Ageing Research Reviews 45 (2018) 62–82

Contents lists available at ScienceDirect

Ageing Research Reviews

journal homepage: www.elsevier.com/locate/arr

Review

Muscle morphology and performance in master athletes: A systematic review and meta-analyses

James Mckendry[a,*], Leigh Breen[a,b], Brandon J. Shad[a], Carolyn A. Greig[a,b]

[a] School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Birmingham, B15 2TT, UK
[b] MRC-Arthritis Research UK Centre for Musculoskeletal Ageing Research, University of Birmingham, Birmingham, B15 2TT, UK

ARTICLE INFO

Keywords:
Sarcopenia
Lifelong exercise
Muscle mass
Muscle strength
Endurance capacity

ABSTRACT

Introduction: The extent to which chronic exercise training preserves age-related decrements in physical function, muscle strength, mass and morphology is unclear. Our aim was to conduct a systematic review of the literature to determine to what extent chronically trained master athletes (strength/power and endurance) preserve levels of physical function, muscle strength, muscle mass and morphology in older age, compared with older and younger controls and young trained individuals.

Methods: The systematic data search included Medline, EMBASE, SPORTDiscus, CINAHL and Web of Science databases.

Inclusion criteria: i) master athletes mean exercise training duration ≥20 years ii) master athletes mean age of cohort > 59 years) iii) at least one measurement of muscle mass/volume/fibre-type morphology and/or strength/physical function.

Results: Fifty-five eligible studies were identified. Meta-analyses were carried out on maximal aerobic capacity, maximal voluntary contraction and body composition. Master endurance athletes (42.0 ± 6.6 ml kg^{-1} min^{-1}) exhibited VO_{2max} values comparable with young healthy controls (43.1 ± 6.8 ml kg^{-1} min^{-1}, P = .84), greater than older controls (27.1 ± 4.3 ml kg^{-1} min^{-1}, $P < 0.01$) and master strength/power athletes (26.5 ± 2.3 mlkg^{-1} min^{-1}, $P < 0.01$), and lower than young endurance trained individuals (60.0 ± 5.4 ml kg^{-1} min^{-1}, $P < 0.01$). Master strength/power athletes (0.60 (0.28–0.93) $P < 0.01$) and young controls (0.71 (0.06–1.36) $P < 0.05$) were significantly stronger compared with the other groups. Body fat% was greater in master endurance athletes than young endurance trained (−4.44% (−8.44 to −0.43) $P < 0.05$) but lower compared with older controls (7.11% (5.70–8.52) $P < 0.01$).

Conclusion: Despite advancing age, this review suggests that chronic exercise training preserves physical function, muscular strength and body fat levels similar to that of young, healthy individuals in an exercise mode-specific manner.

1. Introduction

The UK population is projected to increase by ~25% between 2013 and 2060, from 64.1 to 80.1 million (Mitchell et al., 2012) which heralds a demographic shift towards an ageing society. This changing demographic presents a significant and overwhelming challenge to healthcare provision in the UK (Holloszy, 2000). Indeed, although individuals are living longer (i.e., lifespan), many endure a large portion of their later years with a number of age-related comorbidities (Seals et al., 2016). Extending the length of time individuals remain healthy and disease-free (i.e. health-span) with an emphasis on compressing morbidity is therefore an important focus (Seals et al., 2016). Physical function (e.g., aerobic capacity and muscular strength) typically declines with advancing age and this is often highlighted as a principal risk factor for the development of a number of degenerative chronic health conditions (Niccoli and Partridge, 2012). However, it has been suggested that exercise throughout the lifespan (i.e., 'chronic' exercise training) can attenuate or even prevent age-related declines in physical function. Understanding whether, and to what extent, chronic exercise training preserves physical function, muscle strength, mass and morphology is of great importance in the pursuit of appropriate countermeasures to age-related health deterioration.

Reductions of aerobic capacity (VO_{2max}) and muscular strength are major risk factors for all-cause mortality in older age (Lee et al., 2011; Ortega et al., 2012; Ruiz et al., 2008). VO_{2max} and muscular strength are often considered robust measures of physical function and health as

* Corresponding author at: School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Edgbaston, B15 2TT, UK.
E-mail address: jxm965@student.bham.ac.uk (J. Mckendry).

https://doi.org/10.1016/j.arr.2018.04.007
Received 19 January 2018; Received in revised form 26 March 2018; Accepted 24 April 2018
Available online 30 April 2018
1568-1637/

they require successful integration of the cardiovascular, respiratory and neuromuscular systems (Harridge and Lazarus, 2017). The gradual decline of these bodily systems with ageing ultimately reduces the ability of older individuals to carry out activities of daily living (ADL); forcing many into a state of reduced physical independence and a poorer quality of life (Sonn, 1996). Delineating the relative contribution of primary ageing and environmental influences (or secondary ageing) to the age-related decline in physical function, muscle strength, mass and morphology is problematic. One aspect of secondary ageing that is considered to be particularly influential is habitual physical activity. The majority of older adults reduce habitual physical activity with advancing age (Blair, 2009), and this is often accompanied by the presence of at least one chronic disease (Hung et al., 2011). However, a small sub-set of the population, referred to as master athletes, are unique in that they have chronically undertaken and continue to maintain high levels of physical activity, including structured exercise training. Indeed, Zampieri and colleagues (Zampieri et al., 2015) demonstrated that senior sportsmen from varied training backgrounds exhibited muscular strength, performance, myofibre properties and function comparable with young, healthy individuals. These findings suggest that chronic exercise training can preserve physical function and skeletal muscle properties in older age. As such, the study of Master athletes may allow us the opportunity to distinguish the contribution of primary and secondary ageing to the age-related decline in health, function and performance (Harridge and Lazarus, 2017; Lazarus and Harridge, 2007). However, Mackey and colleagues observed no difference in type I or type II fibre size between young and old regardless of training status, despite differences in VO_{2max}; making it challenging to draw firm conclusions regarding the impact ageing and/or chronic endurance exercise elicits on fibre area (Mackey et al., 2014). To further complicate the variable findings in these unique individuals, Piasecki and colleagues demonstrated that the loss of muscle size, strength and motor units in the *Tibialis anterior* was similar between master endurance athletes and age-matched untrained controls (Piasecki et al., 2016a). The inconsistent findings highlighted advocate the need for a quantitative summary of the existing literature surrounding the effect of chronic exercise training on indices of performance and skeletal muscle properties.

Earlier comparisons between young and older individuals and master athletes have typically included master athletes younger than 60 y (Gent and Norton, 2013; Kusy and Zielinski, 2014; Maffulli et al., 1994). Specifically, this systematic review will focus on master athletes 60 y or older as these individuals would typically have begun to experience age-related decrements in physical function, muscle strength, mass and morphology (Doherty, 2003; Janssen et al., 2000). Additionally, most systematic review comparisons between young and older individuals and master athletes have focused on single outcome measures, specifically body composition (Ballor and Keesey, 1991), aerobic capacity (Fitzgerald et al., 1997; Wilson and Tanaka, 2000), muscular strength (Peterson et al., 2010) adaptations to training (Daskalopoulou et al., 2017) and protein supplementation (Doering et al., 2016). Therefore, the primary aim of this systematic review was to establish whether older individuals who have undertaken chronic exercise training, preserve physical function, muscular strength, mass and fibre properties (i.e. size and relative distribution) compared with untrained age-matched individuals, as well as younger trained and untrained individuals. A secondary aim was to determine the influence of exercise modality (i.e., strength/power vs. endurance) on the included parameters.

2. Methods

2.1. Information sources and literature search

A systematic literature search of online databases was conducted in November 2017 using selected key words, free text terms; indexed terms; and Boolean operators. The search strategies were applied to Medline; EMBASE; SPORTDiscus; CINAHL and Web of Science databases. Recursive searching of the bibliographies of eligible studies and relevant reviews was performed to identify additional articles. The systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) report (Moher et al., 2009).

2.2. Study selection criteria

2.2.1. Inclusion criteria

Studies were included in the review if they met the following inclusion criteria: 1) Exercise training for a minimum of 20 years in the master athletes group, explicitly stated within the study. 2) Mean age of older cohorts older than59 years. 3) Inclusion of at least one measurement of muscle mass/volume/fibre type morphology (fibre type, size, area) and/or a measurement of strength/physical function. 4) Muscle mass measurement using magnetic resonance imaging (MRI), computed tomography (CT), dual x-ray absorptiometry (DXA), air displacement plethysmography (BodPod), hydrostatic weighing, bioelectrical impedance analysis (BIA) or B-Mode ultrasonography. Physical function/strength/performance measurements to include one, or more, of: handgrip strength, isometric/isotonic strength/power/torque or aerobic capacity (VO_{2max}). 5) Freedom from any neurological, neuromuscular, cardiovascular and metabolic disease. 6) Studies published only in English with no date restrictions.

2.2.2. Exclusion criteria

Studies were excluded from the review if: 1) The authors did not explicitly state the length of time that master athletes had been continuously training, or if that time was less than 20 years. 2) No inclusion of relevant measures of muscle mass/morphology or physical function. 3) Relevant data could not be obtained directly from potentially eligible articles or via contact with the study authors.

2.3. Participant criteria

Sedentary older control groups were required to be of a similar age to master athlete groups (mean group > 59 years) and have undertaken little, to no, structured exercise training. Older control groups did not have to be completely sedentary compared with master athlete groups. Young controls were required to be younger than 40 years, and have undertaken little to no structured exercise training. Young controls did not have to be completely sedentary compared with young trained individuals, who were required to be younger than 40 years and undertaking either structured endurance or strength/power-based exercise training.

2.4. Study selection

Titles and abstracts were screened for relevance by 2 reviewers (J.M. and B.J.S). Irrelevant titles were removed. Full-text articles were obtained for potentially relevant studies via a combination of online databases, hardcopy sourcing and direct contact with the authors, and these were further evaluated to determine whether they met the inclusion criteria. Studies deemed eligible were included in the systematic review. Two reviewers (J.M and B.J.S.) independently assessed full-texts for eligibility; any disagreements between the two reviewers were settled by consensus. All records were managed using the reference software EndNote (Thomson Reuters, v.X7)

2.5. Data extraction

Predetermined variables were extracted from each of the included studies using a customised data extraction form (J.M and B.J.S). Measures of interest included participant characteristics (number, age,