pro-inflammatory cytokines, which can subsidise various chronic diseases. In addition, appealing to physical activity helps regulate stress hormones like cortisol, which, when raised for prolonged periods, can suppress immune function [39]. However, while moderate exercise fortifies the immune system, excessive-resolution training without proper recovery can have the opposite effect. Overtraining can lead to a temporary destruction of immune function, increasing exposure to infections. It is important to balance exercise strength with passable rest and proper nourishment to prevent this.

Table 3: A severe exercise regimen's impact on the immune system

	Through Exercise	**Afterward Exercise**
Neutrophil count	↑	↑↑
Monocyte count		↑
Lymphocyte count	↑	↓
CD4+ T cell count	↑	↓
CD8+ T cell count	↑	↓
CD19+ B cell count	↑	↓
CD16+56+ NK cell count	↑	↓
Lymphocyte apoptosis	↑	↓
	During Exercise	After Exercise
Proliferative reply to mitogens	↓	↓
Antibody response in vitro	↓	↓
Saliva IgA	↓	↓
Overdue type hypersensitivity response (skin test)		↓
NK cell activity	↑	↓
Lymphokine-activated killer cell activity.	↑	↓
C-reactive protein		↑
Neopterin		↑
Plasma concentration of TNF-α	↑	↑
Plasma concentration of IL-1	↑	↑
Plasma concentration of IL-6	↑↑	↑
Plasma concentration of IL-1ra	↑↑	↑
Plasma concentration of IL-10	↑	↑
Plasma concentration of TNF-R	↑	↑
Plasma concentration of MIP-1β, IL-8		↑

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As people age, their immune system experiences a decline known as immunosenescence, making them more susceptible to infections, autoimmune disorders, and chronic inflammation. One important change related to ageing is the reduction in naïve T cells, which are essential for adaptive immune responses [40]. In addition, ageing leads to increased levels of pro-inflammatory cytokines, a disorder termed "inflammaging." This chronic inflammation additionally weakens immune defences and subsidises age-related diseases. An additional task older adults face is a debilitated vaccine response, as their immune systems do not react as strongly to immunisations as younger adults do.

In spite of the natural decline in immune function at this stage, several lifestyle involvements can help to make these effects reasonable. Proper nutrition is indispensable, with adequate protein intake supporting immune cell function. Intense antioxidant-rich nourishments, such as berries, root vegetables, and whole grains, help contest oxidative stress, while vitamin D supplements are predominantly advantageous for older adults with deficiencies. Regular physical activity, including moderate exercises like ambulatory, yoga, and aerophilic training, helps maintain immune health without excessive strain. Strength training is also cherished for preserving muscle mass and metabolic health, directly supporting immunity. Individuals can improve their immune purpose and overall well-being by long-suffering these methods [41].

Table 4: Dietary Mechanisms, Immune Function, and Age-Related Changes in Health

	Possessions	**Associated Illnesses**
Nutritional fiber	Parameter of bacterial equilibrium	Colorectal cancer
	Development of intestinal transportation	Constipation=diverticulosis
	Dilution of carcinogenic agents	Hypercholesterolemia
	Growth in bile salt excretion.	Diabetes
	Parameter of blood glucose levels	Obesity
Antioxidants	Removal of free radicals (protection against cellular oxidative damage)	Cardiovascular diseases
Vitamins A, E & C	Inhibition of lipid peroxidation	Cancer

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Xanthophylls flavonoids	Development of lactose digestibility	Milk sugar intolerance
Lactic bacteria	Development of lactose digestibility	Milk sugar intolerance
	Growth in calcium engagement.	Constipation/diarrhea
		Gastro-enteritis Cancer
o-3 fatty acids	Reduction of triglycerides and LDL-cholesterol levels	Cardiovascular disease
	Reduction of platelet accumulation	
	Encouragement of the immune system	
Amino acids	Hypnotic and sedating effect	Sleep parameter
Participants	**URTI detection method**	**Major discovery**
36 sedentary, slightly obese ladies from California, USA	Everyday records of precoder, self-reported URTI symptoms for 15 weeks during the winter	The ambulatory group had fewer days with URTI symptoms (5.1 vs. 10.8) than the control group.
42 older citizens from North Carolina, USA (30 inactive, 12 athletes).	12 weeks of self-reported, precoder URTI symptoms were recorded each day during the fall (autumn) season.	8% of athletes, 21% of walkers, and 50% of sedentary controls experience URTI.
Casually assigning inactive people to sedentary or walking controls for 12 weeks.	-	-
Participants	**URTI detection method**	**Major discovery**
90 overweight and 30 normal-weight women, North Carolina, USA	everyday records of precoder, self-reported URTI symptoms for 12 weeks during the winter	Days with URTI symptoms: 9.4 ± 1.1, 5.6 ± 0.9, and 4.8 ± 0.9, respectively, in overweight, overweight walkers, and normal-weight controls.
Type of cell	Age-related increase	Age-related decrease
T lymphocyte	Number of memory and effector cells	Number of naïve T cells
	Prolonged clones of effector cells	Diversity of the T cell repertoire
	Release of pro-inflammatory cytokines	Expression of co-stimulatory molecules (CD28, CD27, CD40L). Proliferative capacity
B lymphocytes	Autoreactive serum antibodies	Generation of B cell precursors
		Number of naïve B cells

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		Diversity of the B cell repertoire
		Appearance of costimulatory molecules (CD27, CD40)
		Antibody empathy
		Isotype switch

Stress Management

- **Mindfulness and Meditation:** Reduce stress-related immune destruction.
- **Adequate Sleep:** Indispensable for proper immune parameters [42].

Conclusion

Food, workout, and age suggestively influence immune function. A nutrient-rich regime and consistent physical activity can improve immune responses and reduce the influence of ageing on immunity. Sympathetic to these factors and spreading lifestyle changes can promote long-term health and plasticity compared to infections and chronic diseases. By accepting an active method, characters can maintain healthy immune function throughout life.

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