Warm cells, cool science: Brown adipose tissue and longevity

Dawood Abid[1,2], Bhuwaneswaran Vijayam[1,2]

[1]Newcastle University Medicine Malaysia (NUMed), 79200 Iskandar Puteri, Johor, Malaysia, [2]Faculty of Medical Sciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, United Kingdom

ABSTRACT

Introduction: Brown adipose tissue (BAT) has gained increasing attention for its role in thermogenesis and its potential implications in aging and metabolic health. Unlike white adipose tissue (WAT), which primarily stores energy. BAT structurally consists of higher mitochondrial content and rather than a singular large vesicle it has many small lipid vesicles. This underpins BAT's ability to generate heat via uncoupling protein 1 (UCP1) and non-shivering thermogenesis (NST). A narrative review was conducted to consolidate current knowledge and explore future opportunities regarding the regenerative properties of BAT in relation to longevity. **Materials and Methods:** A literature search was carried out using PubMed, Cochrane and ResearchGate, appropriate wordings for the search strategies were applied accordingly for BAT, beige fat, UCP1, NST, ageing, longevity. Findings from selected reviews, clinical studies, and experimental models related to BAT were evaluated. Sources were selected based on their relevance to BAT structure, function, age-related changes, environmental and dietary influences, imaging techniques, and regenerative applications. **Results:** The location of BAT differs in neonates and adults. Neonates have interscapular, perirenal, and cervical BAT depots, while adults retain supraclavicular and paravertebral stores as the most metabolically active regions. Over time, aging markedly reduces BAT volume and activity. Research have found that preserved BAT activity in older adults is linked to improved metabolic processes. Environmental and dietary influences also shape BAT's lifespan. People living in hot climates often show reduced or undetectable BAT on imaging, largely due to the lack of cold-induced thermogenesis. Diet plays a role in which certain diets suppress BAT thermogenesis and increase visceral fat deposition. Because of this, strategies to maintain BAT into older age have become a focus. Regular cold exposure is still considered the most reliable trigger via sympathetic activation. There is also numerous "browning cocktail" in the form of food and nutraceuticals that may form and activate BAT. Beyond metabolism, BAT is being studied for regenerative medicine. It is packed with stem cells which can differentiate into any type of cells, which opens possibilities for tissue repair. In animal studies, BAT transplantation has shown to improve metabolism, liver function and glucose levels which gives rise to a potential future treatment to conditions such as diabetes, heart disease and peripheral artery disease. However, assessing BAT in humans is still technically difficult. PET-CT remains the most sensitive and specific method. Thermal imaging and other emerging, low-cost and radiation-free alternatives are gaining traction as quantitative methods measure BAT activity. **Conclusion:** In summary, BAT represents the "warm cell" with "cool" implications for longevity. With its unusual combination of metabolic and regenerative capacity, BAT has been described as an "elusive regenerative therapy" that deserves far more attention in the context of human aging. Preserving BAT function could offer a practical, non-pharmacological way to extend health span by connecting thermogenesis, metabolism, and regenerative medicine.

Keywords: Brown adipose tissue, longevity, mitochondria, UCP1, thermogenesis