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Review

The role of exercise capacity in the health and longevity of centenarians

Massimo Venturelli[a,b,c,*], Federico Schena[a], Russell S. Richardson[c,d,e]

[a] Department of Neurological, Neuropsychological, Morphological and Movement Sciences, University of Verona, Verona, Italy
[b] Mons Mazzali Foundation, Mantua, Italy
[c] Department of Internal Medicine, Division of Geriatrics, University of Utah, Salt Lake City, UT, USA
[d] Geriatric Research, Education and Clinical Center, George E. Whalen VA Medical Center, Salt Lake City, UT, USA
[e] Department of Exercise and Sport Science, University of Utah, Salt Lake City, UT, USA

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ABSTRACT

Ageing is a continuum of biological processes characterized by progressive adaptations which can be influenced by both genetic and physiological factors. In terms of human maturation, physically and cognitively functional centenarians certainly represent an impressive example of successful healthy ageing. However, even in these unique individuals, with the passage of time, declining lung function and sarcopenia lead to a progressive fall in maximal strength, maximal oxygen uptake, and therefore reduced exercise capacity. The subsequent mobility limitation can initiate a viscous downward spiral of reduced physical function and health. Emerging literature has shed some light on this multi-factorial decline in function associated with aging and the positive role that exercise and physical capacity can play in the elderly. Recognizing the multiple factors that influence ageing, the aim of this review is to highlight the recently elucidated limitations to physical function of the extremely old and therefore evaluate the role of exercise capacity in the health and longevity of centenarians.

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1. Introduction

Unveiling the 'secret' of human longevity is undoubtedly one of the most intriguing challenges for the scientific community. Certainly, genetic factors are amongst the determinants of successful ageing, however, an active lifestyle, especially regular exercise, is also a positive contributor [1–4] and has been recognized as such for quite some time. Indeed, in 44 BC Marcus Tullius Cicero, a Roman philosopher, reported in the XXXIV paragraph of the Cato Maior de Senectute, "*Potest igitur exercitatio et temperantia etiam in senectute conservare aliquid pristini roboris*" which translates to, rather profoundly for this early period in human history, 'Even in old age exercise and moderation can preserve something of young vigour' [5]. It is now clearly apparent that a decline in specific physical characteristics such as maximal strength, maximal oxygen uptake, and reduced exercise capacity can initiate a viscous downward spiral of reduced physical function and health.

* Corresponding author at: Geriatric Research, Education and Clinical Center, George E. Whalen VA Medical Center, Bldg 2 GRECC 182, 500 Foothill Drive, Salt Lake City, UT, USA. Tel.: +1 801 582 1565 4355.
E-mail addresses: massimo.venturelli@univr.it, massimo.venturelli@utah.edu (M. Venturelli).

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In terms of human maturation, physically and cognitively functional centenarians represent an impressive example of successful healthy ageing. In fact, some would argue, and perhaps correctly so, that people of 100 years of age and beyond represent the best example of successful human aging as they live ~50% longer than the world average. Although human functional independence and health undoubtedly decline progressively with advancing age, a significant percentage of centenarians maintain some level of independence and are able to perform the basic activities of daily of life [6]. To our knowledge, the first document that identifies the determinants of longevity in centenarians is a manuscript published in 1899 and authored by T.E. Young. It was aptly entitled: '*On centenarians and the duration of the human race*'. Interestingly, more than 100 years ago factors such as moderation, genetics, and physical activity were already being methodically documented as contributors to the longevity of centenarians: '*The majority of centenarians were moderate or small eaters . . . took but little animal food or alcohol . . . had experienced few illnesses during their life-time . . . and as a rule the records showed that outdoor exercise and early rising constituted important factors*' [7].

While living to an age of 100 years is not a new phenomenon, it was far less frequent in the relatively recent past. Indeed, in western countries, the number of centenarians is growing at the rapid rate of approximately 8% per year, while, to put this in perspective, the worldwide population is only growing at a rate of 1% per year [8]. Significant improvements in the quality of life and advances in medicine in the last half century have, at least in part, influenced this growth in the centenarian population. Such medical advances are particularly important because centenarians die as a consequence of disease and not because of 'old age', as commonly assumed, with the majority of centenarians presenting with chronic co-morbidities even if they are considered otherwise healthy [9]. However, centenarians, despite great variability in terms of health, cognitive function and independence [10], have a better pathological profile than the majority of their elderly, but still much younger, counterparts who are likely not to survive to the age of 100 years. Although epidemiological studies agree that regular exercise appears to positively enhance health and independence in centenarians, it was not until recently that direct assessments were made of what limits their physical function, facilitating an examination of the role of exercise capacity in the health and longevity of this population. Therefore, considering the multiple factors influencing successful ageing, the aim of this review is to describe the physical capacity of extremely old individuals and to evaluate how exercise impacts the health and longevity of centenarians.

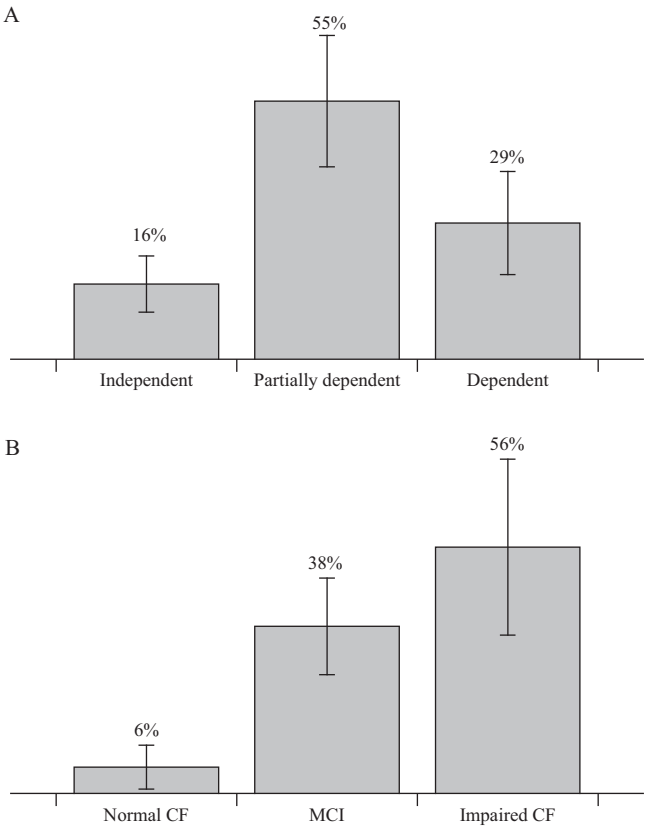

Fig. 1. Independence and cognitive function (CF) of centenarians. Data are presented as mean ± SD. The average level of independence (Panel A) was calculated by taking into account the ADL scale from 6 epidemiological studies (3341 centenarians). The mean level of cognitive function (Panel B) was calculated from the cognitive scores reported in 3 epidemiological studies (1150 subjects). MCI, mild cognitive impairment.

2. Inspirational examples of human longevity and more typical experiences with extreme ageing

Although certainly in the minority, some centenarians maintain a standard of physical capacity commensurate with continued professional activities, and therefore it is now possible to find some centenarians that continue to work as managers, artists, scientists, and politicians. An example of the latter being the Nobel Prize winner Dr. Rita Levi-Montalcini who, at the age of 103, in 2012, is a senator for life in the Italian Parliament [11]. There are also longevous individuals whose functional capacity allows them to continue to participate in challenging sporting events such as Mr. Fauja Singh, who, in 2011, as a centenarian completed a marathon in Toronto, Canada, in 8 h and 25 min [12]. However, despite these rare and rather inspiring examples of successful ageing, the reality is that several epidemiological studies [6,10,13–17] have revealed that only ~16% of centenarians have the physical capacity to independently perform the activities of daily living, with the majority being partially or totally dependent (Fig. 1; Panel A). Moreover, age-related cognitive dysfunction also plays a significant role in centenarians, with a combination of data from 3 epidemiological studies [10,14,18], indicating that only 6% of centenarians display completely preserved cognitive function (Fig. 1; Panel B). This diminished cognitive function in the very old is clearly an important and widespread issue that likely interacts significantly with physical function and the potential role that exercise can play in the health of this population, but is beyond the scope of this review.

3. Physical capacity, ageing, and longevity

Many factors including genetics and quality of health care combine to yield longevity, however, the important components of a healthy life-style, such as maintaining exercise capacity, is certainly important [1]. Indeed, the capacity to limit age-related diseases has been proposed as one of the mechanisms responsible for successful aging in extremely old subjects [19], and maintaining exercise capacity and subsequently physical function likely plays a significant role in this process. Exercise capacity, defined by maximal oxygen consumption (VO_{2max}) in response to a graded exercise test, is a strong predictor of health and independence in older adults [20] and has been documented to decline by 10–15% per decade between the ages of 50 and 75 years [21]. Indeed, there is a strong association between ageing, independence, and maximal aerobic capacity; thus, understanding the physiological basis for the decline in VO_2 with age has clear practical significance in terms of identifying the means by which the capacity for an independent lifestyle can be maintained [22].