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Effects of different strength training frequencies on maximum strength, body composition and functional capacity in healthy older individuals

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A R T I C L E I N F O

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A B S T R A C T

There is controversy in the literature regarding the dose-response relationship of strength training in healthy older participants. The present study determined training frequency effects on maximum strength, muscle mass and functional capacity over 6 months following an initial 3-month preparatory strength training period. One-hundred and six 64–75 year old volunteers were randomly assigned to one of four groups; performing strength training one (EX1), two (EX2), or three (EX3) times per week and a non-training control (CON) group. Whole-body strength training was performed using 2–5 sets and 4–12 repetitions per exercise and 7–9 exercises per session. Before and after the intervention, maximum dynamic leg press (1-RM) and isometric knee extensor and plantarflexor strength, body composition and quadriceps cross-sectional area, as well as functional capacity (maximum 7.5 m forward and backward walking speed, timed-up-and-go test, loaded 10-stair climb test) were measured. All experimental groups increased leg press 1-RM more than CON (EX1: 3 ± 8%, EX2: 6 ± 6%, EX3: 10 ± 8%, CON: −3 ± 6%, $P < 0.05$) and EX3 improved more than EX1 ($P = 0.007$) at month 9. Compared to CON, EX3 improved in backward walk ($P = 0.047$) and EX1 in timed-up-and-go ($P = 0.029$) tests. No significant changes occurred in body composition. The present study found no evidence that higher training frequency would induce greater benefit to maximum walking speed (i.e. functional capacity) despite a clear dose-response in dynamic 1-RM strength, at least when predominantly using machine weight-training. It appears that beneficial functional capacity improvements can be achieved through low frequency training (i.e. 1–2 times per week) in previously untrained healthy older participants.

1. Introduction

Strength training is a widely used method to combat the deleterious effects of aging and age-related reduced physical activity on maximum strength, muscle mass and functional capacity. There are many combinations of acute program variables (identified by Kraemer and Ratamess, 2004) that can influence the overall outcome of a strength-training program. These variables are; the choice of exercise(s) and exercise order, number of sets/repetitions, inter-set and inter-exercise rest interval, and the intensity of each exercise. The effects of several of these variables on maximum strength and muscle mass development have been examined over previous decades (e.g. Campos et al., 2002; Moss et al., 1997). But one variable, training frequency, has received little attention (Steib et al., 2010). It is important to be clear that training frequency in the present study is limited to whole-body strength training (rather than split programs; training one specific muscle group per day) and the vast majority of studies using training 2–3 times per week does not allow reviews/meta-analyses to accurately determine the effects of different frequencies on outcome variables.

Nevertheless, physical activity guidelines from bodies such as the World Health Organization and the American College of Sports Medicine recommend whole-body strength training for healthy individuals above 65 years at a frequency of *at least* two times per week (Ratamess et al., 2009; World Health Organization, 2010). This is despite the little experimental evidence to support such a recommendation regarding development of maximum strength or muscle mass, and particularly functional capacity, in previously untrained healthy older individuals. This is in contrast to the quite well-established evidence base to recommend progressive loading and volume to promote achieving these desirable outcomes (Ratamess et al., 2009).

A seminal paper investigating training frequency (one versus two versus three times per week) on improvements in maximum strength and functional capacity observed no difference in improvements between groups (Taaffe et al., 1999). Also, a recent meta-analysis showed no evidence of different strength improvements comparing frequencies of one, two or three times per week (Silva et al., 2014). Maintenance of

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muscle mass is another important consideration for older adults given its role in force production and also metabolic regulation. However, to our knowledge, no study has investigated the effect of training frequency on muscle hypertrophy in healthy older individuals. The effect of training frequency on muscle hypertrophy would be pertinent to examine since most studies use either two or three times per week, which has been shown to exert little difference (Wernbom et al., 2007), but recent evidence suggests these frequencies are more beneficial than one time per week (Schoenfeld et al., 2016), which does support the physical activity guidelines.

One important methodological consideration when evaluating these studies is the existing training status of the participants. All four original articles that we identified in the literature investigating training frequency in healthy older individuals used previously untrained participants (DiFrancisco-Donoghue et al., 2007; Farinatti et al., 2013; Padhila et al., 2015; Taaffe et al., 1999). As it is known that untrained individuals respond more robustly to a variety training protocols, the use of completely untrained participants may reduce any potential to identify differences in adaptive responses in response to different training frequencies.

Therefore, there is a need to further study the influence of training frequency on improvements in maximum strength, muscle mass and functional capacity in healthy older individuals that have undergone (some) strength training prior to separation into different training frequencies. Consequently, the purpose of the present study was to determine whether training frequency affects improvements in maximum strength, muscle mass and functional capacity over a 6-month period following an initial 3-month low-intensity preparatory strength training period.

2. Materials and methods

2.1. Participant recruitment and randomization

This study was the second arm of a randomized controlled trial (NCT02413112). Participants were 64–75-year-old men and women. Exclusion criteria were; (1) regular aerobic exercise (> 180 min·week^{-1}), (2) any previous strength training experience, (3) Body Mass Index > 37, (4) serious cardiovascular disease or lower limb injuries/disease that may lead to complications during exercise or affect the ability to perform testing and training, (5) use of walking aids, (6) use of medication that affect the neuromuscular or endocrine systems, (7) previous testosterone-altering treatment, and (8) smoking. Therefore, participants were otherwise healthy apart from conditions such as Type II diabetes, high blood pressure, and/or high cholesterol in several cases, were not frail or obese, were not engaged in systematic fitness training, and were able to perform strength training with no restrictions. While the participants did not engage in aerobic exercise, it was clear from the pre-study interviews that typical 'Nordic' low-intensity physical activity (e.g. berry-picking, gardening, forestry etc.) was part of their lifestyle – and may, in part, explain their largely healthy condition despite not meeting recommended levels of physical activity (WHO, 2010).

The recruitment process and exclusion of participants in shown in Fig. 1. Prior to physician assessment, advertisement letters were posted to 2000 65–75-year-old men and women in the Jyväskylä region and potential participants registered to the study by completing an online researcher-designed questionnaire (n = 454). As part of the registration questionnaire, potential participants were asked about their current and previous level of physical activity, medical history including any current/ongoing/permanent conditions, current and previous medications and also immediate family medical history. The participants were blind to the purpose of these questions (i.e. to assess eligibility). After assessing the eligibility of the registered individuals for lower limb injuries, skeletomuscular diseases and physical activity levels, potential participants were invited to an information session (n = 148). Each participant was carefully informed of the study design and potential risks before the study, after which they provided written consent and attended a physician's examination (n = 116). During the physician's examination, potential participants were interviewed by the researchers to ensure that they were eligible to be included to the study. After baseline testing, the participants (n = 106) were allocated an identification number and a computer-generated random number sequencer was used to allocate each participant into one of four groups (Fig. 1); training one (EX1), two (EX2), three (EX3) times per week and non-training/wait control (CON).

During the study, one participant dropped out due to back pain induced by the strength testing in month 3, one participant dropped out due to re-occurrence of heart arrhythmia and one participant dropped out due to stress-related illness. Six participants failed to attend at least 90% of the assigned training sessions for their group and were consequently removed from the analyses (as noted in Fig. 1). Furthermore, after data checking, several participants' electromyography and voluntary activation level data were excluded from final analysis due to technical faults. The study was conducted according to the Declaration of Helsinki and was approved by the ethical committee of the University of Jyväskylä, Finland. Baseline characteristics of the participants in each group are shown in Table 1, with the only differences observed between men and women in height and body mass.

Some participants were taking medication during the study that was deemed not to interfere with their ability to participate in training or testing. The total number users of each type of medication are listed here; EX1: cholesterol medication (3 men + 3 women), blood pressure medication (4 men + 3 women), blood glucose medication (1 men + 1 women), thyroid medication (1 men + 2 women), beta-blockers (1 woman); EX2: cholesterol medication (2 men + 3 women), blood pressure medication (5 men + 6 women), blood glucose medication (2 women), thyroid medication (1 man + 2 women), beta-blockers (1 man + 1 woman); EX3: cholesterol medication (1 man + 3 women), blood pressure medication (5 men + 5 women), blood glucose medication (2 men), thyroid medication (1 man + 4 women), beta-blockers (1 man + 2 women); CON: cholesterol medication (2 men + 2 women), blood pressure medication (4 men + 3 women), beta-blockers (1 man + 1 woman).

2.2. Dynamic leg press performance

Concentric bilateral leg press one-repetition maximum (1-RM) load (kg) was used to assess maximum dynamic strength (David Sports Ltd., Helsinki, Finland). Briefly, following warm-up, single repetitions with increments of 5 kg were performed until the participants could no longer fully extend their hips and legs (full extension = 180°). Each trial was separated by 1.5 min. All data were relayed to a pc via an AD converter (Micro 1401, Cambridge Electronic Design, UK) and recorded using Signal 4.04 software (Cambridge Electronic Design, UK). Data was sampled at 2000 Hz and filtered by a 10-Hz low-pass filter (fourth-order Butterworth) and the best trial was used in further analyses.

2.3. Isometric knee extension and plantarflexion performance

Maximum unilateral isometric knee extension torque of the right leg was measured using a custom-built isometric force chair. Inelastic straps were used to secure the participant with both hip and knee angles of 110°. Participants were instructed to kick "as fast and as hard as possible" and maintain their maximum force for approximately 3 s. The force signal was sampled as described in the leg press trials with the highest force used in further analysis. Three trials were performed with a fourth trial performed if improvements were > 5%. Thereafter, two additional maximum isometric knee extension trials were performed with femoral nerve stimulation delivered during the force plateau and 2 s after contraction cessation following similar procedures as Walker et al. (2014). Rectangular pulses (400 V) of 200 μs were delivered by a