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Bachelor's thesis in Human Movement Science
Supervisor: Mireille van Beekvelt
March 2024

Bachelor's thesis

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## Abstract

**Background:** Adequate muscle function is vital for independence and quality of life in older people. For postmenopausal women this may be particularly challenging to maintain as they age, because this group is at higher risk for developing conditions such as sarcopenia and osteoporosis. Therefore this study will investigate resistance training's effect on muscle function in older women. Hand grip strength will be used as the primary outcome measure, as this is commonly used as an indicator for general muscle function. **Methods:** The literature search was conducted using the PubMed database. 10 studies were selected that included participants with a mean age from 63-81 years. All studies involved some form of resistance exercise intervention. The health status differed among the studies encompassing sarcopenic, osteoporotic, obese and healthy individuals. **Results:** 6 out of 10 studies showed an improvement in hand grip strength. Additionally, most groups improved in other tests relevant to muscle function. **Conclusion:** Our findings suggest that several factors can affect the improvement in hand grip strength. The most important seem to be intervention length, number of sets per week, baseline strength and fitness level. Still there needs to be a more detailed description of the protocol to better compare interventions between studies.

## Abstrakt

**Bakgrunn:** Tilstrekkelig muskelfunksjon er avgjørende for selvstendighet og livskvalitet hos eldre mennesker. For postmenopausale kvinner kan dette være spesielt utfordrende å opprettholde ettersom de eldes, fordi denne gruppen har økt risiko for å utvikle tilstander som sarkopeni og osteoporose. Derfor vil denne studien undersøke effekten av styrketrening på muskelfunksjonen hos eldre kvinner. Håndgrepsstyrke vil bli brukt som hovedutfallsmål, da dette vanligvis brukes som en indikator for generell muskelfunksjon. **Metode:** Litteratursøket ble utført ved bruk av PubMed-databasen. 10 studier ble valgt ut. Disse inkluderte deltakere med en gjennomsnittsalder fra 63 til 81 år. Alle studiene involverte en form for styrketrening i intervensjonen. Helsetilstanden varierte blant studiene og omfattet friske individer og individer med sarkopeni, osteoporose og fedme. **Resultat:** 6 av 10 studier viste en forbedring i håndgrepsstyrke. I tillegg forbedret de fleste gruppene andre tester som var relevant for muskelfunksjon. **Konklusjon:** Våre funn antyder at flere faktorer kan påvirke forbedringen i håndgrepsstyrke, og de viktigste faktorene viste seg å være intervensjonens varighet, antall sett per uke, styrkegrunnlag og treningsnivå. Det trengs imidlertid mer detaljert beskrivelser av protokoller for å bedre kunne sammenligne intervensjoner mellom studier.

## Introduction

In modern society, people tend to live longer than ever before. The rapid advancement of modern medical science is probably the biggest reason for this. The problem however, is that while the average lifespan is increasing, the quality of life and independence of the elderly may not be preserved at the same rate (1). In turn this brings about serious challenges for society as a whole, regarding resources and healthcare costs tied to caring for an aging population. Therefore, giving people the knowledge and tools to maintain health and function into older age seems to become increasingly important. A big part of staying healthy and independent is associated with a person's level of muscle mass and function (2). Thus, one of the most advantageous objectives to pursue as one ages, is to maintain healthy muscle function. Increasing mobility, independence, bone health and functional capacity are just some of the benefits that can be experienced by focusing on this one goal (3).

For women in particular, maintaining muscle function and bone health can be extra challenging. This is due to the rapid hormonal changes that occur as women experience menopause. The estrogen-levels of females decline sharply during menopause, usually as they approach their late 40s to early 50s. The decline of sex hormones is associated with loss of muscle mass and strength. In comparison, men also experience a decline in sex hormones although in a much more gradual and less abrupt fashion (4). The changes during menopause can further increase the age-related decline in muscle function and put women at a higher risk for developing both sarcopenia and osteoporosis. Hence, sarcopenia and osteoporosis are two conditions with considerable prevalence among postmenopausal women and can contribute greatly to the decline of muscle function in older women (5) (6).

Sarcopenia is a condition characterized by progressive loss of muscle mass, strength and performance (7). However, the world has not yet reached a consensus on the clinical definition of sarcopenia. This means that the cutoff thresholds for muscle mass and function used for diagnosis can vary wildly depending on the year and geographical location. In fact, a systematic review from 2019 (8), found that sarcopenia prevalence among community dwelling older adults vary from 9.9% to 40.4% depending on which definition was used.
In other words, depending on the region and point in time, adults of comparable health conditions could be classified differently. In 2018, the European Working Group on Sarcopenia in Older People (EWGSOP) released a paper updating the clinical definition of

sarcopenia (9). This is the definition that will be used in this review to determine whether the subjects in the original articles meet the requirements for sarcopenia.

Osteoporosis on the other hand is a systemic skeletal disease characterized by low bone mineral density and deterioration of bone tissue (10). It is the most prevalent disease in postmenopausal women and is estimated to affect one in three women over the age of 50 (6). Naturally, the risk of bone fractures increases substantially in women diagnosed with osteoporosis. Bone fractures in postmenopausal women are associated with low quality of life, immobility and increased mortality.

Obesity and overweight are two conditions that are also relatively common among adults and elderly worldwide. Resistance exercise has been shown to greatly improve both muscle strength and function in obese and overweight individuals (11). However, a study from 2015 found that beneficial adaptations from resistance training may be less pronounced in people with more adipose tissue (12).

In general, resistance exercise has been shown to increase muscle mass and function in humans (13). Various forms of resistance exercise can be implemented safely in both healthy women and women diagnosed with either sarcopenia, osteoporosis or obesity. Resistance training with the goal of strengthening muscle function can potentially benefit all these groups in similar ways, and slow down the natural or accelerated muscular atrophy and strength. Additionally, resistance exercise can improve functional capacity and mobility to lower the risk of bone fractures due to falls. Given the prevalence and nature of these conditions in postmenopausal women, it does not make sense to exclude them from this review.

Muscle function can be measured in a number of ways. One of the simplest and most useful metrics seems to be handgrip strength. The test is conducted using a dynamometer which measures the force development of each hand in kilograms. A grip strength test can be completed in a matter of minutes per person. The reason why it is the most common measure is because grip strength seems to correlate strongly to overall muscle function. As seen in the paper from the EWGSOP (9), handgrip strength is the very first test conducted in the process of diagnosing sarcopenia. However, grip strength is still just used as an indicator for overall muscle function. So if the rest of the muscles in the body are strong, the handgrip strength itself may be of less importance (14).

Therefore, this study will investigate resistance training's effect on muscle function in older women, using handgrip strength as the key metric. The threshold of 60 years was chosen to increase the chance that all participants have had their menopause. Will general resistance training, not geared specifically towards grip strength, increase grip strength in older postmenopausal women (60+ years) and improve their muscle function? Additionally, we will investigate whether something can be said about which method and intensity of resistance training seems most suitable for older postmenopausal women.

## Methods

The database used for the literature search was PubMed. The following keywords were used: *((resistance training* OR *weight training* OR *strength training* OR *resistance exercise)* AND *(healthy* OR *normal* OR *control* OR *healthy adults* OR *healthy participants* OR *sarcopenia* OR *osteoporosis)* AND *(grip strength* OR *handgrip strength)).*

### *Inclusion- and exclusion criteria*

PubMed provides filters integrated in the search engine. The following filters were checked off using this function: Free full text, clinical trial, randomized controlled trial, humans, english, female, 45-64 years, 65+ years and 80+ years.
The search resulted in 143 articles which were manually screened to further narrow down the search. Most of the 143 articles included mixed gender participants. These were excluded manually. Any article where the mean age minus the standard deviation was under 60 years, was excluded. All articles were also checked to confirm they included some form of resistance training intervention and a grip strength test both pre and post intervention.
All articles that included participants with serious medical conditions except for sarcopenia, obesity or osteoporosis, were excluded. All types of resistance training (resistance bands, bodyweight, free weights and machines) were deemed acceptable for this study. Ultimately, 10 articles were considered eligible for the purpose of this study.

## Results

10 studies [15-24] were included with a total of 572 participants. The group of subjects consisted of individuals with a mean age of 63 to 81 years. Some studies included individuals with different health conditions, namely sarcopenia, obesity and osteoporosis, while the other studies consisted of healthy participants. The studies had different aims and different control groups, but they all had one factor in common: at least one group that did resistance training (table 1). Among the 10 studies analyzed, eight exclusively focused on resistance training as the primary intervention, while the remaining two incorporated a nutrition or supplementation plan alongside resistance training.

The study by **Kim et al (2023)** (15) aimed to investigate the effectiveness of an intervention combining exercise and nutrition for treatment of spinal sarcopenia. The study included 26 women (mean age: 72.5 ± 4.0 years) diagnosed with spinal sarcopenia. All participants were put through the same intervention. The intervention lasted 12 weeks and consisted of bodyweight resistance exercises. The workout was performed 3 times per week, lasting 60 minutes each time. The program included 5 exercises focusing on abdominal and back extensor muscles. This was followed by a single squatting exercise for the legs. The training intensity was defined for each individual in the initial evaluation. Intensity was based on the number of repetitions and maintenance of time for each exercise. Every two weeks, the training intensity was increased by 20%. The handgrip strength (HGS) did not increase after the intervention. The baseline value for HGS was 22.1 ± 3.4 kg. Post intervention the HGS was measured as 22.2 ± 2.9 kg. However, the group showed significant improvement in three other tests relevant to muscle function. These tests measured gait speed, leg strength and balance.

**Valdés-Badilla (2023a)** (16) aimed to investigate the effect of exercise on functional performance in older sarcopenic women. In total, 40 sarcopenic women (mean age: 73.3 ± 8.4 years) completed the intervention. The women were randomized into two training groups: a resistance training (RT) group, and a dance group representing our control group (CON). The exercise period lasted for 12 weeks. The RT group used elastic bands, while the CON group attended dance classes. Workouts for both groups lasted for 60 minutes 3 times a week. The RT group performed 6 exercises for upper body and 6 exercises for lower body each session, working both big and small muscle groups. Each exercise was done for 2 sets close to failure or to failure. The RT group trained with an intensity of moderate to high. The CON group did dance activity with an intensity of moderate to high. For the RT group, HGS (dominant and non-dominant hand respectively) improved significantly from 16.3 ± 3.4 kg to 18.1 ± 3.2 kg (10.9 %), and 15.2 ± 3.1 kg to 16.7 ± 2.7 kg (10.2%). The CON group did not significantly increase HGS from 17.0 ± 3.5 kg to 16.9 ± 2.9 kg and 14.8 ± 2.0 kg to 15.3 ± 3.5 kg. The RT group improved in several other outcome measures, including fat-free mass and performance in walking and strength exercises. The CON group did not improve in any of these tests.

**Seo et al. (2021)** (17) aimed to investigate the effect of a bodyweight and elastic band resistance training program on muscle quality in older sarcopenic women. 22 sarcopenic women (mean age: 71.5 ± 5.4 years) completed the intervention. They were randomized into 2 groups: a resistance training (RT) group and a non-exercise (CON) group. The intervention lasted for 16 weeks, and the RT group exercised 3 times per week, for 60 minutes. The RT group did 19 exercises in a session. About 2/3 of them with elastic bands, and 1/3 with bodyweight, targeting bigger muscle groups. Number of sets per exercise varied between 3 and 5. Training intensity was increased progressively through the intervention period, starting at moderate and ending at high intensity. The RT group significantly increased HGS from 20.8 ± 2.9 kg to 24.3 ± 2.3 kg (+ 16.8%). The CON group decreased their grip strength significantly from 18.6 ± 3.1 kg to 17.3 ± 3.6 kg. The RT group also improved in several other tests measuring limb strength, gait speed and cardiorespiratory fitness. The CON group did not improve in any of these tests and even decreased performance in some.

**Stojanović et al. (2021)** (18) aimed to examine the effects of low-load resistance training on functional fitness and metabolic biomarkers in older women. 168 older women (mean age: 75.3 ± 8.4 years) completed the intervention. They were divided into two groups: a resistance training group using elastic bands (RT), and a control group (CON), who were asked to behave as normal. The RT group exercised twice weekly for 12 weeks. The resistance training program was designed with the general goal of maintaining internal load over time, achieved by progressively increasing intensity through the use of various elastic bands. 12 exercises were done: 5 for upper body, 5 for lower body and 2 for core, with 2 sets per exercise. The RT group performed exercises at moderate intensity. HGS in the RT group increased significantly from 32.6 ± 15.2 kg to 37.1 ± 16 kg (+ 13.8%). In the CON group, HGS did not significantly increase from 38.1 ± 17.7 kg to 38.5 ± 17.9 kg. The RT group also significantly increased all other functional fitness tests: 6 tests measuring strength, dynamic balance, cardiovascular fitness, and flexibility. The CON group also increased 3 of these tests significantly: strength and cardiovascular fitness.

**Kim et al. (2022)** (19) aimed to investigate the effect of resistance exercise training program on body composition, bone mineral density, functional fitness and isokinetic muscle strength. The study included 40 obese women (mean age: 80.6 ± 4.9 years) who were split into a resistance training group (RT) and a control group (CON). The intervention lasted 24 weeks. The RT group did 15 different exercises with elastic bands, which they performed for 60 minutes 2 times per week: 8 exercises for upper body, and 7 for lower body, 3 sets per exercise. The sessions were performed at moderate to high intensity which was increased progressively every 4 weeks. The CON group did not exercise during the intervention. HGS for the RT group increased significantly from 21.2 ± 3.5 kg to 22.9 ± 3.3 kg (+ 8.0 %), whereas the HGS in the CON group did not significantly change from 19.8 ± 4.3 kg to 19.0 ± 3.5 kg. The RT group also increased lower body strength, while the CON group measured negative changes in lower body flexibility, upper body strength, agility and dynamic balance.

**Piastra et al. (2018)** (20) aimed to evaluate the effects on muscle mass, strength, and static balance of the training programs. 72 sarcopenic women (mean age: 70.0 ± 2.8 years), were divided randomly into 2 groups: one free weight resistance training group (RT) and one bodyweight resistance training, balance and mobilization group (CON). The intervention lasted for 39 weeks and the groups exercised twice a week for 60 minutes each session. The specific exercises were not described in detail in the study, but the exercises in the RT group covered the whole body, and the exercises in the CON group covered hips, trunk, shoulders and neck. The training intensity for the RT group was low to moderate, while for the CON group it was not described. HGS increased significantly in the RT group, from 17.8 ± 4.9 kg to 19.9 ± 5.2 kg (11.3%), while the HGS results in the CON group did not change significantly: 17.8 ± 5.3 kg to 17.6 ± 4.9 kg. The RT group also significantly increased lean mass values, skeletal muscle mass, and balance. The CON group only increased some balance values, but not as much as the RT group, despite exercising more balance than the RT group.

**Lee and Directo (2023)** (21) investigated the effect of resistance training compared with resistance training and fish oil supplementation. 20 healthy women (mean age: 65.7 ± 3.4 years) were randomly assigned to either a resistance training group with placebo supplementation (RT) or a resistance training group with fish oil supplementation (CON). The intervention lasted 8 weeks and both groups did the same workouts. They exercised twice per week for 8 weeks, with 3 exercises for upper body, and 2 exercises for lower body. The exercises were done for 3 sets until failure. The length of the training sessions were not mentioned in the study. The exercise program was performed at moderate to high intensity. The RT group's HGS results did not change significantly: 20.4 ± 4.0 kg to 20.8 ± 4.3 kg, while the CON group significantly increased their HGS results from 20.9 ± 3.9 kg to 22.1 ± 4.0 kg (5.74%). Both groups increased the results on leg strength tests and activities of daily living tests.

**Valdés-Badilla (2023b)** (22) aimed to investigate the effects of an adapted taekwondo program concerning multicomponent training. 28 women (mean age: 63.0 ± 2.4 years) were randomized into 2 groups: one multicomponent training group (RT), and one taekwondo group (CON). The intervention lasted for 8 weeks. Both groups exercised 3 times per week with a duration of 60 minutes each session. The RT group did a circuit style resistance training program targeting the whole body using both bodyweight, free weights and elastic bands as resistance. Each exercise was performed for 3-4 sets. The CON group performed basic martial arts based choreography both individually and in pairs. The exercise programs for both groups were performed at moderate to high intensity. HGS did not increase significantly in either of the groups. The RT group results were 22.2 ± 3.6 kg to 23.1 ± 3.1 kg (right hand), and 23.0 ± 3.6 kg to 23.3 ± 2.3 kg (left hand). The CON group results were 22.1 ± 3.4 kg to 23.0 ± 2.9 kg (right hand), and 20.6 ± 3.7 kg to 22.0 ± 3.1 kg (left hand). The RT group did not improve any tests significantly. The CON group improved the results in several tests, including flexibility, strength and cardiovascular fitness.

**Nahas et al. (2019)** (23) aimed to investigate the effect of a moderate increase in protein intake on different health outcomes in women following resistance exercise. 47 women (mean age: 63.3 ± 7.5 years) were randomized into a normal protein group (RT), and a high protein group (CON). Both groups did the same resistance workouts, lasting 10 weeks. The workouts were done for 60 minutes, 3 times per week, and the women did the sets close to failure. The number of sets were increased during the 6 first weeks (from 1 to 6 sets), while weight load was increased the following weeks. The exercise program was performed at moderate to high intensity in both groups. The workouts included 5 exercises for upper body and 3 exercises for lower body. Machines and free weights were used. The RT group increased HGS significantly from 25.5 ± 1.0 kg to 27.3 ± 1.0 kg (+7.1 %) (right hand), and from 23.7 ± 0.9 kg to 25.3 ± 1.0 kg (+ 6.8 %) (left hand). The CON group also increased their HGS significantly from 26.6 ± 1.0 kg to 30.3 ± 0.9 kg (+ 13.9%) (right hand) and from 24.0 ± 1.1 kg to 26.2 ± 0.9 kg (+ 9.2%) (left hand). Both groups demonstrated similar improvements in strength tests and daily activities, with some additional benefits observed in the CON group.

The aim of the study by **Stanghelle et al. (2020)** (24) was to measure walking speed of women with osteoporosis. 128 women participated in the study (mean age: 74.2 ± 5.8 years). They were randomized into two groups: an intervention group (RT) and a control group (CON). The intervention lasted for 13 weeks, and the RT group did resistance and balance exercises. Participants in the CON group were asked to live their life as usual. The main muscles worked in the RT group were back extensors and upper arm muscles. The workout was performed 2 times per week and lasted for 60 minutes each session. The workout included 8 different strength and balance exercises for the whole body, 4 for the upper body and 4 for the lower body. They used elastic bands, free weights and bodyweight as resistance. The exercise program was performed at moderate intensity. The RT group did not increase HGS significantly from 21.6 ± 4.7 kg to 21.2 ± 4.9 kg. The CON group did not increase HGS significantly from 22.3 ± 5.4 kg to 21.6 ± 4.5 kg. The RT group did not improve walking speed, but showed significant improvements in balance, arm strength, leg strength and mobility compared to the control group.

***Table 1***: *Original articles overview.*

| Article | Mean age (years) | *n* | Health status | Mean baseline HGS value and fitness level for RT group (low, moderate, high) | Training period Frequency per week (m/w) Resistance type | HGS Change in RT group |
|---|---|---|---|---|---|---|
| **Kim et al. (2023)** | 72.5 ± 4.0 | 26 | Spinal sarcopenia | Moderate 22.1 kg | 12 weeks **3 x 60 min** BW | = |
| **Valdés-Badilla et al. (2023a)** | 73.2 ± 8.4 | 40 | Moderate sarcopenia | Low 15.7 kg | 12 weeks **3 x 60 min** EB | ↑ **10,6 %** |
| **Seo et al. (2021)** | 71.5 ± 5.4 | 22 | Mild sarcopenia | Moderate 20.8 kg | 16 weeks **3 x 60 min** FW and EB | ↑ **16,8 %** |
| **Stojanović et al. (2021)** | 75.3 ± 8.4 | 168 | Healthy | Good 32.6 kg | 12 weeks **2 x 60 min** EB | ↑ **13,8 %** |
| **Kim et al. (2022)** | 80.5 ± 4.9 | 30 | Obese | Moderate 21.2 kg | 24 weeks **2 x 60 min** EB | ↑ **8,0 %** |
| **Piastra et al. (2018)** | 70.0 ± 2.8 | 66 | Moderate sarcopenia | Moderate 17.8 kg | 39 weeks **2 x 60 min** BW and FW | ↑ **11,3 %** |
| **Lee and Directo (2023)** | 65.7 ± 3.4 | 20 | Healthy | Moderate 20.4 kg | 8 weeks **2 x (undisclosed)** FW and M | = |
| **Valdés-Badilla et al. (2023b)** | 63.0 ± 2.4 | 25 | Healthy | Moderate 22.6 kg | 8 weeks **3 x 60 min** BW, EB and FW | = |
| **Nahas et al. (2019)** | 63.4 ± 2.6 | 47 | Healthy | Good 24.6 kg | 10 weeks **3 x 60 min** FW and M | ↑ **6,9 %** |
| **Stanghelle et al. (2020)** | 74.2 ± 5.8 | 128 | Osteporosis | Moderate 21.4 kg | 13 weeks **2 x 60 min** FW and BW | = |

*Abbreviations: BW: Bodyweight EB: Elastic bands FW: Free Weights M: Machines*

*Low fitness level: HGS below 16 kg (defined as sarcopenia). Moderate fitness level: HGS between 16 and 23.9 kg. High fitness level: HGS 24 kg or higher*

## Discussion

6 out of 10 RT groups measured an increase in HGS after the intervention. In 1 out of 4 studies, the RT group did not show an increase in HGS, but the CON group did. This CON group did resistance training as well. 7 out of 10 articles included a group that improved HGS after a resistance exercise period, which indicates that resistance exercise can have a good effect on HGS. This will be further investigated below.

### *Baseline strength level*

The magnitude of strength adaptations to resistance training seems to be dependent on a person's baseline level of strength and training experience (25). With regards to resistance training, inexperienced individuals can potentially expect faster and greater strength adaptations compared to the more experienced individuals. It was difficult to assess the training experience of the participants in the 10 studies. However, baseline HGS values were used to get a rough idea of strength level and experience.

The average baseline level of HGS varied from 15.7 kg to 32.6 kg. The studies by Valdés-Badilla et al. (16) and Piastra et al. (20) measured the lowest baseline HGS values of its participants by a good margin. Both of these studies showed great significant increases in HGS post-intervention. This supports the idea that the most frail individuals can have a lot to gain by implementing resistance training in their daily life. One of the four studies that measured the greatest increase in HGS post-intervention did however demonstrate the strongest mean baseline HGS value. This highlights that baseline strength level and training experience are definitely not the only factors to consider. Moreover, our way of assessing training experience is limited and flawed. This is because HGS is just a small part of overall strength and fitness. In addition, the HGS values are absolute and not relative to body weight. Strength levels relative to body weight could potentially be a more accurate representation of strength and fitness level.

### *Age difference, health status and comparability*

The mean age varies from approx. 63 to 81 years in the different studies. Healthy participants in our studies were defined as being independent with no orthopedic or debilitating conditions that could compromise the adherence to the interventions. The studies with the youngest and healthiest participants seem to achieve the weakest strength gains overall. This observation supports the findings in the previous paragraph about baseline strength. One exception to this was the study by Stojanović et al. (18) which produced the second best result in terms of HGS gains. The subjects in this study were classified as healthy and also had the greatest baseline HGS of any study in our review. This again points to other factors that could be of more importance than age and baseline strength and fitness.

For classification of sarcopenia in our review, the revised document from 2018 (9) was used as the reference. Only the study by Valdés-Badilla et al. (16) used these classification criteria for sarcopenia. While both studies by Seo et al. (17) and Piastra et al. (20) used the outdated version from 2010 (7) as their reference for sarcopenia classification. Upon further investigation it seems most participants in these studies still qualify for the diagnosis of sarcopenia. However, it is possible some of the subjects in these studies would be defined as healthy by today's standards. Spinal sarcopenia is in its own category and does not fall under the guidelines from the EWGSOP.

In 3 out of 3 studies with sarcopenic participants, there was measured a significant increase in HGS post-intervention. The RT group in these studies also improved in other tests measuring limb strength and gait speed. The studies that investigated healthy, obese and osteoporotic individuals did not produce as convincing improvements in terms of overall muscle function. This again highlights the profound benefits the most frail individuals can experience from incorporating more resistance exercise in their lives.

***Volume, intensity and training forms***

The length of the intervention seems like it may have an effect on HGS. The three longest interventions all observed improvements in HGS, while 4 of the 7 shortest did not. The 7 shortest interventions all had lengths of 8 to 13 weeks, while the three longest had lengths of 16, 24 and 39 weeks. The two shortest interventions, both at 8 weeks, observed no improvement in HGS. This may suggest that longer resistance training periods increase the chance of improvement in muscle function.

To consider the total volume in the different studies, not only the length of the intervention matters. Our study has chosen to consider the number of sets and exercises per workout and week, as a measure of the volume. The number of repetitions has been thought to have a smaller effect, because similar repetition ranges were used in the different studies. 6 of the 10 studies have disclosed the number of sets and exercises. The total number of sets per week in these studies varied from 30 to 214. Among these, all, except the one with the value of 30 sets per week measured an increase in grip strength. The one with 214 sets, Seo et al. (17), was the one that measured the highest increase in HGS: 16.8 %. This indicates that the number of total sets per week could have an effect on strength adaptations.

The intensity levels of the RT groups varied somewhat between the studies. 4 of the 6 studies with moderate to high, had an increase in HGS. 1 of 2 studies with moderate intensity measured an increase in HGS. The only study with low to moderate intensity measured an increase, while the study with individualized intensity did not measure an increase in HGS. This might suggest that higher intensity gives a somewhat higher HGS result, but at the same time there are several inaccuracies with these protocols, and with our interpretation of the intensities. Several studies indicate the intensity levels by themselves, while some studies use different scales for perceived intensity. In addition, some studies increased their intensity during the intervention, which makes it difficult to conclude what type of intensity level they used. The only study with low to moderate intensity, Piastra et al. (20), measured an increase in HGS. This is contraindicating to the thought that higher intensity will give better results. At the same time, the RT group in this study had the second lowest baseline level, and the effect from resistance training may therefore be obtained easier (25).

All studies investigated 4 different types of resistance training: bodyweight, elastic bands, free weights and machines. Among these, there were four studies that included bodyweight exercises in their intervention, with only one of them showing an increase in HGS. The groups that used elastic bands showed improvements, with a majority experiencing an increase in HGS. Those using free weights also showed a positive improvement, though to a less extent. Two studies used machines during their interventions, and one of them showed an increase in HGS. It appears that bodyweight training may have the lowest probability of increasing HGS. However, it is still relevant to mention that participants engaging in bodyweight exercises showed improvement in other tests. This might be due to the fact that these exercises usually do not require grip strength, or that bodyweight exercises might be more difficult to progressively overload. Elastic band training is the one with most success on muscle function. This could be because it is simple to gradually increase resistance just by adjusting the grip width on the band, or that using an elastic band requires HGS. Therefore, depending on the frailty of the trainees, elastic band resistance exercise is often the best way to get started. It is worth mentioning that 6 of the 10 studies used different types of resistance, and if all of the studies had only been using one type, they might have been easier to compare.

Handgrip was not required for all exercises across the studies. Almost none of the exercises from the study by Kim et al. (15) required hand gripping, and did not observe an increase in HGS. Three studies (Piastra et al. (20), Stanghelle et al. (24), Valdés-Badilla et al. (22)) used HGS in some exercises, and only one of them observed an increase in HGS. Of the last six studies, where most exercises involved hand gripping, five of them observed an increase in HGS. This suggests that doing exercises that require hand gripping improves HGS more than doing exercises that do not need it. This also highlights the weaknesses of using HGS as an indicator for overall muscle function. HGS can be increased by specific training that does not necessarily translate to improved muscle function in the rest of the body.

***Variations in hand dynamometers***

The tool used to measure HGS is a hand dynamometer. There are several different brands available but they all measure grip strength in kilograms. There is a variation between which equipment and protocols each study uses to assess HGS. In 5 of the studies they used the "Jamar" hand dynamometer by Sammons Preston which is the most commonly used tool, known for its consistent reliability in repeated tests. The other 4 studies used different dynamometers: 'Takei 5001' in three studies and 'Camry EH101' in one. The dynamometer in the last study was not specified. Since they used different hand dynamometers it can influence the compatibility and reliability of the results across the studies. It also can lead to various protocols for testing HGS, which include differences in grip technique, number of trials or which hands are tested. This can make it difficult to compare results between different studies.

***Secondary outcomes***

Because HGS is considered a good measurement of muscle function, it is intuitive to think that the studies that measured an increase in HGS also measured increases in secondary outcomes. This is partly the case. The results of the secondary outcomes were on average a bit better in the studies that measured increases in HGS, but the results varied a lot among the studies. This variety might be due to the fact that they measured different tests. The most relevant tests to compare HGS with might be other strength tests. Most of the studies measured lower body and upper body strength. Many studies measuring improvements in lower body strength also measured increases in HGS. However, this relation was not observed in upper body strength. This variety in strength results can indicate that different tests give different outcome results depending on what has been exercised in the intervention, and not that any strength tests are necessarily better than others.

### *Implications and limitations*

The training interventions are generally poorly described, and therefore difficult to replicate. Their intensities are also difficult to analyze. If the training interventions were described in more detail, it would have been easier to compare them. Additionally, one study had one group, which makes it difficult to analyze the results. Several studies included two training groups instead of a training group and a non-training group. Having a non-training group could have given more conviction to the results of the RT groups. As mentioned earlier, the different HGS measurement equipment may be a limitation. If all the studies had been using the same equipment, the results could have been more reliable.

## Conclusion

The investigation of resistance training's effect on muscle function in older women revealed several findings. The first is that the majority of the interventions led to increased HGS, particularly among frail individuals with lower baseline HGS values. Longer training periods and higher volume of sets per week had a positive effect on increases in HGS. Exercises that involved using hand gripping during the intervention were better at increasing HGS compared to exercises that did not involve hand gripping. On the other hand, age and the type of resistance training had limited impact on the primary outcome. However, HGS alone may not fully represent overall strength, as seen in the variation of secondary outcomes. Limitations such as poorly described interventions and the absence of control groups underscore the need for more standardized protocols to easier compare the studies. To conclude, the most important factors for improving muscle function seem to be intervention length, number of sets per week, baseline strength and fitness level.

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