УДК 576.311.347:[612.67+612.681]

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MITOCHONDRIAL DYSFUNCTION IN AGING AND IMPLICATIONS FOR LONGEVITY

Introduction

Aging is a complex biological process characterized by the gradual decline of cellular and physiological functions, leading to increased vulnerability to disease and death. Among the key contributors to aging is mitochondrial dysfunction, as mitochondria play a central role in energy production, redox balance, and cellular signaling. Over time, mitochondria accumulate damage due to factors such as oxidative stress, genetic mutations, and impaired quality control mechanisms, resulting in reduced efficiency of ATP production, increased generation of reactive oxygen species (ROS), and disrupted mitochondrial dynamics. These changes not only compromise cellular energy homeostasis but also contribute to the development of age-related diseases, including neurodegenerative disorders, cardiovascular diseases, and metabolic syndromes. Understanding the mechanisms underlying mitochondrial dysfunction in aging is therefore critical for unraveling the biological basis of longevity and identifying strategies to promote healthy aging.

Goal

The primary goal is to provide a comprehensive understanding of how preserving mitochondrial function could serve as a promising strategy to extend health span and lifespan, ultimately improving the quality of life in aging populations. Specifically, this study seeks to identify the spectrum of mitochondrial diseases in diverse populations, elucidate socio-economic determinants influencing disease distribution, analyze trends and patterns in disease understanding among patients and what measures could be used in the future for disease elimination or suspending.

Material and methods of research

An online survey was conducted and based on the results from various countries. Results were obtained from citizens from an age range of 14 years to 67 years from countries like Sri Lanka, Japan, Maldives, Philippines, United Kingdom, Pakistan, Saudi Arabia, Syria, Italy, Belarus, Australia and Sweden. Many other well-known sources like WHO Foundation, ScienceDirect and NIC govt articles were also utilized.

The results of the research and their discussion

Mitochondrial dysfunction has been reported to be associated with aging and almost all chronic aging-associated diseases through reduced ATP production, alteration in the regulation of apoptosis, increased ROS production, and defective calcium signaling. Accumulation of mutations in mitochondrial DNA (mtDNA) is the primary cause of mitochondrial anomalies, further contributing to aging and associated diseases [1]. While increased levels of mitochondrial ROS (Reactive Oxygen Species) may not be the direct cause of aging according to existing evidence, they do contribute significantly to the development of age-related diseases when combined with other factors, such as epigenetic alterations or a decrease in quality control systems. On the other hand, mitochondrial activity may not decline linearly throughout the aging

process. Research suggests that middle-aged individuals experience increased mitochondrial ROS as a signal to activate protective systems. However, persistent induction of ROS can lead to oxidative damage in old age. As a result, ROS has the potential to accelerate the onset of aging and diminishes the quality of life in senior individuals [2]. The public do not necessarily have a comprehensive idea as to which mitochondrial supplements to obtain for one heath as shown in Figure 01.

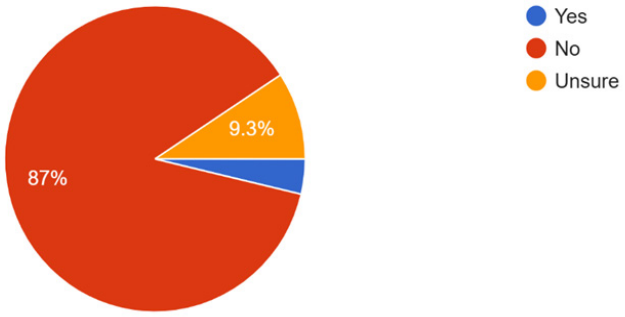

Figure 01 – Percentage of the population who have the knowledge of supplements for mitochondrial health (e.g.: CoQ10, NAD+ ,PQQ,Reservatrol)

Various pharmacological molecules targeting mitochondrial dysfunction have been identified, with potential anti-aging properties. Polyphenols such as resveratrol and green tea have been reported to extend lifespan in various model organisms, including mice [4]. Resveratrol improves mitochondrial function as observed in a mouse as a model. Apart from polyphenols, natural and synthetic compounds are reported to improve mitochondrial functions. Natural compounds such as Urolithin A, a gut metabolite of ellagic acid, have been widely studied for their anti-aging activity in model organisms such as C. elegans and rodents [3].

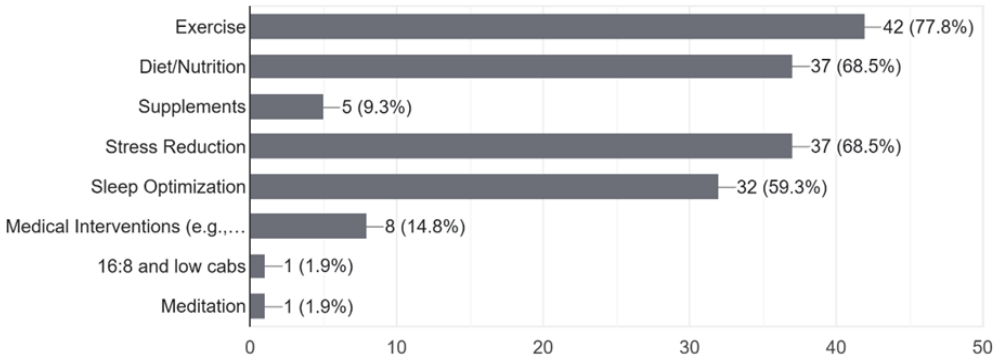

Figure 02 – Public opinion of interventions that help slow aging

Accumulating scientific evidence from studies conducted in various organisms and species suggests that targeting aging will not just postpone chronic diseases but also prevent multiple age-associated metabolic alterations while extending healthy lifespan. A number of pathways affecting metabolism, growth, inflammation, and epigenetic modifications that alter the rate of aging and incidence of age-related diseases have been identified. Interventions with the potential to target these pathways safely and to induce protective and rejuvenating responses that increase human health span are becoming available. These include intermittent or prolonged fasting, mild CR combined with a low glycemic index diet and protein restriction, inhibition of the GH/IGF-I axis, inhibition of TOR–S6K signaling, and activation of sirtuins or AMPK0[5].

Conclusions

The association of increased mitochondrial dysfunction with other hallmarks of aging makes it a possible target for developing therapies for treating aging phenotypes and associated disorders. Behavioral interventions and pharmacological compounds targeting mitochondrial dysfunction have increased hope in designing future therapeutic management of aging phenotypes and related diseases. Various therapeutic natural and synthetic molecules targeting mitochondrial functions have been studied for their implications on aging**.** Mitochondrial quality control (MQC) maintains mitochondrial function and biogenesis. Increased ROS, DNA mutations, oxidized proteins, and impaired energy metabolism cause mitochondrial dysfunction in aging. Dysfunctional mitochondria accumulated from a failure of MQC and expanding defects lead to cellular senescence and death. Targeting molecular pathways early in life could be a promising therapy for age-related diseases. Acknowledging the public of the probable efforts of methods and drugs to improve aging processes can also help them in decreasing the rates of mitochondrial diseases.

LITERATURE

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