Experimental Gerontology 108 (2018) 159–165

Contents lists available at ScienceDirect

Experimental Gerontology

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

Reduced body weight or increased muscle quality: Which is more important for improving physical function following exercise and weight loss in overweight and obese older women?

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ARTICLE INFO

Section Editor: Christiaan Leeuwenburgh

Keywords:
Aging
Exercise
Diet
Obesity
Health

ABSTRACT

The purpose of this study was to examine the relative contributions of changes in muscle quality and body composition to changes in lower-extremity physical function (LEPF) following a 6-month exercise and weight loss intervention in overweight and obese older women. Thirty-eight overweight and obese (BMI = 30.0 ± 4.4 kg/m^2) older (age = 69.3 ± 4.1 y) women completed 6 months of multicomponent exercise (cardiorespiratory, resistance, balance and flexibility training) and weight loss (hypocaloric diet that reduced energy intake by ~500 kcal/d). Body composition was measured via dual-energy X-ray absorptiometry and muscle quality (N-m/kg) was defined as maximal concentric isokinetic knee torque divided by upper-leg lean mass. The standardized scores of four objective measures of physical function were summed to yield a composite LEPF Z-score. At 6 months, there were significant reductions in body weight (−9.6 ± 3.5%, $p < 0.01$), absolute fat mass (−6.8 ± 2.4 kg, $p < 0.01$) and relative adiposity (−4.9 ± 2.1%, $p < 0.01$). There were also improvements in both muscle quality (+1.6 ± 1.8 N-m/kg, $p < 0.01$) and individual measures of LEPF (11–57%, $p < 0.01$). Multivariate linear regression indicated that increased muscle quality was the strongest independent predictor of an improvement in LEPF Z-score (standardized β = 0.64, $p < 0.01$) and explained 34% of the variance. A reduction in body weight also predicted an improvement in LEPF, independent of the change in muscle quality. In conclusion, muscle quality can be increased in the presence of clinically meaningful weight loss, and is the primary determinant of improved physical function in overweight/obese older women.

1. Introduction

Overweight and obesity among older adults is a major public health challenge in the United States (Villareal et al., 2005), with 69% of women aged ≥60 years classified as overweight or obese (BMI ≥ 25.0 kg/m^2) in 2011–2012 (Ogden et al., 2014). Among a myriad of adverse health consequences, excess adiposity has consistently been linked to reductions in physical function among older adults (Davison et al., 2002; Zamboni et al., 1999; Zoico et al., 2004), especially women (Friedmann et al., 2001; Riebe et al., 2009; Straight et al., 2015a). Conversely, exercise and weight loss interventions have been shown to be effective at improving physical function in overweight and obese older adults (Anton et al., 2011; Nicklas et al., 2015; Villareal et al., 2006; Villareal et al., 2011), but the factors responsible for these improvements are unclear. Characterizing these factors is critical for the development of targeted interventions among overweight and obese older women toward the end of preventing future physical disability.

Observational studies indicate that muscle quality (strength per unit of muscle size or mass) and adiposity are salient determinants of physical function in the older adult cohort (Beavers et al., 2013a; Fragala et al., 2012; Misic et al., 2007; Straight et al., 2015b). A few clinical trials have found that reducing overall body mass predicts improvements in physical function (Villareal et al., 2006; Beavers et al., 2013b; Mojtahedi et al., 2011), but only one of these studies examined whether a change in muscle quality was related to an improvement in functional outcomes (Villareal et al., 2006). Conversely, a small number of studies suggest a link between changes in muscle quality and changes in

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https://doi.org/10.1016/j.exger.2018.04.011
Received 15 December 2017; Received in revised form 6 April 2018; Accepted 16 April 2018
Available online 19 April 2018

specific functional tasks following relatively short exercise interventions (e.g., 6–12 weeks) in older adults (Marsh et al., 2009; Pinto et al., 2014; Santos et al., 2017). However, those studies did not examine these relationships in the context of body composition changes for overweight and obese older adults undergoing intentional diet-induced weight loss. Therefore, the interplay between variables responsible for improving physical function following exercise and weight loss is poorly understood, which begs the question: is reducing body weight (the load to be moved) or increasing muscle quality (the ability to move the load) more important for improving physical function? This is particularly relevant for older women, who have lower physical activity levels (Sun et al., 2013), greater adiposity (Jankowski et al., 2008) and lower muscle quality (Newman et al., 2003) relative to their male counterparts.

In this context, the present study examined the relative contributions of changes in muscle quality and body weight/adiposity to a change in lower-extremity physical function (LEPF) in overweight and obese older women following a 6-month exercise and weight loss intervention. Based on prior research (Misic et al., 2007; Straight et al., 2015b; Beavers et al., 2013b), it was hypothesized that a) muscle quality would be the strongest independent predictor of a change in LEPF, and b) changes in body weight and/or adiposity would also be significant contributors with a similar strength of association.

2. Methods

2.1. Study design

This study is a secondary analysis of a larger project that was designed to compare the effects of 6-month exercise and calorically-restricted weight loss interventions on body composition and LEPF in overweight and obese older women. In the parent study, 81 women were randomized into one of three treatment groups, and 61 participants completed the trial. For this analysis, only participants who 1) were enrolled in the exercise and weight loss arms of the trial and, 2) achieved ≥3% loss of baseline body weight, were included. We used 3% as the threshold because weight maintenance has been defined as < 3% change in body weight (Stevens et al., 2006), and research suggests health benefits can be achieved with at least 3% weight loss (Donnelly et al., 2009). Participants obtained medical clearance from their physician and provided written informed consent prior to enrollment. All procedures of this study were approved by the Institutional Review Board at the University of Georgia.

2.2. Participants

Community-dwelling, overweight and obese older women (n = 38) completed the 6-month intervention and baseline and post measures. Women aged 65–80 y were eligible to participate in the study if they met the following inclusion criteria: BMI ≥ 25.0 kg/m^2, stable body weight during the previous six months (within 2 kg), sedentary (defined as < 1 h/wk of physical activity or < 2 exercise sessions per week in the past six months), non-smoking or tobacco using, and free of any chronic disease/condition that would preclude safe participation in exercise training or dietary restriction. Self-reported use of prescription medications was ascertained via a questionnaire and cognitive state was measured using the Mini-Mental State Examination (Folstein et al., 1975).

2.3. Body composition

Standing height and weight were measured with participants wearing light-weight clothing and no shoes. Height was obtained using a stadiometer (Seca, Model 242) with measures obtained to the nearest 0.1 cm, and weight was measured on a calibrated digital scale (Tanita, Model WB-110A). Whole-body and regional soft tissue composition was assessed via dual-energy X-ray absorptiometry (iDXA, GE Healthcare-Luna, Madison, WI). Regional analyses were performed per manufacturer guidelines and involved bisecting the femoral neck to determine mineral-free lean mass of the legs.

2.4. Muscle strength and quality

Maximal concentric isokinetic knee extension and flexion torque was measured at 60°/s via isokinetic dynamometry to provide a measure of lower-body muscle strength (System 4 Pro, Biodex Medical Systems Inc., Shirley, NY). Participants performed 2 sets of 4 extension and flexion repetitions for the left and right legs. The greatest extension and flexion peak torque values for each leg were summed to calculate maximal concentric isokinetic knee torque at 60°/s. Muscle quality has traditionally been defined as the ratio of muscle strength or power per unit size (Nicklas et al., 2015; Delmonico et al., 2009; Ivey et al., 2000; Reid et al., 2008), and thus was calculated by dividing maximal isokinetic knee torque (N-m) by mineral-free lean mass of the upper leg (kg).

2.5. Lower-extremity physical function

Performance-based physical function was measured with tests conventionally used in the older adult population: a) 6-minute walk (Rikli and Jones, 1998), b) 8-foot up-and-go (Rikli and Jones, 1999; Rikli and Jones, 2013), c) 30-second chair stand (Rikli and Jones, 2013; Jones et al., 1999), and d) transfer task (Mojtahedi et al., 2011). Similar to previous work from our laboratory (Straight et al., 2015a; Straight et al., 2015b) and others (Bouchard et al., 2011; Santos et al., 2012; Li et al., 2001; Lebon et al., 2016), we calculated a composite LEPF Z-score by summing the standardized values of each individual assessment to provide a global index of LEPF.

2.6. Exercise intervention

All participants were expected to complete three 75-minute sessions of supervised exercise on nonconsecutive days during each week of the intervention for 6 months. The exercise intervention was a multi-component program (cardiorespiratory training, resistance training, balance, flexibility and functional activities) in accordance with physical activity recommendations set forth in position stands by the ACSM (Garber et al., 2011; Nelson et al., 2007). Cardiorespiratory training included 30 min of continuous exercise (walking on a treadmill, cycling or using an elliptical) at 70–80% of age-predicted maximal heart rate. Exercise intensity during the cardiorespiratory training was monitored throughout each session by recording heart rate and rating of perceived exertion at 10, 20, and 30 min of exercise. Three upper-body (chest press, shoulder press, and back row), three lower-body (leg press, knee extension, and knee curl), and one core (abdominal crunch) resistance training exercise was performed during every session. Participants performed 2 sets of 8–10 repetitions at 65% of one-repetition maximum (1-RM) for each exercise, and muscle strength was reassessed every 6 weeks to ensure a progressive overload. Congruent with ACSM guidelines promoting neuromuscular training and the recommendation for functionally relevant exercises (McKinnon et al., 2017), body weight activities (e.g., wall push-ups) were also performed. Finally, 5–10 min of balance and flexibility exercises were performed at the end of every training session.

2.7. Diet intervention

Participants were prescribed a hypocaloric diet that reduced estimated energy needs by ~500 kcal/d to facilitate ~10% weight loss at 6 months from one of two dietary treatments: 1) a higher protein diet [30% protein (1.6 g/kg/d) and 40% carbohydrate], or 2) a conventional protein diet [18% protein (0.8 g/kg/d) and 52% carbohydrate]; dietary