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The Effect of Power Training on Neuromuscular Performance in the Elderly: A Systematic Review

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Mehmed Akif Yoldas Bakk.rer.nat.

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Abstract

Increasing life expectancy and an aging population pose challenges to society and healthcare systems. One of the earliest age-related declines occurs in muscle power, a key determinant of functional independence in daily life. Training methods that emphasize the rapid production of force are therefore of particular interest within sports science and health promotion. Yet, research in this field remains inconsistent, with considerable variation in protocols, loads, and outcome measures, underscoring the need for systematic evaluation. To examine the effects of power-oriented training on neuromuscular function in the elderly, a systematic review was performed using the databases PubMed, Web of Science, Sports Discus, CINAHL, and Scopus. Out of 6,143 identified records, 17 studies met the inclusion criteria. The results demonstrate that power training has strong effects on peak power, mean power output, rate of torque development, one-repetition maximum, and three-repetition maximum strength. Moderate to low effects were observed for physical performance parameters and muscle activation outcomes including electromyographic activity, rate of torque development and rate of force development. Future studies should apply standardized training and testing protocols. Furthermore, assessments of physical performance parameters should be aligned with tasks of daily living to ensure physical relevance.

Kurzzusammenfassung

Die steigende Lebenserwartung und die alternde Bevölkerung fordern Gesellschaft und Gesundheitssystem heraus. Mit zunehmendem Alter kommt es zuerst zur Abnahme der muskulären Leistungsfähigkeit, die ein wichtiger Parameter für Unabhängigkeit im Alltag darstellt. Trainingsmethoden, die eine schnelle Kraftentwicklung fokussieren, sind daher im Interesse der Sportwissenschaft und der Gesundheitsförderung. Durch eine große Variabilität der Trainingsprotokolle, Gewichte und Ergebnisparameter ist die Forschung in diesem Bereich inkonsistent und verdeutlicht den Bedarf an einer systematischen Bewertung der vorhandenen Daten. Um den Effekt einer Schnellkrafttraining-Intervention auf die neuromuskuläre Leistungsfähigkeit bei älteren Menschen zu bestimmen, wurden die Datenbanken PubMed, Web of Science, Sports Discus, CINAHL und Scopus durchsucht. Von insgesamt 6.143 identifizierten Studien haben 17 die Einschlusskriterien erfüllt. Die Ergebnisse demonstrieren, dass eine Schnellkrafttraining-Intervention deutliche Verbesserungen der Maximalleistung, der mittleren Leistungsfähigkeit, der Rate der Drehmomententwicklung, des Ein-Wiederholungs-Maximum und des Drei-Wiederholungs-Maximum zeigt. Moderate bis geringe Effekte konnten auf die physischen Leistungsparameter und auf muskuläre Aktivierungsgrößen wie der elektromyographischen Aktivität, der Rate der Drehmomententwicklung und der Rate der Kraftentwicklung gezeigt werden. Zukünftige Forschungsarbeiten sollten standardisierte Trainings- und Testprotokolle nutzen. Zudem sollten sich physische Leistungsparameter an alltäglichen Aufgaben orientieren, um die praktische Aussagekraft der Ergebnisse zu verbessern.

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Preface

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1 Introduction

It is well known that aging is associated with degenerative processes in living creatures. Sarcopenia, recently described as a loss of skeletal muscle function, primarily muscle strength (Sayer & Cruz-Jentoft, 2022), and osteoporosis are among the most significant degenerative processes in the musculoskeletal system of humans, leading to major restrictions in quality of life later in age (Marzetti et al., 2017; Silverman, 2005). Given the worldwide decrease in fertility rates and increase in life expectancy, Lunenfeld (2008) predicts that by 2050, there will be more people on earth over the age of 65 than under the age of 15 for the first time in human history. Thus, with this demographic shift to an older population, it is crucial to delay the onset of these degenerative processes, since immobility due to diseases or a physical inactive lifestyle accelerates the degenerative processes of the musculoskeletal system which happens primarily due to endocrinological changes (Das et al., 2023; Tarantino et al., 2013; Tournadre et al., 2019). The consequences of this demographic shift and additionally with an increased life expectancy, pose a threat in the form of gait-related falls. A publication on arzteblatt.de analysed the incidence of fractures over a 10-year period from 2009 to 2019 within the aged population in Germany. According to the paper on arzteblatt.de, the incidence of fractures increased overall by 14% in 2019 compared to 2009 (Rupp et al., 2021). Moreover, it was observed that 59% of all fractures occurred in the age group over 70 years and the fracture with the highest incidence was the femoral neck fracture (Rupp et al., 2021). To illustrate the magnitude of the problem, the incidence of femoral neck fractures in 1990 was 1.66 million and is estimated to be 6.26 million in 2025 (Cooper et al., 1992; Dhanwal et al., 2011). This trend presents significant challenges that must be addressed in the future because a femoral neck fracture is a critical incident for the elderly. The mortality rates for a year after trauma resulting in a femoral neck fracture range from 14% to 58% (Mundi et al., 2014; Schnell et al., 2010). In addition, the quality of life of the patients is threatened by the loss of mobility and autonomy right after the trauma or as a permanent loss (Mukka et al., 2017). Besides social isolation as a consequence, the neck fractures are a big cost for the healthcare system (Ossendorf et al., 2010; Tidermark, 2003). Therefore, interventions are needed to maintain a healthy musculoskeletal system as long as possible to address the threats mentioned above with aging. A global prevalence of 10–16% for sarcopenia among elderly was recently reported by Yuan & Larsson (2023) in their meta-analysis. Although degenerative processes in the neuromuscular system occur earlier, the human body seems to compromise due to collateral reinnervation, resulting in undetected strength losses in daily life (Power et al., 2013). While muscle power is defined as the product of force and velocity, it has been demonstrated that initially loss of muscle power occurs in life and to a greater extent, about twice the rate of muscle strength (McKinnon et al., 2017; Radaelli et al., 2023). In addition, many reviews stated that muscle power is more significant in the functional capacity of humans compared to muscle strength (Guizelini et al., 2018; McKinnon et al., 2017; Radaelli et al., 2023; Rice & Keogh, 2009). McKinnon et al. (2007) recorded that the decline of muscle power during aging explains reduced mobility in combination with increased risk of falls.

Besides sarcopenia, additional morphological changes in the aging muscle such as replacing contractile with non-contractile elements for example adipocytes and connective tissue instead of sarcomeres (Overend et al., 1992) results in a decrease in cross sectional area, the volume and sarcomere length of the muscle (Morse et al., 2005; Narici et al., 2003) and in an insufficient myosin functioning (Hunter et al., 2016; Power et al., 2013). Coupled with decreasing tendon stiffness in elderly (Narici et al., 2008), these changes in muscle composition is affecting power output negatively (McKinnon et al., 2017).

One essential element of this systematic review is to investigate the changes in neuronal activation of muscle during aging and to detect its effect in the ability to generate power. It has been indisputably reported that aging is associated with loss of alpha motor neurons (Allen et al., 2021; McKinnon et al., 2017; McNeil & Rice, 2018; Power et al., 2013; Vandervoort, 2002). Although, the central and peripheral nervous system is affected differently. For example, it has been shown that cortical neurons suffer a reduction in volume up to 43% (Haug & Eggers, 1991) and a decrease in myelination which results in disturbed integrity (Marner et al., 2003). However, the peripheral nervous system is characterized by a significant loss of motor neurons. Furthermore, the destruction of Schwann cells due to a lack of protein expression over time leads to bigger Ranvier nodes with the result of a decrease in conduction velocity of action potentials in the alpha motor neuron (Delbono, 2003; Jang & Van Remmen, 2011; Rivner et al., 2001; Vandervoort, 2002) . Additionally, the innervation speed of muscle fibres is reduced due to the preferred destruction of alpha motor neurons which innervate fast twitch muscle fibres (McKinnon et al., 2017; McNeil & Rice, 2018; Power et al., 2013). Power et al. (2013) and Allen et al. (2021) stated that the loss of motor neurons is compensated by collateral reinnervation, resulting in a single alpha motor neuron innervating more fibres with slower innervation rates. Since, the alpha motor neurons which compensate are typically alpha motor neurons of slow twitch fibres

(McKinnon et al., 2017; McNeil & Rice, 2018; Power et al., 2013). Thus, neuromuscular junctions of these compensating alpha motor neurons have decreased acetylcholine concentrations in the neuronal endplate which affects the transmission of the action potential (Allen et al., 2021). Besides that, power output is influenced duo to wiring at spinal level (McKinnon et al., 2017). During the transmission of the first neuron of the pyramidal tract to the alpha motor neuron on spinal level, interneurons inhibit alpha motor neurons of the antagonist muscle groups. The loss of function of the inhibitory alpha interneuron leads to so called agonist-antagonist co-activation (Hortobágyi et al., 2009; Hortobágyi & DeVita, 2006; Monaco & Micera, 2012; Schmitz et al., 2008), resulting in a decreased capacity for generating power because of simultaneous co-activation of the antagonist muscle group. However, McKinnon et al. (2017) stated that antagonist co-activation could provide joint stability for elderly.

Therefore, to address the potential risks of aging mentioned above it is necessary to provide precise interventions such as power training for elderly. Radelli et al (2023) points out that despite much scientific evidence (over 300 articles) which is showing the effectiveness of power training, it plays a minor role in practise. Additionally, Radelli et al. (2023) concludes that power training is safe to practise with the elderly. Thus, the argumentation that resistance training is safer compared to power training is proven to be false. A recent review of Bandeira-Guimaraes et al. (2023) investigated the effect of different intensities of power training on neuromuscular parameters in older people to provide some guidelines for power training interventions. They have shown that low-to-moderate intensities of power training have similar effects on increasing power output compared to high-intensity power training. However, Bandeira-Guimaraes et al. (2023) only included three studies in their review and assessed peak power exclusively as outcome variable. The purpose of this systematic review is, to provide more knowledge on the effects of power training on neuromuscular functions in the elderly to contribute to a wider implementation of power training as an intervention to tackle the problems emerging with the demographic changes in the 21st century.

It has been shown that muscle power correlates with functional capacities later in age compared to pure muscle strength (Bandeira-Guimarães et al., 2023; Radaelli et al., 2023). Furthermore, it has been shown that muscle power, as a product of strength and velocity, decreases at an early onset in age (McKinnon et al., 2017; Power et al., 2013; Radaelli et al., 2023). Despite much scientific evidence of the effectiveness of power training interventions in the elderly (Radaelli et al., 2023), it is poorly implemented in practice compared to strength training interventions in the elderly. Thus, there is a need to answer why muscle power training interventions are not implemented in practice, since it has been shown to be as safe as strength training for elderly. Furthermore, there is a need for guidelines and instructions for power training interventions in the elderly to prevent current problems and the danger of future demographic threats mentioned above. The purpose of this systematic review is to provide knowledge on the effects of power training in neuromuscular performance in the elderly, resulting in a better understanding of the neuromuscular effects of power training in the elderly to provide a better understanding for improving the implementation of muscle power training interventions

2 Methods

This systematic review is written following the guidelines of Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement of 2020 (Page et al., 2021).

2.1 Eligibility criteria

To answer the purpose of this systematic review, accurate inclusion and exclusion criteria are required. Thus, a definition of power training is necessary to validate the results of this systematic review, since the effectiveness of a power training intervention is investigated. In the methods section (2.6), there is an extra passage which defines power training. The following inclusion criteria are defined for this systematic review: All studies in this systematic review are randomized controlled trails (1). Randomized controlled trails are the gold standard of interventional studies; hence, this criterion is required to give this systematic review significance. Studies performed with humans over the age of 60 with no limitations regarding diseases or fitness level will be included (2). Since the incidence of illnesses in the elderly population increases, it was not a reason for exclusion. Additionally, there were no requirements for the fitness level because it can vary in the older population. The intervention must meet the criteria for power training as mentioned above (3). The primary outcome of the included studies must be a neuromuscular performance parameter (4), which will be measured at baseline, post-intervention and compared to controls. Furthermore, all studies which assess the same outcome parameters will be grouped, to ensure comparability. To be included, studies need to be written in English (5) and must be available in full text (6). Additionally, the included studies must comply with scientific guidelines, otherwise they will be excluded for poor reporting (7). Therefore, all studies which do not meet the inclusion criteria will be excluded. The following criterion is determined for exclusion: all studies which have performed combined training interventions consisting of power training and an additional training modality, for example balance exercises, resistance, or endurance training, will be excluded (8). Additionally, studies with an adaptation period over a certain period will be excluded if the adaptation period consists of a non-power training protocol (9). However, studies with a short familiarization period will be tolerated since they prevent injuries in a population consisting mostly of the elderly without participation in resistance training. Furthermore, studies with a crossover design will be excluded from this systematic review (10). Home-based training interventions will be excluded (11) because a high-quality intervention, especially a power training intervention, needs to be supervised. On the one hand, in the majority of the interventions, participants were verbally motivated by the instructors since they performed the concentric phases of the exercises as fast as possible, on the other hand, the instructors reviewed the proper execution with the right intensity. Studies which assessed acute responses to one session of power training, or studies with no intervention, will be excluded (12). Furthermore, studies which assessed the effectiveness of a power training intervention on participants with an additional supplementation, for instance vitamins or certain protein diets, will be excluded (13). Thus, this could be a potential bias as a confounding variable. As mentioned above, only randomized controlled trials will be included. Furthermore, randomized controlled trials which compare two different intervention modalities such as power and classical resistance training will be excluded, if there is no additional control group (14). Therefore, a comparison of the outcome parameters between a power training intervention and control group is necessary. Additionally, two studies which investigated the same population with the same outcome parameters will be excluded (15). To ensure a better overview, the criteria listed above were summarized into meta-criteria. The criterion relating to study language (5), available in full text (6), and poor reporting (7) are summarized as meta-criteria (1). Criteria relating to participants, such as age (2) and supplementation (13), belong to meta-criteria (2). Additionally, all criteria relating to study design, for instance, randomized controlled trial (1), neuromuscular outcome parameter (4), crossover design (10), same population (15) and no control group (14) are summarized as meta-criteria (3). Finally, the remaining criteria which relate to the intervention, for example, power training intervention (3), combined training (8), adaptation period (9) and home-based training (11) are assembled into meta-criteria (4). The actual number of excluded studies for each meta-criterion is listed in the PRISMA Flow Diagram. However, more detailed information about the number of the excluded studies in the original criteria is given in the study selection section.

2.2 Information sources & search strategies

In the context of this systematic review, the following databases, like PubMed, Web of Science, Sports Discus, CINAHL, and Scopus will be examined for articles which fit the inclusion criteria. First, an initial search was conducted after a search string was generated based on similar literature and the MeSH database in PubMed. The initial search resulted in 4,371 matches in all five databases. After revising the search string, by adding additional keywords, a final search was conducted in all five databases with 6,143 findings (PubMed n = 511; Web of Science n = 673; Scopus n = 1,830; CINAHL n = 1,671; Sports Discus n = 1,419). The following search string was used in the final search in all five databases:

(“explosive power training” OR "high-speed power training” OR “high velocity power training” OR “explosive resistance training” OR "explosive-type resistance training” OR "high-speed resistance training” OR “high velocity resistance training” OR “power oriented resistance training” OR “explosive strength training” OR "explosive-type strength training” OR “high velocity strength training” OR “power oriented strength training” OR “power training” OR “muscle power” OR “plyometric training”) AND ("older adults" OR "seniors" OR "elderly" OR "aging population") AND ("neuromuscular performance" "neuromuscular junction" "neural adaptation" "neural drive" "neural innervation" "neuronal function" OR “nervous system” "musculoskeletal performance" OR "physical performance" OR "motor performance" OR "functional capacity" OR "muscle strength" OR "muscle mass" OR "muscle activity" OR "muscle power" OR "maximal dynamic strength" OR “contractile velocity” OR "muscle morphology" OR “muscle fiber” OR “neuroplasticity”)

The search in PubMed, CINAHL and Sports Discus was performed without any filters or limitations. In contrast the search in Scopus and Web of Science was filtered by language (English). In addition, the type of results in Web of Science were filtered to article type. Furthermore, 39 additional studies were screened for inclusion from reference lists of relevant studies and reviews. Thus, a total of 6,143 articles were screened for this systematic review for inclusion.

2.3 Study selection & data collection

All 6,143 articles were extracted from the databases where search was performed into Zotero (version 6.0.36). Next, Zotero was used to remove duplicates. Zotero detects duplicates automatically while the removing process was performed manually by actively removing the duplicates. Subsequently, a second screening for duplicates was performed by the author for duplicates that were not recognized automatically by Zotero. Thus, this resulted in 1,384 total duplicates being removed from the results. The remaining 4,759 records were screened by the author with the following steps. First, the title was screened and if the record was not excluded, the abstract was assessed for eligibility according to the criteria mentioned above. During this screening process of the title and abstract, 4,105 records were excluded, which left 654 records for full-text screening. Subsequently, 637 records were excluded during full-text assessment which left a total of 17 records meeting the inclusion criteria (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008; Lee et al., 2011; Lopes et al., 2014, 2016; Pazit et al., 2018; Reid et al., 2008; Richardson et al., 2019; Sañudo et al., 2019; Sayers et al., 2016; Sayers & Gibson, 2010, 2014; Webber & Porter, 2010). The eligibility criteria, mentioned above in detail, are categorized into four meta-criteria. The number of exclusions according to the meta-criteria and the overall selection process can be seen in the PRISMA Flow Diagram below. Since the number of excluded records in the sub-criteria is not shown in the PRISMA Flow Diagram, it will be listed here for completeness. Excluded records listed by criteria: (7) poor reporting (n = 5), (8) combined training (n = 48), (9) adaptation period (n = 2), (10) crossover design (n = 8), (11) home-based (n = 7), (13) supplementation (n = 7), (2) under the age of 60 (n = 86), (14) no-intervention control group (n = 56), (3) no power training intervention (n = 249), (1) no randomized controlled trial (n = 87), (4) outcome parameter (n = 3), (5) language (n = 19), (6) not available in full text (n = 34) and (15) same population (n = 3).

The data collection process started with generating an Excel spreadsheet with detailed information about the population, intervention, and results reported in the records. This process was performed by the author. The 17 studies that met the inclusion criteria were screened to extract relevant information for the Excel spreadsheet. The following information about the population was extracted from the studies: age of the population, the sex of the participants, the BMI of the population, and the size of the sample. Additionally, a short description of the sample was composed according to the information given in the methods section of the studies about the population. Furthermore, the following data was collected about the training intervention performed: the equipment used in the intervention, the intensity of the exercises performed, the frequency, and period of the training sessions performed. In addition, a short description of the training session was composed according to the information given in the methods section of the studies. All collected information can be seen in Table 1. In case of missing information, for example if a study did not report the BMI of the participants, it was calculated from the given data if possible. Detailed information on all values can be found in Table 1. Studies were grouped according to the outcome measures assessed. Further information about the outcome measures is given below in the section on data items. As mentioned above, study selection and data collection processes were performed only by the author, which is a potential limitation. Detailed information about the limitations of this systematic review can be found in the discussion.

2.4 Data items

For the purpose of this review, outcome measures of all 17 studies were divided systematically into different categories based on their physiological and functional nature since neuromuscular performance is a broader term. The following outcome categories were extracted from the studies, dynamic muscle strength, neuromuscular activation and physical performance measures. All outcome measures are presented in six different tables. Dynamic muscle strength measures were reported as: the one-repetition or three-repetition maximum, peak torque, mean power or peak power output. Table 3 shows maximal strength measures during different exercises reported as the one-repetition maximum (Caserotti et al., 2008; de Vos et al., 2005; Lopes et al., 2014, 2016; Reid et al., 2008; Richardson et al., 2019; Sayers & Gibson, 2010, 2014), whereas Pazit et al. (2018) measured the three-repetition maximum. Additionally, peak torque is presented in Table 4 by eight studies (de Vos et al., 2005; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008; Lee et al., 2011; Lopes et al., 2014, 2016; Webber & Porter, 2010) investigating different exercises. Muscle activation abilities reported as rate of force development and rate of torque development are demonstrated in Table 6. Only Caserotti et al. (2008) investigated rate of force development while the remaining four studies (Kobayashi et al., 2016; LaRoche et al., 2008; Lopes et al., 2014, 2016) measured rate of torque development. Furthermore, Table 5 demonstrates the peak power output of various exercises investigated by eight studies (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; S. Lee et al., 2011; Reid et al., 2008; Sayers & Gibson, 2014; Sayers & Gibson, 2010; Webber & Porter, 2010). It should be mentioned that all studies measured peak power whereas Caserotti et al. (2008) reported peak power and mean power output. In addition, three studies (Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008) investigated neuromuscular activation as electromyography measurements during different testing procedures. Electromyographic (EMG) outcome measures are shown in Table 7. The impact of power training on functional and physical performance is shown in Table 8 measured by six studies (Henwood et al., 2008; Pazit et al., 2018; Richardson et al., 2019; Sañudo et al., 2019; Sayers et al., 2016; Webber & Porter, 2010) during various tests.

For detailed information on all relevant variables relating to different outcome parameters, see the specific table of interest. Finally, some general assumptions referring to all tables are going to be made. All tables report mean differences between baseline and post-intervention values for the intervention and control groups. Furthermore, the difference between the groups is shown in the tables. If the mean difference was not reported, it was calculated by the author. Only baseline values were reported for LaRoche et al. (2008) for EMG measurements since the study did not report post-intervention values. Despite the lack of reporting, LaRoche et al. (2008) was included in the EMG table since it reported the results of statistical testing for the comparison between intervention and control. Furthermore, some studies reported the results in figures without reporting numbers for the baseline and post-intervention values. Lopes et al. (2014, 2016) and Reid et al. (2008) only reported one-repetition maximum results visually in figures. Additionally, Reid et al. (2008) reported peak power only in a figure whereas, Lopes et al. (2016) showed rate of torque development and peak torque results in figures. In these cases, baseline and post-intervention values were measured using Microsoft Word. This procedure was conducted as follows: First, the figure was imported into Microsoft Word. After zooming in on the figure, the ruler tool of Word was activated. By adding bars set at 90 degrees, drawing and measuring biases were limited. After these values were assessed, the mean difference was calculated. All reported values in the tables are specified by a footnote for validation. Furthermore, effect sizes and confidence intervals (95%) are demonstrated in the tables if reported by the respective study. It should be noted that Sayers et al. (2016) used the Short Physical Performance Battery as a physical performance assessment test and reported baseline and post-intervention values for intervention and control groups as seen in Table 8. However, three additional studies tested the participants with the Short Physical Performance Battery but only reported baseline values (Reid et al., 2008; Richardson et al., 2019; Webber & Porter, 2010). Thus, these tests were not considered in the outcomes for physical performance.

2.5 Study risk of bias assessment

The bias assessment of the included 17 studies was performed with the PEDro Scale. The PEDro Scale is a bias assessment tool for randomized controlled trials with a scoring system from 0-10 (Macedo et al., 2010; Verhagen et al., 1998). The scoring for the PEDro Scale is performed according to a checklist consisting of eleven separate points, while items 2-11 are used for scoring. The first criterion, which investigates whether eligibility criteria are specified for the study, is a measure of external validity. Therefore, it is not part of the scoring. While items 2-9 assess internal validity of the study, items 10 and 11 investigate biases in the statistics of the study. It is important to state that points are only scored when each criterion is clearly fulfilled. Although the PEDro scale is a bias assessment tool for randomized controlled trials, it is limited to interventional studies due to the nature of blinding the subjects and therapists. Since criteria 5 (blinding of the subjects) and criteria 6 (blinding of the therapists) cannot be satisfied, the maximum possible score is eight. The PEDro scoring for the purpose of this systematic review was conducted only by the author, which is a potential limitation. Further information on the limitations of this review is provided in the Discussion section below. PEDro scores for each study are presented in Table 1, which is the Summary of characteristics of all included studies. In addition, a separate detailed Table 2 shows the scoring for each criterion for each study.

2.6 Definition of power training

One of the key factors determining the quality of this systematic review is the definition of power training intervention. According to this definition, eligibility criteria are determined and contribute significantly to the findings of this review. Since this review investigates the effects of power training on neuromuscular performance in the elderly, it is critical for valid recommendations in physical practice if power training will show an effect. In fact, there are many interventional studies that investigate the effects of power training on neuromuscular performance, lack a clear definition of power training (el Hadouchi et al., 2024). Hence, it is important to tackle this problem because it is a potential bias that can lead to conflicting results. At the beginning, it is important to define the term “power” in the context of training to distinguish between muscle strength and muscle power. The term "power" is defined as work per time, or force times velocity, whereas muscle “strength” just describes the force output (Sapega & Drillings, 1983). Strength and power can be measured in all dynamic muscle contractions independently of contraction velocity, however, muscle performance cannot be differentiated into “strength” and “power” (Sapega & Drillings, 1983). It should be further stated that according to Sapega and Drillings (1983) the term “power” is misused when terming activities such as sprinting, jumping, and throwing that are performed forcefully and propulsively. Therefore, it is critical to investigate the measured parameters of the included studies. Apart from the physical perspective, muscle power can be described from the physiological perspective through Hill’s force-velocity relationship. Hill demonstrated in 1938 that the relationship between muscle shortening against a load is a hyperbolic equation. Hence, muscle shortening velocity against low loads is high, and with increasing weights, the shortening velocity starts to decrease. Finally, contractions against maximal weights result in isometric contractions without shortening of the muscle. Nowadays, it has been shown that the Hill equation is limited in predicting contraction velocities at higher loads, which is explained by molecular mechanisms during contraction in the sarcomere (Seow, 2013). The American College of Sports Medicine underlines the importance of power training for the elderly in their paper, “Exercise and Physical Activity for Older Adults”. Despite the evidence and its superiority compared to resistance training in increasing muscle power reported in the paper, it does not define the characteristics of a power training intervention (Chodzko-Zajko et al., 2009). However, the American College of Sports Medicine published a recent paper, “Benefits of Power Training for the Elderly Population” where explicit recommendations for the practical application of power training for the elderly are provided.

The recommendations can be summarized as follows; the external loading during power training can vary from 20–80% of the one-repetition maximum (Green et al., 2022). Whereas the contraction speed in the concentric phase is linked to the external load, Green and colleagues recommend rapid contractions such as “as fast as possible” and contractions of 2-3s. Slower contractions are the result of higher loads as shown above. Coelho-Junior et al.

(2021) recommended explicitly “as fast as possible” contractions in the concentric phase for power training interventions for elderly which is contradictory to the ACSM recommendation in this point. The recommendation of “as fast as possible” contractions during concentric phase matches the recommendations of further reviews (Cadore & Izquierdo, 2018; Reid & Fielding, 2012). The review of Coelho-Junior et al. (2021), titled “Evidence-based recommendations for resistance and power training to prevent frailty in community-dwellers”, elaborates that, during power training with high external loads, resulting slower contraction speeds would increase muscle strength to a higher extend, whereas power training with lower loads would result in increased muscle power. Furthermore, Coelho-Junior and colleagues reported beneficial effects of power training with low, moderate and high intensity which match the range from 20-80% of Green et al. (2022). In addition, machine-based and free-weight exercises are sufficient to increase muscle power, while functional task exercises should be preferred when the execution is safely possible (Green et al., 2022). Furthermore, Green and colleagues propose plyometric exercises like squat jumps, box jumps and hops as an effective method in increasing muscle power; however, they should be performed safely by participants who fulfill the necessary requirements. It has been proven to be effective to motivate the participants verbally during the performance of power training to increase the effectiveness of the intervention (Coelho-Júnior et al., 2021). Consequently, studies that performed power training interventions with wide range of loading from low to high intensity, the concentric phase performed “as fast as possible”, with different equipment, such as body weight, bands, free-weights or flywheels and different modalities like plyometric exercises, functional tasks or classical resistance movement patterns for the upper and lower body such as squats, knee extension, pulling or pressing exercises meet the definition of a power training intervention for the purpose of this systematic review.

3 Results

3.1 Study selection

For this review, a sum of 6,143 studies was extracted from databases and other sources while 17 of these studies fulfilled the inclusion criteria. For more details, see the selection process above or Figure 1 below. After removing the duplicates, 4,759 studies remained for further examination. After screening the title or the title and abstract, 4,105 records were excluded, which remained 654 records for full-text examination. As shown in Figure 1 and mentioned in the methods, excluded articles were categorized into four specific meta-criteria. Meta-criteria (1) consist of the following exclusion criteria: study language (5), available in full text (6), and poor reporting (7). During full text screening, 19 studies were excluded according to criterion (5), while 34 studies were not available in full text (6) and five studies were excluded for poor reporting (7). An example of poor reporting is Yoon and colleagues. They investigated the effects of elastic band-based high speed power training in elderly women on different neuromuscular outcome parameters, while they did not provide any information about the exercises performed (Yoon et al., 2017). Meta-criteria (2) consist of two sub criteria such as age (2) and supplementation (13). Thus, 83 studies were excluded because the participants were under the age of 60, while 7 studies were excluded due to supplementation (13). Four studies of these seven, which were excluded, supplemented protein shakes (Aas et al., 2020; Conlon et al., 2016; Conlon et al., 2017; de Carvalho Bastone et al., 2020), while three studies supplied their participants with vitamin D supplements (Drey, 2011; Gianoudis et al., 2012; Schaupp et al., 2022). Criteria defining the study design are summarized in meta-criteria (3), consisting of randomization (1), outcome as a neuromuscular parameter (4), crossover design (10), studies investigating the same population (15), and studies with no control group (14). Overall, 180 records were excluded in the category meta-criteria (3). The number of records that did not use a randomized controlled intervention was 108, while eight studies used a crossover design. Whereas two studies used a randomized controlled intervention but did not assess a neuromuscular outcome (Katula et al., 2008; Valenzuela et al., 2022). Katula and colleagues (2008) investigated the effects of power training and strength training on quality of life in older adults by using different questionnaires (Measures of self-efficacy, satisfaction with physical function and Satisfaction with Life Scale). Furthermore, Valenzuela and colleagues (2022) investigated the effects of a power training intervention on the cognitive function of older adults with computerized and paper and pencil tests. Therefore, both studies were excluded because they did not measure neuromuscular performance parameter as an outcome. In addition, three studies were excluded because they used data from the same population investigated in another record included in this review (de Vos et al., 2008; Orr et al., 2006; Taaffe et al., 2009). Taaffe and colleagues (2009) measured the amount of fatty infiltration in the muscle after a power training intervention with computed tomography scans. They used the same population as Henwood et al. (2008) and reported the same data on one-repetition maximum testing. Thus, this record was excluded. De Vos et al. (2005)

investigated different loading schemes for power training interventions in the elderly, which was included in this systematic review. However, Orr et al. (2006) and de Vos et al. (2008) analysed the data of de Vos et al. (2005) for further outcome measures such as balance parameters or average change in one-repetition maximum at peak power; therefore, both records were excluded. Based on the criteria (14) no non-intervention control group, 56 records were excluded. To provide some details on this criterion, a few examples of excluded studies are presented below. Arnold and colleagues conducted a randomized training intervention to improve upper body reaction time to falls in older women. Forty women were randomly allocated to a standard or fast training group without an additional non-intervention control group (Arnold et al., 2022). Most excluded records due to this criterion (14) used a comparison of two different training modalities without a control group. However, another study used a within-subject randomized design by comparing light versus heavy power training over 12 weeks for neuromuscular adaptations in older adults (Rodriguez-Lopez et al., 2022). An eight-week non-intervention period was used as a control in this study. As a further example of a control group with an intervention design, the multicenter study of Tou and colleagues can be mentioned. The intervention was a randomized comparison between usual care training and power-oriented resistance training, while the control group performed the usual care training (Tou et al., 2021). Finally, 306 records were excluded in the category of meta-criteria (4), including sub-criteria according to the details of the intervention, which will be discussed in detail above. Criteria (3), for example, which define the power training intervention, includes 249 records. Thus, all 249 excluded records do not fulfil the definition of power training in this systematic review. For detailed information, see the methods section under Definition of Power Training Intervention. According to the definition of power training, the execution of the concentric phase must be performed as fast as possible. The following records did not explicitly state that they used an "as fast as possible" effort in the concentric phase of the exercises (Bårdstu et al., 2020; Coelho-Júnior et al., 2019; Donath et al., 2014; Hruda et al., 2003; Lee et al., 2020; Saeterbakken et al., 2018; Wallerstein et al., 2012). For example, Bårdstu et al. (2020) stated that, "participants were encouraged to train with high intentional velocity during the concentric phase". Thus, "high intentional velocity" is not "as fast as possible", and this record was excluded. Coelho-Júnior and colleagues conducted a resistance training program with elderly women and investigated the effects on body composition and physical function, while the training intervention included concentric and eccentric exercises with a two-second duration. Furthermore, Lee et al. (2020) specified the concentric phase of the exercises in their intervention as one second. Given that a fixed time period to perform the concentric phase limits the participants from performing the exercises at highest possible execution velocity, these records were therefore excluded. Even Saeterbakken et al. (2018) described the execution of the exercises as, "fast and explosive", in the concentric phase, which is inaccurate because it does not explicitly include an "as fast as possible" effort. Therefore, the intervention of Saeterbakken and colleagues (2018) was excluded. As mentioned above, for the accuracy of this review, criteria (3) are essential and are applied as precisely as possible. To provide an example of different training modalities in the context of this criterion, the study of Donath et al. (2013) can be mentioned. Donath and colleagues investigated the effect of stair-climbing on seniors. Although stair-climbing with two steps at a time is a high effort exercise for seniors, the study did not state explicitly that the participants were instructed to perform stair climbing "as fast as possible". A water-based training was conducted by Bento et al. (2012). The 12-week intervention started with slow voluntary contractions and gradually increased in intensity to maximum voluntary speeds. The slow voluntary contractions during the first half of the intervention led to the exclusion of this study. Based on criteria (8), which comprises the combination of different training types such as classical resistance training elements and power training elements, or power training combined with balance training, 48 records were excluded. Marsh et al. (2009) conducted a training intervention to improve the lower extremity muscle function of older adults. Even though this investigation was three-armed trial with a power training group, a strength training group, and a control group, the participants in the training groups performed classical strength training exercises for the upper body: "Although the focus of the intervention and study outcomes was the lower extremity, they included several upper body ST exercises using dumbbells (chest press, biceps curl, triceps kickback) and Nautilus machines (overhead shoulder raise, seated row) to assist with participant retention and compliance" (Marsh et al., 2009). This study protocol was evaluated as a combination of two different training methods for the power training group, although outcome measures were only performed on the lower extremity and the classical strength training was performed on the upper extremity. To provide further examples in the category of combining power training with other training modalities, studies that used as power training intervention along with an additional "transitional cycle" can be mentioned. A randomized controlled study with multiple sclerosis patients conducted a power training intervention while the effect on brain mass and neuromuscular performance was investigated (Gaemelke et al., 2024). Gaemelke and colleagues (2024) built a "translational mesocycle" including walking drills, interval walking, seated row, and shoulder presses into the training intervention to translate the gains in the power training to functional tasks in daily life. Hvid and colleagues, for example, used additional balance exercises, while Zubac and colleagues included body weight exercises such as balance, coordination, and gymnastics movements in the power training intervention (Hvid et al., 2017; Zubac et al., 2019). An adaptation period before a power training intervention with the elderly is considered reasonable for injury prevention during power training and was conducted by several included studies in this systematic review which is further addressed in the discussion. However, two studies were excluded in the study selection process for using a long adaptation period within the intervention (Filho et al., 2022; Gray et al., 2018). Filho et al. (2022) used six weeks of training without performing a power training intervention, which was classified as a bias. Furthermore, Gray and colleagues (2018) had the "high velocity group" train for 24 weeks at low velocity, resulting in 24 weeks without power training. In addition, seven studies used a home-based training intervention and were excluded from this systematic review due to criteria (5) (Ema et al., 2017; Granet et al., 2023; Gras et al., 2004; Hirata et al., 2024; Jin et al., 2015; Jungreitmayr et al., 2022; Topp R et al., 1996). After the full-text screening was conducted for eligibility, a sum of 17 studies was included in this systematic review (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008; Lee et al., 2011; Lopes et al., 2014, 2016; Pazit et al., 2018; Reid et al., 2008; Richardson et al., 2019; Sañudo et al., 2019; Sayers et al., 2016; Sayers & Gibson, 2014; Sayers & Gibson, 2010; Webber & Porter, 2010). For a detailed overview, see PRISMA flow diagram (Figure 1) below.

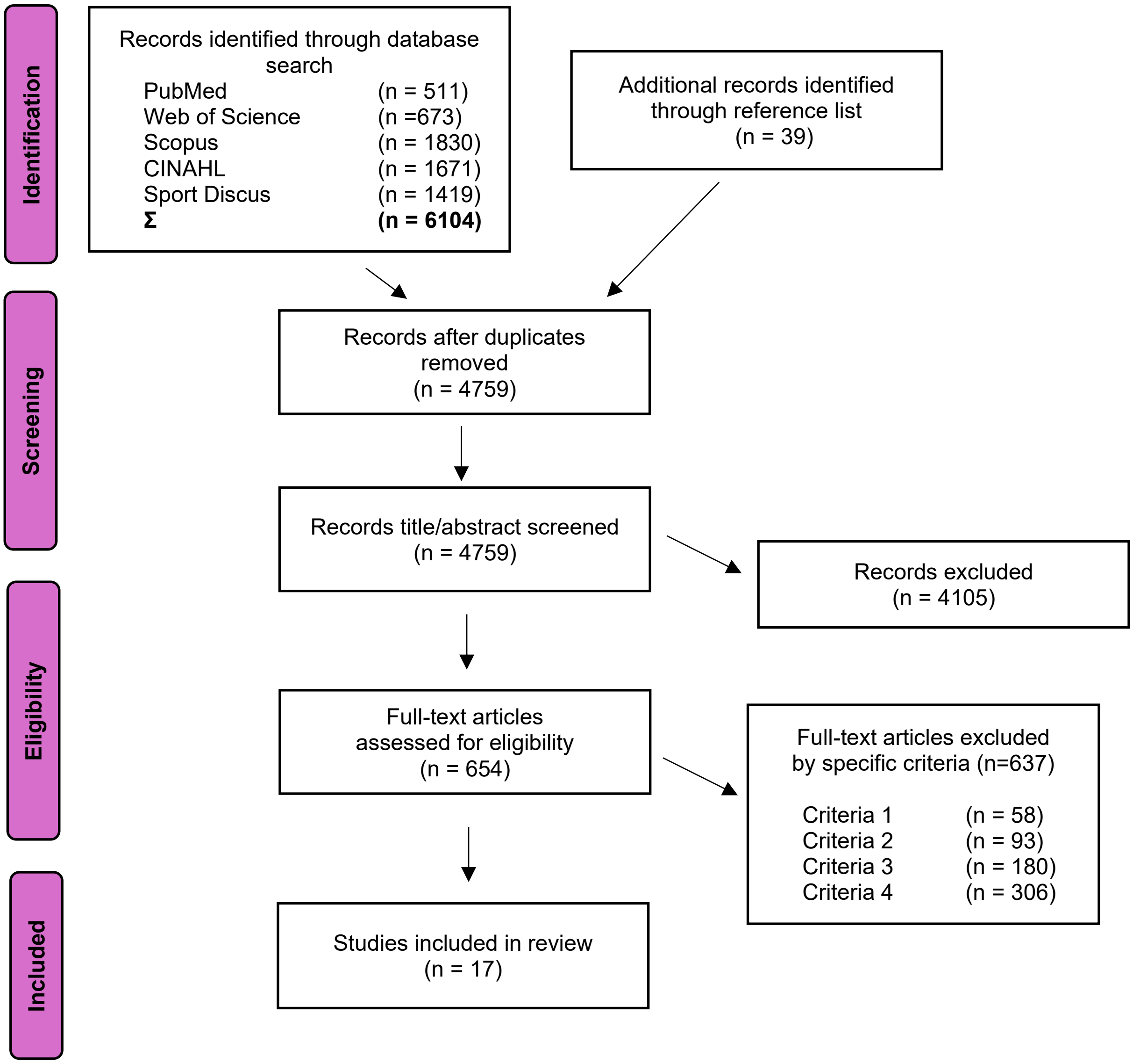

Figure 1: PRISMA Flow Diagram. Criteria 1–4 relate to meta–criteria "for details" see Methods section.

3.2 Study characteristics

A sum of 17 records published from 2008-2019 were included in this systematic review, whereby all records are randomized controlled trails, and their main characteristics are summarized in Table 1. The following section presents additional information about study characteristics. Blocked randomization was used by four records, using block sizes from 3 - 7 participants (LaRoche et al., 2008; Pazit et al., 2018; Reid et al., 2008; Webber & Porter, 2010). Three studies used a stratified randomization method to allocate their participants into different groups of the investigation. Two of these three studies stratified by assessing muscle power scores or maximal leg-muscle power measures before randomization (Caserotti et al., 2008; Holsgaard-Larsen et al., 2011), while one study performed the Time Up and Go test and used the test scores for stratification followed by randomization (Lopes et al., 2014). In addition, de Vos et al. 2005 used a block randomization and stratified the participants according to their gender before randomization. Considering that only randomized controlled trials were included in this systematic review, one study used a minimization method after truly randomly allocating participants into five different groups (Richardson et al., 2019). Finally, the remaining studies used a general 1:1 randomization method, allocating participants to the different groups without mentioning further details (Henwood et al., 2008; Kobayashi et al., 2016; Lee et al., 2011, 2016; Sañudo et al., 2019; Sayers et al., 2016; Sayers & Gibson, 2010, 2014). Of the 17 included studies, five explicitly reported that they used a computer-generated program for randomization (de Vos et al., 2005; LaRoche et al., 2008; Lopes et al., 2016; Sañudo et al., 2019; Sayers et al., 2016). Five of the 17 studies included in this review conducted a two-arm design by dividing the participants into intervention and no-intervention groups (Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; Lee et al., 2011; Sañudo et al., 2019; Sayers et al., 2016). LaRoche et al. (2008) executed a four-arm study by assessing the effects of power training on neuromuscular parameters in young and old participants. Each age group was divided into a control and intervention group. For the purpose of this systematic review, only the results of the intervention with the older participants were included. Furthermore, Caserotti and colleagues used the same design of a four-arm study with parallel intervention to compare different age groups. Since the younger age group of participants in Caserotti et al. (2008) was older than 60, both intervention groups were included. In addition, a three-arm study design was performed by six of the 17 studies, dividing their participants into a power training intervention group, a traditional resistance training group, and a no-intervention control group (Henwood et al., 2008; Lopes et al., 2014, 2016; Reid et al., 2008; Sayers & Gibson, 2010, 2014). Furthermore, two more studies conducted a three-arm study design (Pazit et al., 2018; Webber & Porter, 2010). Webber & Porter divided the participants, besides from a no-intervention control group, into a weights or bands intervention group, while both groups performed a power training intervention. However, Pazit et al. (2018) allocated the participants in the intervention groups into a high-speed resistance group and a high-speed resistance group with additional balance exercises. As mentioned above, the combination of different training methods is listed as an exclusion criterion. Therefore, the results of the high-speed resistance group plus balance exercises were not considered in this systematic review. De Vos et al. (2005) performed a three-arm power training intervention study with an additional control group. The participants in the intervention groups were categorized according to different exercise intensities of power training intervention ranging from 80 - 20% one-repetition maximum. By using five different parallel arms, Richardson and colleagues investigated the effect of training frequencies along with power training or traditional strength training on neuromuscular performance parameters. Richardson et al. (2019) divided the participants into power training or traditional slow speed resistance training groups and categorized these groups into training regimens of once or twice weekly. Whereas five of the included studies were conducted in the USA (LaRoche et al., 2008; Reid et al., 2008; Sayers et al., 2016; Sayers & Gibson, 2010, 2014), four studies were performed in Europe (Caserotti et al., 2008; Holsgaard-Larsen et al., 2011; Richardson et al., 2019; Sañudo et al., 2019). In addition, three studies were executed in Australia (de Vos et al., 2005; Henwood et al., 2008; Pazit et al., 2018) and two studies each in Brazil (Lopes et al., 2014, 2016), and Japan (Kobayashi et al., 2016; Lee et al., 2011). One study was performed in Canada (Webber & Porter, 2010). Pazit and colleagues performed a multicentre study as the only study among all included records. The sample sizes of the included records varied from 18 to 56 with a total number of 734 participants across all studies included. However, five studies exclusively investigated female participants (Caserotti et al., 2008; Holsgaard-Larsen et al., 2011; LaRoche et al., 2008; Lopes et al., 2016; Webber & Porter, 2010), while the rest of the included records investigated both genders. Since studies with participants over 60 years of age are included in this systematic review, there is a wide range of different age groups investigated across the studies. Caserotti et al. (2008) investigated participants with an average age of 62.7 years and an additional training group with older participants with an average age of 81.8 years, while the average age of the remaining populations lie in between of these two groups. Furthermore, Reid et al. (2013) investigated participants ranging from 65-94 years and is the only study investigating participants over 90 years. Table 1 provides a brief sample description for every study. As mentioned above, besides age over 60 years there were no other limitation on the population investigated in the studies included in this review. Therefore, heterogeneous populations were investigated across the included studies. Webber & Porter (2010), for example, investigated mobility-impaired elderly women with chronic diseases and an average intake of three medications. In contrast, Caserotti and colleagues investigated independently living and active elderly without experience in strength training. Only Pazit et al. (2018) included participants with osteoarthritis, which was necessary for inclusion, since one purpose of this study was to investigate the effect of power training on this medical condition. All studies excluded participants who had recently participated in structured strength exercises. Characteristics relating to the interventions performed in the studies can be summarized as follows. The longest intervention period lasted for 22 weeks (Henwood et al., 2008), while the shortest intervention was performed in four weeks (Kobayashi et al., 2016). In addition, one study assessed the effects of a six-week intervention period (Sañudo et al., 2019), whereas all remaining studies performed an 8 or 12-week intervention. Every included study conducted pre- and post-intervention testing of the outcome measures, while no study performed a detraining period followed by additional testing. Most of the included studies used machine-based training with weight-stacked, pneumatic, or hydraulic resistance machines. Webber & Porter (2010) performed a three-arm study and investigated power training in a machine- and elastic-resistance-band-based training. Furthermore, Sañudo and colleagues used a flywheel for the power-training intervention. Moreover, two studies combined machine-based training interventions with bodyweight exercises or exercises with a weighted vest (Lopes et al., 2014; Pazit et al., 2018). Training frequencies varied across 2-3 sessions per week, except for one training arm of Richardson et al. (2019), which trained once per week. Variability of the exercises performed, and intensity used across all included studies can be seen in Table 1. For example, two studies isolated the ankle joint with power training exercises. Webber & Porter (2010) performed ankle dorsi- and plantarflexion, whereas Kobayashi and colleagues only performed plantarflexion. Leg press exercises were performed by eleven studies, while four studies exclusively performed leg press and knee extension (LaRoche et al., 2008; Sayers et al., 2016; Sayers & Gibson, 2010, 2014). Eight studies used five or more exercises in their power training interventions (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; Lee et al., 2011; Lopes et al., 2014, 2016; Pazit et al., 2018; Richardson et al., 2019). The exercise protocol of Lee et al. (2011) consists of twelve exercises and contains the highest number of variations in the exercises performed among all included studies. The intensity of the performed exercises varied from 20-80% of the one-repetition maximum across all studies, while two records need to be mentioned as exceptions. Lee and colleagues used a hydraulic resistance-machine device for training and testing. Lee and colleagues reported the resistance provided by the machine during exercise and testing in different resistance modes D1 – D6. The D1 mode equals fast and low resistance and the D6 mode equals slow and high resistance. However, Lee at al. (2011) did not describe these different modes by using SI units. However, Kobayashi et al. (2015) provided a setup with instant visual feedback during training provided by the dynamometer and a computer used for training. Therefore, this setup was able to adapt the force exerted by the participants during each repetition, while the participants were instructed to perform "as fast and hard as possible", thus maximum effort. Neuromuscular outcome measures assessed by the studies can be categorized as physical performance tests, muscle activation parameters, or dynamic strength testings. Six of the 17 included studies performed physical-performance testing as outcome measures for assessing the effects of power training interventions (Henwood et al., 2008; Pazit et al., 2018; Richardson et al., 2019; Sañudo et al., 2019; Sayers & Gibson, 2010; Webber & Porter, 2010). While Henwood and colleagues performed eight different tests, Webber & Porter (2010) conducted one physical performance test. Moreover, three studies assessed electromyographic signals during a variety of different exercises. Holsgaard-Larsen et al. (2011) measured EMG signals during stair ascent and Kobayashi et al. (2016) conducted measurements during plantar flexion and one-leg standing. Furthermore, LaRoche and colleagues (2008) investigated EMG activity during knee extension exercises. Dynamic muscle strength as one-repetition or three-repetition maximum was investigated by ten of seventeen studies included in this systematic review (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; Lopes et al., 2014, 2016; Pazit et al., 2018; Reid et al., 2008; Richardson et al., 2019; Sayers & Gibson, 2010, 2014). While all studies measured the one-repetition maximum during leg press or leg extension, the number of exercises tested in each study varied from one to eight different exercises. For details on the exercises see the results section below. However, dynamic muscle strength expressed as peak torque were assessed by eight studies across different exercises (de Vos et al., 2005; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008; Lee et al., 2011; Lopes et al., 2014, 2016; Webber & Porter, 2010). Absolute and mean values of peak power were assessed by seven studies (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; Lee et al., 2011; Reid et al., 2008; Sayers

& Gibson, 2010, 2014), while rate of force and torque development were investigated by five studies (Caserotti et al., 2008; Kobayashi et al., 2016; LaRoche et al., 2008; Lopes et al., 2014, 2016). To see each exercise performed by each study during different measures see the results section.

Table 1: *Summary of characteristics of all studies meeting the inclusion criteria*

Authors and year	Population			Training program					
	Sample size (n), sex and age (years) [mean ± SD]	BMI ($kg \cdot m^{-2}$) [mean ± SD]	Sample description	Equipment	Training description (exercises & procedure)	Resistance	Frequency (times/week)	Duration (weeks)	Study quality (PEDro)
Caserottie et al. (2008)a	40 F (62.7 ± 2.2)	25.2[9]	Independent in daily tasks; no medication or hormonal therapy	Machine-based training	Bilateral knee extension, horizontal leg press, hamstring curls, calf raises, and inclined leg press performed in 4 sets of 8–10 repetitions	75–80% of 1RM	2	12	4
Caserottie et al. (2008)b	25 F (81.8 ± 2.7)	26.7[9]	Independent in daily tasks; no medication or hormonal therapy	Machine-based training	Bilateral knee extension, horizontal leg press, hamstring curls, calf raises, and inclined leg press performed in 4 sets of 8–10 repetitions	75-80% of 1RM	2	12	4
De Vos et al. (2005)a	51 M F (68.5 ± 5.9)	25.7 ± 3.7	Living independently in the community, with no participation in resistance or power training in the past 6 months	Keiser pneumatic machine	Leg press, chest press, leg extension, seated row, and leg flexion. First training session: 3 sets of 8 repetitions; second session: 1RM testing and 2 sets of 8 repetitions	20% of 1RM	2	8-12	6
De Vos et al. (2005)b	51 M F (67.8 ± 5.2)	25.8 ± 3.8	Living independently in the community, with no participation in resistance or power training in the past 6 months	Keiser pneumatic machine	Leg press, chest press, leg extension, seated row, and leg flexion. First training session: 3 sets of 8 repetitions; second session: 1RM testing and 2 sets of 8 repetitions	50% of 1RM	2	8-12	6
De Vos et al. (2005)c	50 M F (68.3 ± 6.1)	25.6 ± 3.5	Living independently in the community, with no participation in resistance or power training in the past 6 months	Keiser pneumatic machine	Leg press, chest press, leg extension, seated row, and leg flexion. First training session: 3 sets of 8 repetitions; second session: 1RM testing and 2 sets of 8 repetitions	80% of 1RM	2	8-12	6
Henwood et al. (2008)	34 M F (70.3 ± 4.9)	26.2 ± 4.1	Community-dwelling older adults living independently, with no resistance training in the past 12 months	Extek resistance equipment	Chest press, supported row, biceps curl, leg press, prone leg curl, and leg extension, performed in 3 sets of 8 repetitions, progressing from 45% to 60% to 75% of 1RM across sets	45–75% of 1RM	2	8-22	4
Holsgaard-Larsen et al. (2011)	19 F (69.7 ± 3.3)	27 ± 3	Community-dwelling elderly individuals with no prior strength training experience	Isokinetic resistance training equipment	Bilateral knee extension, horizontal leg press, hamstring curl, calf raise, and inclined leg press, performed in 4 sets of 8–10 repetitions	75–80% of 1RM	2	12	4
Kobayashi et al. (2016)	56 M F (71.4 ± 5.6)	23.1	Functionally independent in daily living; 85% physically active, but no resistance training in the past 6 months for the lower body.	Dynamometer	Unilateral plantar flexion on a dynamometer for 3 sets of 10 repetitions	Self–regulated	2	4	5
Laroche et al. (2008)	24 F (72,5 ± 5,5)	28.5 ± 3.8	Largely inactive, with no participation in structured exercise	Dynamometer	Unilateral knee extension and flexion for 3 sets of 8 repetitions at angular velocities of 45°/s (low velocity, high load) and 200°/s (high velocity, low load)	45°/s–200°/s	3	8	5
Lee et al. (2011)	39 M F (68.6 ± 4.8)	23.8 ± 2.7	Sedentary but apparently healthy	Hydraulic resistance machine	Chest press, chest pull, shoulder press, shoulder pull, low back flexion, low back extension, squat, leg press, elbow extension, and elbow flexion. Weeks 0–4: 1–2 × 15 (D2); Weeks 5–8: 1–3 × 10 (D3–D4); Weeks 9–12: 1–3 × 10 (D5–D6). (D1 = fast and slow resistance; D6 = slow and high resistance)	D1–D6	3	12	5

Lopes et al. (2014)	21 M F (64.1 ± 2.5)	28.4	Community-dwelling elderly individuals with no participation in a physical activity program in the past 6 months	Machine and bodyweight	Bodyweight: plantar flexion. Machines: hip abduction and adduction, seated leg extension, bilateral knee flexion, lat pull-down, leg press, and upright row. Weeks 1–4: 3 × 7 at 30–35% 1RM; Weeks 5–6: 3 × 7 at 35% and 1 × 6 at 40% 1RM; Weeks 7–8: 4 × 6 at 40% 1RM; Weeks 9–12: 2 × 6 at 40–45% and 2 × 4 at 45–50% 1RM	30–50% of 1RM	3	12	4
Lopes et al. (2016)	22 F (66 ± 5.7)	29.2 ± 2.3	Independently living elderly women with no participation in structured exercise in the past 6 months	Machine-based training	Horizontal leg press, bilateral knee extension, bilateral knee flexion, plantar flexion on a step, hip abduction, and hip adduction for 3–4 sets of 6–8 repetitions at 40–80% of 1RM (increased by 6–8% every two weeks)	40–80% of 1RM	3	12	5
Pazit et al. (2018)	18 M F (69.1 ± 6.9)	28.3 ± 4.7	Clinically diagnosed osteoarthritis in the knee joint and a fall in the past 12 months but able to ambulate without help; no participation in resistance or balance training in the past 6 months	Leg press machine and weighted vest	Leg press, squat, step-up, lunge, stair climbing, sit-to-stand, and calf raises for three phases. Week 1–2: 3 sets of 8–12 repetitions at 20–40% 1RM; Week 3–5: 3 sets of 5–8 repetitions at 40–60% 1RM; Week 6–8: 2–3 sets of 2–5 repetitions at 60–80% 1RM	20–80% of 1RM	2	8	6
Reid et al. (2008)	35 M F (74.8 ± 7.9)	28.7 ± 5.6	Community-dwelling individuals with preexisting limitations in physical functioning	Keiser pneumatic machine	Bilateral leg press and unilateral left and right knee extensions for 3 sets of 8 repetitions	70% of 1RM	3	12	5
Richardson et al. (2019)a	20 M F (65.5 ± 4.8)	28 ± 5	Community-dwelling, moderately to highly active Caucasian elderly individuals with no participation in resistance training in the past 6 months	Weight-stacked machine	Leg press, calf raise, leg extension, leg curl, seated row, chest press, triceps extension, and biceps curl for 3 sets of 14 repetitions	40% of 1RM	1	10	6
Richardson et al. (2019)b	20 M F (66 ± 5.4)	28 ± 5	Community-dwelling, moderately to highly active Caucasian elderly individuals with no participation in resistance training in the past 6 months	Weight-stacked machine	Leg press, calf raise, leg extension, leg curl, seated row, chest press, triceps extension, and biceps curl for 3 sets of 14 repetitions	40% of 1RM	2	10	6
Sañudo et al. (2019)	34 M F (65.3 ± 4.3)	28.1 ± 4.1	Elderly individuals without cognitive or functional disorders who did not participate in any exercise training in the past 12 months	Flywheel	Squats for 4 sets of 9 repetitions. Week 1–4: 0.025 $kg \cdot m^{-2}$; Week 5–6: 0.05 $kg \cdot m^{-2}$. Training frequency: Week 1, 3, 5 = 2 sessions per week; Week 2, 4, 6 = 3 sessions per week	0.025–0.05 $kg \cdot m^{-2}$	2-3	6	6
Sayers & Gibson (2010)	25 M F (73.4 ± 5.3)	27.5[9]	Community-dwelling individuals with some limitations in either function or mobility, without current participation in structured exercise	Keiser pneumatic machine	Leg press and seated knee extension for 3 sets of 12–14 repetitions	40% of 1RM	3	12	4
Sayers & Gibson (2014)	42 M F (71.1 ± 6.4)	28 ± 6	Community-dwelling, ambulatory with or without an assistive device, and currently not participating in resistance training	Keiser pneumatic machine	Leg press and seated knee extension for 3 sets of 12–14 repetitions	40% of 1RM	3	12	5
Sayers et al. (2016)	42 M F (71.3 ± 6.5)	27.9 ± 5.5	Community-dwelling, ambulatory with or without an assistive device,	Keiser pneumatic machine	Leg press and seated knee extension for 3 sets of 12–14 repetitions	40% of 1RM	3	12	6

			and currently not participating in resistance training						
Webber & Porter (2010)a	33 F 75.5 (70-88)	29.8 ± 5.3	Mobility-limited (self-reported inability to walk 1 mile at a moderate pace) elderly women with no participation in an exercise program in the past 6 months	Hammer Strength machine	Unilateral ankle dorsiflexion and bilateral plantar flexion for 3 sets of 8–10 repetitions	80% of 1RM	2	12	6
Webber & Porter (2010)b	33 F 74.5 (70-88)	31.0 ± 6.9	Mobility-limited (self-reported inability to walk 1 mile at a moderate pace) elderly women with no participation in an exercise program in the past 6 months	Elastic resistance band (Thera-Band)	Unilateral ankle dorsiflexion and plantar flexion for 3 sets of 8 repetitions with heavier bands every 2–3 weeks	no information provided	2	12	6

1RM = one-repetition maximum; *D1–D6* = training resistance: fast and low resistance (D1) to slow and high resistance (D6); [9] = calculated value ($M = \Sigma x_i / n$), *M* = male, *F* = female

3.3 Risk of bias in studies

Study quality of the included seventeen studies was assessed by the PEDro scale. The Physiotherapy Evidence Database scale consists of 11 items designed to measure the quality of randomized controlled interventions in physiotherapy settings. While item one measures external validity, such as whether exclusion- and inclusion-criteria were defined by the study, it is not considered in the scoring. Therefore, items 2-11 contribute to the PEDro score and a sum of ten points can be scored. However, items five and six cannot be scored depending on the nature of the interventional training design of the included studies in this systematic review. Since item five and six of the PEDro scale evaluate whether the participants and therapists are blinded, it cannot be satisfied in a power training intervention. While the participants in the training group will know that they perform a power training intervention, and the control group knows that they did not perform any intervention. Furthermore, blinding the supervisor is not possible since he or she supervises the correct performance of the power training. Thus, the methodological design of the included studies allows a maximum score of eight out of the ten possible points for the PEDro scale. The second criterion is satisfied by all included studies since it requires a random allocation, and all included studies are randomized controlled trials in this systematic review. On the other hand, criterion three, which further evaluates whether the randomisation process was concealed or not, is fulfilled by four studies (Pazit et al., 2018; Sañudo et al., 2019; Sayers et al., 2016; Webber & Porter, 2010). Whether the participants had similar baseline values was assessed by criterion four, which was not satisfied only in Reid et al. (2008). Reid and colleagues (2008) used the score of the Short Physical Performance Battery (≥9) as an inclusion criterion, which was not significantly different after randomization between the control and the power intervention group. However, the age between intervention (73.1 ± 6) and control (79.7 ± 9) were significantly different between groups. As mentioned above, the blinding of subjects and supervisors is not possible in this type of study design, thus criteria five and six is not fulfilled by any study included in this systematic review. On the other hand, blinding of the assessor is possible and was performed by five of the 17 studies included (de Vos et al., 2005; LaRoche et al., 2008; Sañudo et al., 2019; Sayers et al., 2016; Webber & Porter, 2010). In addition, seven studies have reported a dropout rate over 15% of the randomized participants (Caserotti et al., 2008; Henwood et al., 2008; Holsgaard-Larsen et al., 2011; Lopes et al., 2016; Sayers et al., 2016; Sayers & Gibson, 2010; Webber & Porter, 2010), while the remaining studies showed compliance rates over 85%. Reid et al.

(2008) is the only study to implement an intent-to-treat approach in the methods among the 17 studies included. Furthermore, all 17 studies included satisfied criteria 10 and 11 of the PEDro list through statistical between-group comparisons with additional point measures and reported variability. The highest PEDro score was achieved by Sañudo et al. (2019) with seven points out of a possible eight when ignoring the two points given for blinding of subjects and supervisors. This was followed, in descending order, by five studies with a score of six points according to the PEDro scale (de Vos et al., 2005; LaRoche et al., 2008; Pazit et al., 2018; Sayers et al., 2016; Webber & Porter, 2010) and six studies with a score of five (Kobayashi et al., 2016; Lee et al., 2011; Lopes et al., 2014; Reid et al., 2008; Richardson et al., 2019; Sayers & Gibson, 2014). Five studies, however, scored four points (Caserotti et al., 2008; Henwood et al., 2008; Holsgaard-Larsen et al., 2011; Lopes et al., 2016; Sayers & Gibson, 2010), which is at the same time the lowest score given among all included studies. Table 2 below provides a detailed overview of every criterion of the PEDro scale for all studies included in this systematic review.

Table 2: *PEDro criteria and sum scores of the included studies*

Authors and year	Eligibility specified	Subjects randomly allocated	Concealed allocation	Similar baseline values	Blinding of subjects	Blinding of therapists	Blinding of assessor	Dropout rate < 15 %	Received treatment as allocated	Statistical between group comparison	Point measures and variability	Sum (items 2–11)
Caserotti et al. (2008)	1	1	0	1	0	0	0	0	0	1	1	4
De Vos et al. (2005)	1	1	0	1	0	0	1	1	0	1	1	6
Henwood et al. (2008)	1	1	0	1	0	0	0	0	0	1	1	4
Holsgaard-Larsen et al. (2011)	1	1	0	1	0	0	0	0	0	1	1	4
Kobayashi et al. (2016)	1	1	0	1	0	0	0	1	0	1	1	5
Laroche et al. (2008)	1	1	0	1	0	0	1	1	0	1	1	6
Lee et al. (2011)	1	1	0	1	0	0	0	1	0	1	1	5
Lopes et al. (2014)	1	1	0	1	0	0	0	1	0	1	1	5
Lopes et al. (2016)	1	1	0	1	0	0	0	0	0	1	1	4
Pazit et al. (2018)	1	1	1	1	0	0	0	1	0	1	1	6
Reid et al. (2008)	1	1	0	0	0	0	0	1	1	1	1	5
Richardson et al. (2019)	1	1	0	1	0	0	0	1	0	1	1	5
Sañudo et al. (2019)	1	1	1	1	0	0	1	1	0	1	1	7
Sayers & Gibson (2010)	1	1	0	1	0	0	0	0	0	1	1	4
Sayers & Gibson (2014)	1	1	0	1	0	0	0	1	0	1	1	5
Sayers et al. (2016)	1	1	1	1	0	0	1	0	0	1	1	6
Webber & Porter (2010)	1	1	1	1	0	0	1	0	0	1	1	6

PEDro = Physiotherapy Evidence Database scale

3.4 Results of individual studies

3.4.1 Dynamic Muscle Strength and Force: 1 or 3 Repetition Maximum

Nine studies investigated the effect of power training on the one repetition maximum, and one study assessed the effect of a power training intervention on the three-repetition maximum. In addition, Caserotti and colleagues (2008) performed the intervention with two different age groups consisting of elderly and very old women. Whereas de Vos et al. (2005) conducted a three-arm study comparing multiple training intensities for the power training intervention ranging from 20%, 50% to 80% of the one-repetition maximum. Furthermore, Richardson et al. (2019) investigated the variation of training frequency by conducting a once- or twice-per-week power training intervention. Studies with different parallel training arms are listed in the table with additional letters. To see detailed information on the training modalities, as mentioned, see Table 1 for a summary of characteristics of all studies meeting the inclusion criteria above. In addition, variability in the training duration is listed in Table 1. In the following, results for the one- and three-repetition maximum will be categorized according to the exercises, while measurements were performed pre- and post-intervention. Table 3 below provides an overview of all one- and three-repetition measures conducted. Note that confidence intervals marked with an ɣ are calculated by the author. The formula is reported in the Symbols and Abbreviations section under Table 3. While eight studies assessed the effect of the power training intervention for leg press, 12 groups in total performed an intervention (Caserotti et al., 2008; de Vos et al., 2005; Lopes et al., 2014, 2016; Pazit et al., 2018; Reid et al., 2008; Richardson et al., 2019; Sayers & Gibson, 2014). Significant improvements in one-repetition maximum for leg press were reported by four studies (Caserotti et al., 2008a, *MD* = 4.3 $N \cdot kg^{-1}$, 95% CI [2.7, 5.9], $p = .001$; Caserotti et al., 2008b, *MD* = 3.6 $N \cdot kg^{-1}$, 95% CI [1.5, 5.7], $p = .04$; de Vos et al., 2005a, *MD* = 12 N, 95% CI [6.8, 15.2], $p < .05$; de Vos et al., 2005b, *MD* = 12 N, 95% CI [6.5, 17.5] , $p < .05$; de Vos et al., 2005c, *MD* = 11 N, 95% CI [6.7, 15.2] , $p < .05$; Lopes et al., 2014, *MD* = 24 N, 95% CI not reported, $p < .0001$; Sayers & Gibson, 2014 *MD* = 207 N, 95% CI [69, 346], $p = .002$). In addition, Pazit et al. (2018) reported significant improvements in three-repetition maximum for leg press, while being the only study to measure the three-repetition maximum (*MD* = .46 $kg \cdot bw^{-1}$, 95% CI [–.76, –.17], $p < .01$). Eight of the twelve intervention groups reported significant improvements in one- or three-repetition maximum, while four groups showed no significant changes compared to the control after the power training intervention (Lopes et al., 2016, *MD* = 10.7 kg, 95% CI not reported, *p* = *n.s.*; Reid et al., 2008, *MD* = 123 N, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019a, *MD* = 13.9 kg, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = 11.2 kg, 95% CI not reported, *p* = *n.s.*). Five studies assessed knee extension and compared six intervention groups with controls, while three groups showed significant improvements for knee extension (Lopes et al., 2014, *MD* = 18.4 kg, 95% CI not reported, *p* < .05; Reid et al., 2008, *MD* = 22.9 N, 95% CI not reported, *p* < .01; Sayers & Gibson, 2010, *MD* = 25 N, 95% CI not reported, *p* = .003), whereas three groups demonstrated no significant improvements compared to the control (Lopes et al., 2016, *MD* = 15.7 kg, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019a, *MD* = –4.1 kg, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = –4.8 kg, 95% CI not reported, *p* = *n.s.*). On the other hand, knee flexion was assessed by three studies with four intervention groups, while two groups showed a significant improvement in knee flexion compared to the control (Lopes et al., 2014, *MD* = 14.6 kg, 95% CI not reported, *p* < .05; Lopes et al., 2016, *MD* = 8 kg, 95% CI not reported, *p* < .02) and two groups did not (Richardson et al., 2019a, *MD* = 1.4 kg, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = –0.7 kg, 95% CI not reported, *p* = *n.s.*). Only Richardson and colleagues (2019) measured one repetition maximum values for calf raises with two parallel interventional arms and reported no significant improvements compared to the control for both groups (Richardson et al., 2019a, *MD* = 13.6 kg, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = 11.2 kg, 95 % CI not reported, *p* = *n.s.*). Moreover, two studies investigated one-repetition maximum values for upper body exercises (de Vos et al., 2005; Richardson et al., 2019). Since de Vos et al (2005) conducted a three-arm parallel study and Richardson et al. (2019) a two-arm parallel study, results of five interventional groups are available. De Vos and colleagues reported significant improvements in one-repetition maximum for chest press (de Vos et al., 2005a, *MD* = 6 N, 95% CI [2.7, 9.3], *p* < .05; de Vos et al., 2005b *MD* = 8 N, 95% CI [4, 12], *p* < .05; de Vos et al., 2005c, *MD* = 12 N, 95% CI [8, 16], *p* < .05) and seated row (de Vos et al., 2005a, *MD* = 11 N, 95% CI [6.7, 15.3], *p* < .05; de Vos et al., 2005b, *MD* = 18N, 95% CI [13.7, 22.3], *p* < .05; de Vos et al., 2005c, *MD* = 22 N, 95% CI [16.7, 27.3], *p* < .05) for all intervention groups. While de Vos et al. (2005) showed significant improvements in chest press and seated row, Richardson and colleagues (2019) demonstrated significant improvements for only one intervention group in chest press (Richardson et al., 2019a, *MD* = 14.1 kg, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = 16.3 kg, 95% CI [0.1, 13.5], *p* = .047) and seated row (Richardson et al., 2019a, *MD* = 11.5 kg, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = 14.1 kg, 95% CI [0.2, 16.7], *p* = .04). Furthermore, Richardson et al (2019), being the only study investigating one-repetition maximum improvements in triceps extension and biceps curls after a power training intervention, showed no significant improvements for either triceps extension (Richardson et al., 2019a, *MD* = 11.7 kg, 95% CI not reported, p = *n.s.*; Richardson et al., 2019b, *MD* = 12.3 kg, 95% CI not reported, p = *n.s.*) and biceps curls (Richardson et al., 2019a, *MD* = 4.5 kg, 95% CI not reported, p = *n.s.*; Richardson et al., 2019b, *MD* = 1 kg, 95% CI not reported, p = n.s.). Henwood et al. (2008) tested one-repetition maximum in six exercises (bench press, supported row, biceps curl, leg press, leg curl, and leg extension), while reporting the results as a composite score of these exercises, therefore the results of Henwood and colleagues are shown separately from the results listed above. Henwood and colleagues showed a significant improvement (*MD* = 49.9 kg, 95% CI not reported, $p < .0001$) in the composite score for these exercises for the intervention group compared to the control. The results of the included studies investigating the effect of a power training intervention on the one- or three-repetition maximum can be summarized as follows: Ten studies out of seventeen included in this systematic review measured dynamic muscle strength and force as outcome parameters as one- or three-repetition maximum values. Three studies conducted multiple parallel-arm studies (Caserotti et al., 2008; de Vos et al., 2005; Richardson et al., 2019), thus data of fourteen power training intervention groups in total are available.

Table 3: *Dynamic Muscle Strength and Force Expressed as 1RM and 3RM*

				Change from baseline to post (SD)			
Authors (year)	Population	Exercise	Unit	Training	Control	Difference	Significance [95% *CI*]
Caserottie et al. (2008)a	40	Leg press	N·kg^{-1} (net)	5.3*[8]	1.0[8]	4.3[7]	p = .0001 [2.7, 5.9]
Caserottie et al. (2008)b	25	Leg press	N·kg^{-1} (net)	5*[8]	1.4[8]	3.6[7]	p = .004 [1.5, 5.7]
De Vos et al. (2005)a	50	Leg press	N (%)	16 ± 11*	4 ± 7	12[7]	p < .05 [6.8, 15.2]ɣ
		Chest press	N (%)	9 ± 8*	3 ± 4	6[7]	p < .05 [2.7, 9.3]ɣ
		Seated row	N (%)	13 ± 10*	2 ± 6	11[7]	p < .05 [6.7, 15.3]ɣ
De Vos et al. (2005)b	51	Leg press	N (%)	16 ± 13*	4 ± 7	12[7]	p < .05 [6.5, 17.5]ɣ
		Chest press	N (%)	11 ± 10*	3 ± 4	8[7]	p < .05 [4, 12]ɣ
		Seated row	N (%)	20 ± 10*	2 ± 6	18[7]	p < .05 [13.7, 22.3]ɣ
De Vos et al. (2005)c	51	Leg press	N (%)	15 ± 9*	4 ± 7	11[7]	p < .05 [6.7, 15.2]ɣ
		Chest press	N (%)	15 ± 10*	3 ± 4	12[7]	p < .05 [8, 16]ɣ
		Seated row	N (%)	24 ± 13*	2 ± 6	22[7]	p < .05 [16.7, 27.3]ɣ
Henwood et al. (2008)	34	Six exercises$	Kg (%)	51.0 ± 9.0*	1.2 ± 5.1	49.8[7]	p < .001
Lopes et al. (2014)	21	Leg press	Kg (%)	24*	0#	24	p < .0001 [n.r.]
		Knee extension	Kg (%)	23*	4.6#[8]	18.4[7]	p < .05 [n.r.]
		Knee flexion	Kg (%)	13*	–1.6#[8]	14.6[7]	p < .05 [n.r.]
Lopes et al. (2016)	23	Leg press	Kg (net)	14.66 ± 9.73*	4#	10.7	n.s.[1]
		Knee extension	Kg (net)	16.86 ± 11.25*	1.2#[8]	15.7[7]	n.s.[2]
		Knee flexion	Kg (net)	8.88 ± 6.10*	.9#[8]	8[7]	p = .02[3]
Pazit et al. (2018)”	18	Leg press	N·bw^{-1}	.3*[8]	–.2[8]	.5	p < .01 [–.76, –0.17]
Reid et al. (2008)	35	Leg press	N (net)	138#	15#	123[7]	n.s.
		Knee extension	N (net)	27.1*#	4.2#	22.9[7]	p < .01
Richardson et al. (2019)a	20	Leg press	Kg (%)	13.6[8]	0[8]	13.9[7]	n.s.
		Knee extension	Kg (%)	9.8[8]	13.9[8]	–4.1[7]	n.s.
		Knee flexion	Kg (%)	12.5[8]	11.1[8]	1.4[7]	n.s.
		Chest press	Kg (%)	11.43	–2.7[8]	14.1[7]	n.s.
		Seated row	Kg (%)	7.6*[8]	–3.9[8]	11.5[7]	n.s.
		Triceps extension	Kg (%)	16*[8]	4.3[8]	11.7[7]	n.s.
		Biceps curl	Kg (%)	15[8]	10.5[8]	4.5[7]	n.s.
		Calf raise	Kg (%)	13.6[8]	0[8]	13.6	n.s.
Richardson et al. (2019)b	20	Leg press	Kg (%)	11.1[8]	0[8]	11.1[7]	n.s.
		Knee extension	Kg (%)	9.1*[8]	13.9[8]	–4.8[7]	n.s.
		Knee flexion	Kg (%)	10.4*[8]	11.1[8]	–0.7[7]	n.s.
		Chest press	Kg (%)	13.6*	–2.7[8]	16.34	p = .047 [0.1, 13.5]
		Seated row	Kg (%)	10.2*[8]	–3.9[8]	14.09	p = .04 [0.2, 16.7]
		Triceps extension	Kg (%)	16.7*[8]	4.3[8]	12.3[7]	n.s.
		Biceps curl	Kg (%)	11.5*[8]	10.5[8]	1[7]	n.s.
		Calf raise	Kg (%)	11.1[8]	0[8]	11.11	n.s.
Sayers & Gibson (2010)	25	Knee extension	N (%)	25*	0	25	p = .003§
Sayers & Gibson (2014)	42	Leg press	N (net)	310 ± 213	103 ± 131	207	p = .002 [69, 346]

* = significant difference from baseline; # = data extracted from figure; § = *F*-statistic for group × time interaction ($F = 6.9$, $p = .003$); [8] = calculated value (Δ=Mpost−Mpre); [7] = calculated value (Δ=ΔMT−ΔMC); $ = composite score including bench press, supported row, biceps curl, leg press, leg curls, and leg extension; ” = measured as three-repetition maximum (*3RM*); [1] = $F(2, 34) = 5.07$, $p = .012$, $\eta^2_p = .23$ (Groups: power training, strength training, and control); [2] = $F(2, 34) = 16.12$, $p < .001$, $\eta^2_p = .48$ (Groups: power training, strength training, and control); [3] = $F(2, 34) = 11.91$, $p < .001$, $\eta^2_p = .41$ (Groups: power training, strength training, and control); ɣ = self-calculated with the formula $SE = sqrt\ (n_{int} * SD_{int}^2 + n_{con} * SD_{con}^2)$; *(net)* = net value; *(%)* = relative to baseline

3.4.2 Dynamic Muscle Strength and Force: Peak Torque

Peak Torque measures were conducted by eight of the seventeen studies included in this systematic review (de Vos et al., 2005; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008; Lee et al., 2011; Lopes et al., 2014, 2016; Webber & Porter, 2010). While eight studies investigated peak torque, 12 groups were assessed in total compared to the control. As has been previously established, this review includes some randomized controlled trials, which are investigating multiple parallel training arms that differ in training frequencies or intensities. For detailed information on which studies have used multiple parallel arms in which modalities, see Table 1. In total, peak torque was measured by 344 subjects across the twelve intervention groups with their control groups. Lee et al. (2011) being the only study to measure peak torque values additionally for upper body exercises, all eight studies measured peak torque at lower body exercises. Furthermore, the studies can be categorized according to the contraction type performed during the assessment of peak torque. While Lee et al. (2011) measured kinetic peak torque at low resistance with high speed or low speed and high resistance, Webber & Porter (2010) conducted isokinetic peak torque measures at angular velocities of $30° \cdot s^{-1}$. In addition, the remaining six studies measured peak torque under isometric muscle contraction (de Vos et al., 2005; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008; Lopes et al., 2014, 2016). In the following, the findings of the studies will be categorized according to the exercises used. Knee extension was investigated by six of the eight studies, while these six studies assessed nine intervention groups consisting of 288 participants who performed knee extension to assess peak power output. Significant improvements compared to the control were shown by seven intervention groups (de Vos et al., 2005a, *MD* = 15 Nm, 95% CI not reported, $p < .05$; de Vos et al., 2005b, *MD* = 26 Nm, 95% CI not reported, $p < .05$; de Vos et al., 2005c, *MD* = 32 Nm, 95% CI not reported, $p < .05$; Holsgaard-Larsen et al., 2011, *MD* = .07 $Nm \cdot bw^{-1}$, 95% CI not reported, $p < .05$; Lee et al., 2011a, *MD* = 41.9 Nm, ES = 0.41, $p < .01$; Lee et al., 2011b, *MD* = 13.7 Nm, ES = 1.12, $p < .01$; Lopes et al., 2016, *MD* = 17.1 Nm, 95 % CI [1.1, 2.22], $p < .01$), whereas two intervention groups reported no significant differences compared to the control for peak torque in knee extension (Laroche et al., 2008, *MD* = 1 $Nm \cdot kg^{-1}$, 95% CI not reported, $p < .06$; Lopes et al., 2014, *MD* = 10 Nm, 95% CI not reported, *p* < *n.s.*). For the knee flexion, eight groups were investigated by six studies, with one group showing no significant improvements compared to the control (Lopes et al., 2014, *MD* = 1.3 Nm, 95% CI not reported, *p* < *n.s.*) and the remaining seven showed a significant difference (De Vos et al., 2005a, *MD* = 5 Nm, 95% CI not reported, $p < .05$; de Vos et al., 2005b, *MD* = 10 Nm, 95% CI not reported, $p < .05$; de Vos et al., 2005c, *MD* = 17 Nm, 95% CI not reported, $p < .05$; Holsgaard-Larsen et al., 2011, *MD* = 0.1 Nm·bw^{-1}, 95% CI not reported, $p < .01$; Lee et al., 2011a, *MD* = 91.3 Nm, ES = 1.34, $p < .01$; Lee et al., 2011b, *MD* = 25.7 Nm, ES = 1.49, $p < .01$; Lopes et al., 2016, *MD* = 12.1 Nm, 95% CI [1.54, 2.98], $p < .01$). Peak Torque output was assessed for plantar flexion from four studies with five intervention groups with a total number of 150 participants. Only Kobayashi et al. (2016) showed significant improvements for plantar flexion compared to the control (*MD* = 11.3 Nm, 95% CI not reported, $p < .039$), while the remaining studies showed no differences (Lopes et al., 2014, *MD* = 3.1 Nm, 95% CI not reported, *p* < *n.s.*; Lopes et al., 2016, *MD* = 7.2 Nm, 95% CI not reported, *p* < *n.s.*; Webber & Porter, 2010a, *MD* = 9 Nm, 95% CI not reported, *p* < *n.s.*; Webber & Porter, 2010b, *MD* = 3 Nm, 95% CI not reported, *p* < *n.s.*). Besides Kobayashi et al. (2016), the remaining studies further assessed plantar extension, however, none of them found a significant improvement compared to the control (Lopes et al., 2014, *MD* = 0.3 Nm, 95% CI not reported, *p* < *n.s.*; Lopes et al., 2016, *MD* = 3.7 Nm, 95% CI not reported, *p* < *n.s.*; Webber & Porter, 2010a, *MD* = –5 Nm, 95% CI not reported, *p* < *n.s.* and Webber & Porter, 2010b, *MD* = –14 Nm, 95% CI not reported, *p* = *n.s.*). In addition, Peak Torque for hip extension and hip flexion was measured by Lopes et al. (2014) and Lopes et al. (2016). While Lopes et al. (2014) demonstrated no significant improvements for hip extension (*MD* = 17.2, 95% CI not reported, *p* = *n.s.*) and hip flexion (*MD* = 7.5, 95% CI not reported, *p* = *n.s.*), Lopes et al. (2016) reported significant improvements for hip extension (*MD* = 39.5, 95% CI [1.87, 3.59], $p < .01$) and hip flexion (*MD* = 11.3, 95% CI [1.48, 2.88], $p < .01$). Among the eight studies investigating Peak Torque output, only Lee et al. (2011) measured upper body exercises. Furthermore, Lee et al. (2011) has demonstrated significant improvements for both intervention groups in low back extension (Lee et al., 2011a, *MD* = 116 Nm, ES = 1.09, $p < .01$; Lee et al., 2011b, *MD* = 49.2 Nm, ES = 1.82, $p < .01$) and low back flexion (Lee et al., 2011a, *MD* = 77 Nm, ES = 2.1, $p < .01$; Lee et al., 2011b, *MD* = 64.3 Nm, ES = 1.63, p < .01). In addition, Lee et al. (2011) has demonstrated significant changes for the power training intervention groups compared to the control in chest press (Lee et al., 2011a, *MD* = 33.5 Nm, ES = 1.31 $p < .01$; Lee et al., 2011b, *MD* = 15.5 Nm, ES = 1.17, $p < .01$), seated row (Lee et al., 2011a, *MD* = 32.2 Nm, ES = 1.31, $p < .01$; Lee et al., 2011b, *MD* = 13.9 Nm, ES = 1.35, $p < .01$), shoulder pull (Lee et al., 2011a, *MD* = 83.5 Nm, ES = 2.07, $p < .01$; Lee et al., 2011b, *MD* = 28.1 Nm, ES = 1.36, $p < .01$). However, for shoulder press, Lee et al. (2011) reported significant improvements for one group (Lee et al., 2011a, *MD* = 15.8 Nm, ES = 0.5, p = *n.s.*; Lee et al., 2011b, *MD* = 25.8 Nm, ES = 1.27, $p < .01$).

Table 4: *Dynamic Muscle Strength and Force Expressed as Peak Torque*

					Change from baseline to post (SD)			
Authors (year)	Population	Exercise	Unit	Contraction Type	Training	Control	Difference	Significance [95% CI] / (ES)
De Vos et al., (2005)a	50	Knee Extension	Nm (net)	isometric	19 ± 16*	4 ± 13	15[7]	p < .05
		Knee Flexion	Nm (net)	isometric	11 ± 11*	6 ± 8	5[7]	p < .05
De Vos et al., (2005)b	51	Knee Extension	Nm (net)	isometric	30 ± 17*	4 ± 13	26[7]	p < .05
		Knee Flexion	Nm (net)	isometric	16 ± 14*	6 ± 8	10[7]	p < .05
De Vos et al., (2005)c	51	Knee Extension	Nm (net)	isometric	36 ± 24*	4 ± 13	32[7]	p < .05
		Knee Flexion	Nm (net)	isometric	23 ± 11 Nm*	6 ± 8 Nm	17[7]	p < .05
Holsgaard-Larsen et al. (2011)	19	Knee Extension	Nm·bw^{-1} (net)	isometric	.1*[8]	0[8]	.1[7]	p < .05
		Knee Flexion	Nm·bw^{-1} (net)	isometric	.1*[8]	.04	.1[7]	p < .01
Kobayashi et al. (2016)	56	Plantar Flexion	Nm (net)	isometric	16.4	5.1	11.3	p = .039
Laroche et al. (2008)	24	Knee Extension	Nm·kg^{-1}	isometric	7	6	1	n.s.°
Lee et al. (2011)a	39	Knee Extension	Nm (%)	kinetic†	58.4*	16.5	41.9[7]	p < .01 (0.41)
		Knee Flexion	Nm (%)	kinetic†	94.1 *	2.8	91.3[7]	p < .01 (1.34)
		Chest Press	Nm (%)	kinetic†	35.1*	1.6	33.5[7]	p < .01 (1.31)
		Seated Row	Nm (%)	kinetic†	28.9*	–3.3	32.2[7]	p < .01 (1.31)
		Shoulder Press	Nm (%)	kinetic†	14.2*	–1.6	15.8[7]	n.s. (0.50)
		Shoouler Pull	Nm (%)	kinetic†	75.1*	–8.4	83.5[7]	p < .01[€] (2.07)
		Low Back Extension	Nm (%)	kinetic†	83.5*	–32.4	115.9[7]	p < .01[€] (1.09)
		Low Back Flexion	Nm (%)	kinetic†	58.5*	–18.5	77[7]	p < .01 (2.10)
Lee et al. (2011)b[$]	39	Knee Extension	Nm (%)	kinetic‘	9.0*	–4.7	13.7[7]	p < .01 (1.12)
		Knee Flexion	Nm (%)	kinetic‘	21.1*	–4.6	25.7[7]	p < .01 (1.49)
		Chest Press	Nm (%)	kinetic‘	12.3*	–3.2	15.5[7]	p < .01 (1.17)
		Seated Row	Nm (%)	kinetic‘	13.9*	0	13.9[7]	p < .01 (1.35)
		Shoulder Press	Nm (%)	kinetic‘	18.2*	–7.6	25.8[7]	p < .01 (1.27)
		Shoouler Pull	Nm (%)	kinetic‘	18.3*	–9.8	28.1[7]	p < .01 (1.36)
		Low Back Extension	Nm (%)	kinetic‘	34.4*	–14.8	49.2[7]	p < .01[€] (1.82)
		Low Back Flexion	Nm (%)	kinetic‘	45.8*	–18.5	64.3[7]	p < .01[€] (1.63)
Lopes et al. (2014)	21	Knee Extension	Nm (net)	isometric	4.8[8]	–5.2[8]	10[7]	n.s.
		Knee Flexion	Nm (net)	isometric	.7[8]	–.6[8]	1.3[7]	n.s.
		Plantar Extension	Nm (net)	isometric	1.2[8]	.9[8]	.3[7]	n.s.
		Plantar Flexion	Nm (net)	isometric	2.1[8]	–1[8]	3.1[7]	n.s.
		Hip Extension	Nm (net)	isometric	19.9[8]	2.7[8]	17.2[7]	n.s.
		Hip Flexion	Nm (net)	isometric	1[8]	–6.5[8]	7.5[7]	n.s.
Lopes et al. (2016)	23	Knee Extension	Nm (net)	isometric	17.19 ± 8.49*	.1[#8]	17.1[7]	p < .01 [1.1, 2.22]
		Knee Flexion	Nm (net)	isometric	12.37 ± 5.24*	.3[#8]	12.1[7]	p < .01 [1.54, 2.98]
		Plantar Extension	Nm (net)	isometric	3.39 ± 2.79*	–.3[#8]	3.7[7]	n.s.
		Plantar Flexion	Nm (net)	isometric	7.55[#8]	.35[#8]	7.2[7]	n.s.
		Hip Extension	Nm (net)	isometric	34.75 ± 22.12*	–4.7[#8]	39.5[7]	p < .01 [1.87, 3.59]
		Hip Flexion	Nm (net)	isometric	16.34 ± 3.97*	5[#8]	11.3[7]	p < .01 [1.48, 2.88]
Webber & Porter (2010)a	33	Plantar Extension	Nm (%)	isokinetic”	25*	30*	–5	n.s.
		Plantar Flexion	Nm (%)	isokinetic”	17*	8*	9	n.s.
Webber & Porter (2010)b	33	Plantar Extension	Nm (%)	isokinetic”	16*	30*	–14	n.s.
		Plantar Flexion	Nm (%)	isokinetic”	11*	8*	3	n.s.

* = significant difference from baseline; [8] = calculated value (Δ=Mpost−Mpre); [7] = calculated value (Δ=ΔMT−ΔMC); ° = (*p* = .06) trend toward significance; [$] = same population as Lee et al. (2011)a; † = measured at high speed and low resistance; ‘ = measured at low speed and high resistance; ” = measured at $30°\cdot s^{-1}$; [#] = estimated from figure; [€] = analysis of covariance (between groups) week 12 values adjusted for baseline. *p* < 0.05 indicates significant baseline differences despite randomization; *(net)* = net value; *(%)* = relative to baseline

3.4.3 Dynamic Muscle Strength and Force: Peak Power and Mean Power output

This systematic review includes eight studies that assessed dynamic muscle strength and force as peak power and mean power output in groups. These 13 groups, consisting of 402 subjects in total, were investigated over a period of eight to 22 weeks. While one study conducted a 12-week intervention and measured outcomes after eight and 12 weeks (de Vos et al., 2005) and one study investigated a power training intervention over 22 weeks (Henwood et al., 2008). However, the remaining six studies conducted a 12-week intervention (Caserotti et al., 2008; Lee et al., 2011; Reid et al., 2008; Sayers & Gibson, 2010, 2014; Webber & Porter, 2010). Furthermore, 11 different exercises were performed pre- and post-intervention to assess peak power and mean power output. While knee extension (n = 196) was conducted by four studies as an outcome (de Vos et al., 2005; Lee et al., 2011; Sayers et al., 2016; Sayers & Gibson, 2010, 2014; Webber & Porter, 2010), leg press (n = 174) was investigated by three studies (de Vos et al., 2005; Reid et al., 2008; Sayers et al., 2016; Sayers & Gibson, 2010, 2014). Furthermore, two studies analysed knee flexion (n = 135) (de Vos et al., 2005; Lee et al., 2011). In addition, Webber & Porter (2010) examined dorsiflexion (n = 50) and plantar flexion (n = 50). Caserotti and colleagues (2008) conducted countermovement jumps (n = 65) and leg extension with a Power Rig (n = 65) with their participants. Two studies respectively investigated upper body exercises (de Vos et al., 2005; Lee et al., 2011), while chest press (n = 133) and seated row (n = 137) were assessed by both of them, Shoulder press (n = 39), shoulder pull (n = 39), low back extension (n = 39) and low back flexion (n = 39) were only measured by Lee and colleagues (2011). Nonetheless, Henwood and colleagues (2008) reported the mean power output of five exercises, such as chest press, biceps curl, leg press, leg extension, and leg curl as a sum. As mentioned above, knee extension was conducted by four studies investigating seven parallel groups, reporting significant improvements compared to control for all groups (Lee et al., 2011a, *MD* = 138.3 W, ES = 0.97, $p < .001$; Lee et al., 2011b, *MD* = 32.2 W, ES = 1.24, $p < .001$; Reid et al., 2008, *MD* = 23.2 W (40% 1RM), 95% CI not reported, $p < .01$; Reid et al., 2008, *MD* = 26.9 W (70% 1RM), 95% CI not reported, $p < .01$; Sayers & Gibson 2010”, *MD* = 27.2 W, 95% CI not reported, $p < .001$; Sayers & Gibson 2010$^{\alpha}$, *MD* = 33.7 W, 95% CI not reported, $p < .05$; de Vos et al., 2005a, *MD* = 9 W, 95% CI not reported, $p < .05$; de Vos et al., 2005b, *MD* = 13 W, 95% CI not reported, $p < .05$; de Vos et al., 2005c, *MD* = 9 W, 95% CI not reported, $p < .05$). In addition, four intervention groups in two studies showed significant differences in peak power output compared to control after performing a power training intervention in leg press (Sayers & Gibson 2005, *MD* = 155 W, 95% CI [49, 261], $p < .002$; de Vos et al., 2005a, *MD* = 7 W, 95% *CI* not reported, $p < .05$; de Vos et al., 2005b, *MD* = 12 W, 95% CI not reported, $p < .05$; de Vos et al., 2005c, *MD* = 10 W, 95% CI not reported, $p < .05$), while Reid et al., (2008) did not demonstrate any significant differences compared to the control for 40% one-repetition maximum testing (*MD* = 47.5 W, 95% CI not reported, *p* < *n.s.*) and for 70% of one-repetition maximum (*MD* = 40 W, 95% CI not reported, *p* < *n.s.*). However, Caserotti et al. (2008), being the only study in this systematic review performing the leg extension on a Power Rig, demonstrated significant improvements for the older group (mean age = 81.8 years) in power output compared to control (*MD* = 25 $W·kg^{-1}$, 95% CI not reported, $p = .023$), while the parallel training arm (mean age: 62.7 years) provided no evidence of a significant difference compared to the control group (*MD* = 9.8 $W·kg^{-1}$, 95% CI not reported, *p* = *n.s.*). All five power training groups showed significant improvements in power output for knee flexion compared to control (Lee et al., 2011a, *MD* = 83.5 W, ES = 1.6, $p < .004$; Lee et al., 2011b, *MD* = 57.8 W, ES = 1.23, $p < .001$; de Vos et al., 2005a, *MD* = 17 W, 95% CI not reported, $p < .05$; de Vos et al., 2005b, *MD* = 13 W, 95% CI not reported, $p < .05$; de Vos et al., 2005c, *MD* = 14 W, 95% CI not reported, $p < .05$). As mentioned above, Webber and Porter (2010) measured dorsiflexion (Weber & Porter, 2010a, *MD* = 3 W, 95% CI not reported, *p* = *n.s.*; Weber & Porter, 2010b, *MD* = 0 W, 95% CI not reported, *p* = *n.s.*) and plantar flexion (Weber & Porter, 2010a, *MD* = 13 W, 95% CI not reported, *p* = *n.s.*; Weber & Porter, 2010b, *MD* = 8 W, 95% CI not reported, *p* = *n.s.*) as outcome parameters and demonstrated no significant differences for both intervention groups when compared to the control. Caserotti et al. (2008), being the only study to assess countermovement jump as an outcome parameter, demonstrated significant improvements for both intervention groups in peak power (Caserotti et al., 2008a, *MD* = 10 $W·kg^{-1}$, 95% CI not reported, $p < .001$; Caserotti et al., 2008b, *MD* = 9.1 $W·kg^{-1}$, 95% CI not reported, $p = .038$) and mean power (Caserotti et al., 2008a, *MD* = 8.3 $W·kg^{-1}$, 95% CI not reported, $p = .01$; Caserotti et al., 2008b, *MD* = 16.9 $W·kg^{-1}$, 95% CI not reported, $p = .021$) when compared to controls. Besides one intervention group for seated row (de Vos et al., 2005c, *MD* = 7 W, 95% CI not reported, *p* = *n.s.*), all five intervention groups demonstrated significant improvements in six upper-body exercises, such as chest press (Lee et al., 2011a, *MD* = 67 W, ES = 2.22, $p < .001$; Lee et al., 2011b, *MD* = 27 W, ES = 0.63, $p = .001$; de Vos et al., 2005a, *MD* = 11 W, 95% *CI* not reported, $p < .05$; de Vos et al., 2005b, *MD* = 6 W, 95% CI not reported, $p < .05$ and de Vos et al., 2005c, *MD* = 9 W, 95% CI not reported, $p < .05$), seated row (Lee et al., 2011a, *MD* = 71.7 W, ES = 2.55, *p* <

.001; Lee et al., 2011b, *MD* = 34 W, ES = 0.30, $p = .002$; de Vos et al., 2005a, *MD* = 9 W, 95% CI not reported, $p < .05$; de Vos et al., 2005b, *MD* = 12 W, 95% CI not reported, $p < .05$), shoulder press (Lee et al., 2011a, *MD* = 65.3 W, ES = 1.26, $p < .001$; Lee et al., 2011b, *MD* = 44.4 W, ES = 1.62, $p < .001$), shoulder pull (Lee et al., 2011a, *MD* = 172.5 W, ES = 1.93, $p < .001$; Lee et al., 2011b, *MD* = 39 W, ES = 1.83, $p < .001$), low back extension (Lee et al., 2011a, *MD* = 138.9 W, ES = 1.73, $p < .001$; Lee et al., 2011b, *MD* = 84 W, ES = 2.34, $p < .001$), and low back flexion (Lee et al., 2011a, *MD* = 207.6 W, ES = 2.07, $p < .001$; Lee et al., 2011b, *MD* = 132 W, ES = 1.62, $p < .001$). Moreover, Henwood et al. (2008), which reported a sum of five exercises consisting of two upper-body and three lower-body exercises as mentioned above, demonstrated a significant difference between the intervention group and the control group (Henwood et al., 2008, *MD* = 48 W, 95% CI not reported, $p < .05$).

Table 5: *Dynamic Muscle Strength and Force Expressed as Peak Power and mean Power output*

Authors (year)	Population	Exercise	Intensity	Unit	Variable	Change from baseline to post (SD)		Difference	Significance [95% CI]/(ES)
						Training	Control		
Caserotti et al. (2008)a	40	CMJ	BW	$W \cdot kg^{-1}$ (%)	Peak power	5.4*	−4.6*	10[7]	p < .001
		CMJ	BW	$W \cdot kg^{-1}$ (%)	Mean power	4.3	−4.1	8.3[7]	p = .01
		Leg extension power rig	Flywheel‘	$W \cdot kg^{-1}$ (%)	Mean power	12.4*	2.6	9.8[7]	n.s.°
Caserotti et al. (2008)b	25	CMJ	BW	$W \cdot kg^{-1}$ (%)	Peak power	5.8	−3.3	9.1[7]	p = .038
		CMJ	BW	$W \cdot kg^{-1}$ (%)	Mean power	9.3	−7.6	16.9[7]	p = .021
		Leg extension power rig	Flywheel‘	$W \cdot kg^{-1}$ (%)	Mean power	28*	3.1	24.9[7]	p = .023
De Vos et al. (2005)a	50	Leg press	20–85% 1RM	W (%)	Peak power	9 ± 13*	2 ± 8	7[7]	p < .05
		Knee extension	20–85% 1RM	W (%)	Peak power	14 ± 13	5 ± 7	9[7]	p < .05
		Knee flexion	20–85% 1RM	W (%)	Peak power	21 ± 14	4 ± 14	17[7]	p < .05
		Chest press	20–85% 1RM	W (%)	Peak power	13 ± 12	2 ± 7	11[7]	p < .05
		Seated row	20–85% 1RM	W (%)	Peak power	11 ± 8	2 ± 9	9[7]	p < .05
De Vos et al. (2005)b	51	Leg press	20–85% 1RM	W (%)	Peak power	14 ± 9	2 ± 8	12[7]	p < .05
		Knee extension	20–85% 1RM	W (%)	Peak power	18 ± 16	5 ± 7	13[7]	p < .05
		Knee flexion	20–85% 1RM	W (%)	Peak power	17 ± 12	4 ± 14	13[7]	p < .05
		Chest press	20–85% 1RM	W (%)	Peak power	8 ± 8	2 ± 7	6[7]	p < .05
		Seated row	20–85% 1RM	W (%)	Peak power	14 ± 24	2 ± 9	12[7]	p < .05
De Vos et al. (2005)c	51	Leg press	20–85% 1RM	W (%)	Peak power	12 ± 11	2 ± 8	10[7]	p < .05
		Knee extension	20–85% 1RM	W (%)	Peak power	14 ± 13	5 ± 7	9[7]	p < .05
		Knee flexion	20–85% 1RM	W (%)	Peak power	19 ± 16	4 ± 14	14[7]	p < .05
		Chest press	20–85% 1RM	W (%)	Peak power	11 ± 13	2 ± 7	9[7]	p < .05
		Seated row	20–85% 1RM	W (%)	Peak power	9 ± 11	2 ± 9	7[7]	n.s.
Henwood et al. (2008)	34	Mean of five exercises[$]	45%, 60%, 75% 1RM	W (%)	Peak power	50.5 ± 4.1*	−2.5 ± 3.9	48[7]	p < .05
Lee et al. (2011)a	39	Knee extension	D2	W (%)	Peak power	139.5*	1.2	138.3[7]	p < .001 (0.97)
		Knee flexion	D2	W (%)	Peak power	96.1*	12.6	83.5[7]	p = .004 (1.60)
		Chest press	D2	W (%)	Peak power	53.7*	−13.3	67[7]	p < .001 (2.22)
		Seated row	D2	W (%)	Peak power	61.9*	−9.8	71.7[7]	p < .001 (2.55)
		Shoulder press	D2	W (%)	Peak power	54.6*	−10.7	65.3[7]	p < .001 (1.26)
		Shoulder pull	D2	W (%)	Peak power	159.1*	−13.4	172.5[7]	p < .001 (1.93)
		Low back extension	D2	W (%)	Peak power	104.4*	−34.5	138.9[7]	p < .001[€] (1.73)
		Low back flexion	D2	W (%)	Peak power	177.3*	−30.3	207.6[7]	p < .001[€] (2.07)
Lee et al. (2011)b†	39	Knee extension	D11	W (%)	Peak power	26.1*	−6.2	32.2[7]	p < .001 (1.24)
		Knee flexion	D11	W (%)	Peak power	36.0*	−21.8	57.8[7]	p < .001 (1.23)
		Chest press	D11	W (%)	Peak power	27.6*	−6.4	27[7]	p = .001 (0.63)
		Seated row	D11	W (%)	Peak power	18.7*	−5.3	34[7]	p = .002 (0.30)
		Shoulder press	D11	W (%)	Peak power	30.8*	−13.6	44.4[7]	p < .001 (1.62)
		Shoulder pull	D11	W (%)	Peak power	29.7*	−9.3	39[7]	p < .001 (1.83)
		Low back extension	D11	W (%)	Peak power	66.3*	−17.7	84[7]	p < .001[€] (2.34)
		Low back flexion	D11	W (%)	Peak power	127.1*	−4.9	132[7]	p < .001[€] (1.62)
Reid et al. (2008)	35	Leg press	40% 1RM	W	Peak power	66.25 ± 15[#]	18.75 ± 17.5[#]	47.5[7]	n.s.
		Leg press	70% 1RM	W	Peak power	62.5 ± 15.25	22.5 ± 19[#]	40[7]	n.s.
		Knee extension	40% 1RM	W	Peak power	28.75 ± 5*	5.6 ± 3.1	23.2[7]	p < .01
		Knee extension	70% 1RM	W	Peak power	33.1 ± 6.25*	6.25 ± 3.5	26.9[7]	p < .01
Sayers & Gibson (2010)	25	Knee extension	40–90% 1RM”	W (%)	Peak power	26.2[8]	−1[8]	27.2[7]	p < .001
		Knee extension	40–90% 1RM[α]	W (%)	Peak power	35.3[8]	1.7[8]	33.7[7]	p < .05
Sayers & Gibson (2014)	42	Leg press	40–90% 1RM	W	Peak power	186 ± 131	31.7 ± 130	155	p = .002 [CI: 49, 261]
Webber & Porter (2010)a	33	Dorsiflexion	$90° \cdot s^{-1}$[@]	W (%)	Peak power	27	29	3[7]	n.s.
		Plantar flexion	$90° \cdot s^{-1}$[@]	W (%)	Peak power	17	4	13[7]	n.s.
Webber & Porter (2010)b	33	Dorsiflexion	$90° \cdot s^{-1}$[@]	W (%)	Peak power	29	29	0[7]	n.s.
		Plantar flexion	$90° \cdot s^{-1}$[@]	W (%)	Peak power	12	4	8[7]	n.s.

1RM = one-repetition maximum**;** * = statistically significant difference from baseline (*p* < .05); [8] = calculated value (Δ=Mpost−Mpre); [7] = calculated value (Δ=ΔMT−ΔMC); ° = *p* = .055; [$] = sum of five exercises: chest press, biceps curl, leg press, leg extension, and leg curl; † = same sample as in Lee et al. (2011)[a]; ’ = flywheel resistance not reported; ” = measured at a load relative to post-training *1RM*; [@] = measured using an isokinetic dynamometer; α = measured at a load relative to baseline *1RM*; # = value extracted from figure; € = analysis of covariance (between groups) week 12 values adjusted for baseline. *p* < .05 indicates significant baseline differences despite randomization; D2 = measured at high velocity and low resistance; D11 = measured at low velocity and high resistance; *(%)* = relative to baseline

3.4.4 Rate of Force Development & Rate of Torque Development

The effects of a power training intervention on rate of force development and rate of torque development were investigated by four studies which have assessed these parameters during leg press (n = 65), hip extension (n = 44), hip flexion (n = 44), knee extension (n = 68), knee flexion (n = 44), plantar flexion (n = 100), and plantar extension (n = 44). It should be noted that all studies measured Rate of Force and Torque Development only in lower-body exercises. Caserotti et al. (2008) was the only study to measure rate of force development, while the remaining three studies assessed rate of torque development. It should be noted that Caserotti and colleagues investigated two parallel arms, thus five intervention groups were compared against the control group. Caserotti et al. (2008) demonstrated for both training arms significant improvements compared to the control group for leg press (Caserotti et al., 2008a, MD = 18.7 N·kg^{-1}, 95% CI not reported, p = .024; Caserotti et al., 2008b, MD = 54.5 N·kg^{-1}, 95% CI not reported, p = .001). In contrast, for hip extension (Lopes et al., 2014, MD = –63.2 N·m·s^{-1}, 95% CI not reported, p = *n.s.*; Lopes et al., 2016, MD = 86.1 N·m·s^{-1}, 95% CI not reported, p = *n.s.*) and hip flexion (Lopes et al., 2014, MD = 216.8 N·m·s^{-1}, 95% CI not reported, p = *n.s.*; Lopes et al., 2016, MD = 58.6 N·m·s^{-1}, 95% CI not reported, p = *n.s.*) assessed by Lopes et al. (2014, 2016) demonstrated no significant changes compared to the control group for rate of torque development. Furthermore, knee extension was assessed by three studies, and none of them reported significant differences in rate of torque development when comparing intervention and control groups (LaRoche et al., 2008, MD = 1 N·m·s^{-1}·kg^{-1}, 95% CI not reported, p = *n.s.*; Lopes et al., 2014, MD = 113.1 N·m·s^{-1}, 95% CI not reported, p = *n.s.*; Lopes et al., 2016, MD = 54.2 N·m·s^{-1}, 95% CI not reported, p = *n.s.*). In addition, for knee flexion, Lopes et al. (2014, 2016) did not demonstrate significant changes compared to the control group (Lopes et al., 2014, MD = 115.4 N·m·s^{-1}, 95% CI not reported, p = *n.s.*; Lopes et al., 2016, MD = 32.9 N·m·s^{-1}, 95% CI not reported, p = *n.s.*). Conflicting results were reported for plantar flexion, as Kobayashi et al. (2016) demonstrated significant changes in rate of torque development compared to the control group (Kobayashi et al., 2016, MD = 75.1 N·m·s^{-1}, 95% CI not reported, p = .036). Lopes et al. (2014, 2016) reported no differences for the intervention group compared to the control group (Lopes et al., 2014, MD = 18.3 N·m·s^{-1}, 95% CI not reported, p = *n.s.*; Lopes et al., 2016, MD = 30.6 N·m·s^{-1}, 95% CI not reported, p = *n.s.*). Furthermore, Lopes et al. (2014, 2016) reported no significant changes in rate of torque development for plantar extension (Lopes et al., 2014, *MD* = 29.7 $N \cdot m \cdot s^{-1}$, 95% CI not reported, p = *n.s.*; Lopes et al., 2016, *MD* = 36.5 $N \cdot m \cdot s^{-1}$, 95% CI not reported, p = *n.s.*).

Table 6: *Rate of Force Development & Rate of Torque Development*

Authors (year)	Population	Variable	Exercise	Unit	Change from baseline to post (SD)		Difference	Significance
					Training	Control		
Caserotti et al. (2008)a [1]	40	RFD200	Leg press	N·kg^{-1}	18.1*	–.6	18.7[7]	p = .024
Caserotti et al. (2008)b [1]	25	RFD200	Leg press	N·kg^{-1}	50.5*	–4.0	54.5[7]	p = .001
Kobayashi et al. (2016) [2]	56	RTD	Plantar flexion	N·m·s^{-1} (net)	89.6[8]	14[8]	75.6[7]	p = .036°
LaRoche et al. (2008)[3]	24	RTD	Knee extension	N·m·s^{-1}·kg^{-1} (net)	7.2 ± 3.1*	6.2 ± 2.8*	1[7]	n.s.
Lopes et al. (2014)[4]	21	RTD	Knee extension	N·m·s^{-1} (net)	77.6[8]	–35.4[8]	113.1[7]	n.s.
		RTD	Knee flexion	N·m·s^{-1} (net)	76.1[8]	–39.3[8]	115.4[7]	n.s.
		RTD	Plantar extension	N·m·s^{-1} (net)	12.5[8]	–5.9[8]	18.3[7]	n.s.
		RTD	Plantar flexion	N·m·s^{-1} (net)	18.8[8]	–10.9[8]	29.7[7]	n.s.
		RTD	Hip extension	N·m·s^{-1} (net)	–298.4[8]	–235.2[8]	-63.2[7]	n.s.
		RTD	Hip flexion	N·m·s^{-1} (net)	61.2[8]	–155.6[8]	216.8[7]	n.s.
Lopes et al. (2016) [4]	23	RTD	Knee extension	N·m·s^{-1} (%)	60[#8]	5.7[#8]	54.2[7]	n.s.
		RTD	Knee flexion	N·m·s^{-1} (%)	17.6[#8]	–15.3[#8]	32.9[7]	n.s.
		RTD	Plantar extension	N·m·s^{-1} (%)	31.2[#8]	.6[#8]	30.6[7]	n.s.
		RTD	Plantar flexion	N·m·s^{-1} (%)	27.9[#8]	–8.6[#8]	36.5[7]	n.s.
		RTD	Hip extension	N·m·s^{-1} (%)	75*[#8]	–11.1[#8]	86.1[7]	n.s.
		RTD	Hip flexion	N·m·s^{-1} (%)	45*[#8]	–13.6[#8]	58.6[7]	n.s.

* = statistically significant difference from baseline; # = data extracted from a figure; 8 = calculated value (Δ=Mpost−Mpre); 7 = calculated value (Δ=ΔMT−ΔMC); ° = partial eta squared (η^2_p = .087); *(net)* = net value; *(%)* = relative to baseline; 1 = mean tangential slope of the force–time curve within the first 200 ms of contraction; 2 = maximum slope of the torque–time curve within the first 200 ms of contraction; 3 = peak torque recorded within the first 200 ms of contraction; 4 = highest slope derived from the force–time curve values

3.4.5 Electromyographic Assessment of Neuromuscular Activation

Three studies with a sum of 99 participants derived EMG signals as an outcome after a power training intervention to assess changes in neuromuscular activation. The intervention period varied from 12-weeks (Holsgaard-Larsen et al., 2011) to eight weeks (LaRoche et al., 2008) to four weeks (Kobayashi et al., 2016). It should be noted that all three studies assessed EMG activity at different tasks. While Holsgaard-Larsen et al. (2011) measured EMG activity during stair ascent, Kobayashi et al. (2016) obtained EMG signals of muscle activity during plantar flexion and one-leg standing, and LaRoche et al. (2008) during knee extension. For knee extension, LaRoche et al. (2008) showed a significant reduction in coactivation for the antagonist muscle group derived from the biceps femoris after the power training intervention compared to the control group (LaRoche et al., 2008, *MD* = –28.5 pEMG, 95% CI not reported, $p < .05$). However, the obtained signals from the rectus femoris during knee extension did not differ significantly from the control group for onset EMG (LaRoche et al., 2008, *MD* = not reported, 95% CI not reported, *p* = *n.s.*), rate of EMG rise (LaRoche et al., 2008, *MD* = not reported, 95% CI not reported, *p* = *n.s.*), and motor time (LaRoche et al., 2008, *MD* = not reported, 95% CI not reported, *p* = *n.s.*). It should be noted that LaRoche et al. (2008) and Kobayashi et al. (2016) assessed EMG signals during maximal effort, while Holsgaard-Larsen and colleagues derived them during self-selected, maximal effort and standardized conditions. Furthermore, Kobayashi et al. (2016) assessed EMG signals during one-leg standing. Kobayashi and colleagues (2016) demonstrated no significant difference compared to the control group for the plantar flexors (Kobayashi et al., 2016, *MD* = –7.1 EMG_{RTD}, 95% CI not reported, *p* = *n.s.*) and the tibialis anterior (Kobayashi et al., 2016, *MD* = –2.5 EMG_{RTD}, 95% CI not reported, *p* = *n.s.*) during plantar flexion. However, obtained EMG signals during one-leg standing showed a significant improvement in activity of the plantar flexors (Kobayashi et al., 2016, *MD* = 0.08 m·V, 95% CI not reported, $p = .030$), while no significant difference was reported for the tibialis anterior (Kobayashi et al., 2016, *MD* = 0.22 m·V, 95% CI not reported, *p* = *n.s.*). As mentioned above, Holsgaard-Larsen et al. (2011) derived EMG signals while stair climbing at different intensities and phases. Holsgaard-Larsen et al. (2011) reported no significant changes in EMG signals with self-selected speeds during the stance phase for vastus lateralis (Holsgaard-Larsen et al., 2011, *MD* = 1.9 EMG_{max}, 95% CI not reported, *p* = *n.s.*), vastus medialis (Holsgaard-Larsen et al., 2011, *MD* = –3.6 EMG_{max}, 95% CI not reported, *p* = *n.s.*), rectus femoris (Holsgaard-Larsen et al., 2011, *MD* = 4.5 EMG_{max}, 95% CI not reported, *p* = *n.s.*), biceps femoris (Holsgaard-

Larsen et al., 2011, *MD* = 0.5 EMG_{max}, 95% CI not reported, *p* = *n.s.*), and semitendinosus (Holsgaard-Larsen et al., 2011, *MD* = –1.6 EMG_{max}, 95% CI not reported, *p* = *n.s.*). Moreover, Holsgaard-Larsen et al. (2011) reported no significant changes in quadriceps to hamstring activation ratio during the stance phase (Holsgaard-Larsen et al., 2011, *MD* = 5.5, 95% CI not reported, *p* = *n.s.*), loading phase (Holsgaard-Larsen et al., 2011, *MD* = 5.4, 95% CI not reported, *p* = *n.s.*), and unloading phase (Holsgaard-Larsen et al., 2011, *MD* = 11.4, 95% CI not reported, *p* = *n.s.*) at self-selected stair ascent speed. Similarly, recorded EMG signals over the course of stair ascent with maximal effort did not show significant differences for vastus lateralis (Holsgaard-Larsen et al., 2011, *MD* = 10 EMG_{max}, 95% CI not reported, *p* = *n.s.*), vastus medialis (Holsgaard-Larsen et al., 2011, *MD* = 8.2 EMG_{max}, 95% CI not reported, *p* = *n.s.*), rectus femoris (Holsgaard-Larsen et al., 2011, *MD* = 23.7 EMG_{max}, 95% CI not reported, *p* = *n.s.*), biceps femoris (Holsgaard-Larsen et al., 2011, *MD* = 5.1 EMG_{max}, 95% CI not reported, *p* = *n.s.*), and semitendinosus (Holsgaard-Larsen et al., 2011, *MD* = 14.8 EMG_{max}, 95% CI not reported, *p* = *n.s.*). Furthermore, no significant changes in quadriceps to hamstring activation in stair climbing with maximal effort were shown in the stance phase (Holsgaard-Larsen et al., 2011, *MD* = 5.5, 95% CI not reported, *p* = *n.s.*), loading phase (Holsgaard-Larsen et al., 2011, *MD* = 10.4, 95% CI not reported, *p* = *n.s.*), and unloading phase (Holsgaard-Larsen et al., 2011, *MD* = –0.3, 95% CI not reported, *p* = *n.s.*). Throughout standardized conditions at stair ascent, semitendinosus demonstrated significantly greater activation (Holsgaard-Larsen et al., 2011, *MD* = 5.4 EMG_{max}, 95% CI not reported, *p* = .036), while vastus lateralis (Holsgaard-Larsen et al., 2011, *MD* = 2 EMG_{max}, 95% CI not reported, *p* = *n.s.*), vastus medialis (Holsgaard-Larsen et al., 2011, *MD* = 0.3 EMG_{max}, 95% CI not reported, *p* = *n.s.*), rectus femoris (Holsgaard-Larsen et al., 2011, *MD* = –9.0 EMG_{max}, 95% CI not reported, *p* = *n.s.*), and biceps femoris (Holsgaard-Larsen et al., 2011, *MD* = 8.6 EMG_{max}, 95% CI not reported, *p* = *n.s.*) did not. It should be noted that standardized conditions were defined as stride frequencies of 35 per minute. Furthermore, no significant differences compared to the control were reported during standardized conditions for quadriceps to hamstring activation ratio in the stance phase (Holsgaard-Larsen et al., 2011, *MD* = 4.7, 95% CI not reported, *p* = *n.s.*), loading phase (Holsgaard-Larsen et al., 2011, MD = 5.7, 95% CI not reported, *p* = *n.s.*), and unloading phase (Holsgaard-Larsen et al., 2011, *MD* = –1, 95% CI not reported, *p* = *n.s.*).

Table 7: *Electromyographic Assessment of Neuromuscular Activation*

Authors (year)	Population	Exercise / test	Intensity	Variable (unit)	Muscle	Change from baseline to post (SD) Training	Control	Difference	Significance
Holsgaard-Larsen et al. (2011)	19	Stair ascent (stance phase)	Self-selected	%EMG$_{max}$ [£]	Vastus lateralis	2.8#[8]	.9	1.9[7]	n.s.
		Stair ascent (stance phase)	Self-selected	%EMG$_{max}$ [£]	Vastus medialis	−.1	3.5	−3.6[7]	n.s.
		Stair ascent (stance phase)	Self-selected	%EMG$_{max}$ [£]	Rectus femoris	7*	2.5	4.5[7]	n.s.
		Stair ascent (stance phase)	Self-selected	%EMG$_{max}$ [£]	Biceps femoris	−2.3	−2.8	.5[7]	n.s.
		Stair ascent (stance phase)	Self-selected	%EMG$_{max}$ [£]	Semitendinosus	−10	−8.4	−1.6[7]	n.s.
		Stair ascent (stance phase)	Self-selected	%Q/H ratio	Quadriceps vs. hamstrings[$]	0	−5.5	5.5	n.s.
		Stair ascent (loading phase)	Self-selected	%Q/H ratio	Quadriceps vs. hamstrings[$]	−2.1	−7.5	5.4[7]	n.s.
		Stair ascent (unloading phase)	Self-selected	%Q/H ratio	Quadriceps vs. hamstrings[$]	3.3	−8.1	11.4[7]	n.s.
		Stair ascent (stance phase)	Maximal effort	%EMG$_{max}$ [£]	Vastus lateralis	15	5	10[7]	n.s.
		Stair ascent (stance phase)	Maximal effort	%EMG$_{max}$ [£]	Vastus medialis	10.2	2	8.2[7]	n.s.
		Stair ascent (stance phase)	Maximal effort	%EMG$_{max}$ [£]	Rectus femoris	30.6*	6.9	23.7[7]	n.s.
		Stair ascent (stance phase)	Maximal effort	%EMG$_{max}$ [£]	Biceps femoris	−7.6	−12.7	5.1[7]	n.s.
		Stair ascent (stance phase)	Maximal effort	%EMG$_{max}$ [£]	Semitendinosus	−.2	−15	14.8[7]	n.s.
		Stair ascent (stance phase)	Maximal effort	%Q/H ratio	Quadriceps vs. hamstrings[$]	−2.6	−8.1	5.5[7]	n.s.
		Stair ascent (loading phase)	Maximal effort	%Q/H ratio	Quadriceps vs. hamstrings[$]	−3.5	−13.9	10.4[7]	n.s.
		Stair ascent (unloading phase)	Maximal effort	%Q/H ratio	Quadriceps vs. hamstrings[$]	3.7	4	−0.3[7]	n.s.
		Stair ascent (stance phase)	Standardized°	%EMG$_{max}$ [£]	Vastus lateralis	−.8	−2.8	2.0[7]	n.s.
		Stair ascent (stance phase)	Standardized°	%EMG$_{max}$ [£]	Vastus medialis	-1.5	-1.8	.3[7]	n.s.
		Stair ascent (stance phase)	Standardized°	%EMG$_{max}$ [£]	Rectus femoris	−5.1	3.9	−9[7]	n.s.
		Stair ascent (stance phase)	Standardized°	%EMG$_{max}$ [£]	Biceps femoris	−.1	−8.7*	8.6[7]	n.s.
		Stair ascent (stance phase)	Standardized°	%EMG$_{max}$ [£]	Semitendinosus	−2.6	−8*	5.4[7]	p = .036
		Stair ascent (stance phase)	Standardized°	%Q/H ratio	Quadriceps vs. hamstrings[$]	2.4	−2.3	4.7[7]	n.s.
		Stair ascent (loading phase)	Standardized°	%Q/H ratio	Quadriceps vs. hamstrings[$]	3.2	−2.5	5.7[7]	n.s.
		Stair ascent (unloading phase)	Standardized°	%Q/H ratio	Quadriceps vs. hamstrings[$]	1.4	2.4	−1.0[7]	n.s.
Kobayashi et al. (2016)	56	Plantar flexion	Maximal effort	EMG$_{RTD}$ (%) [@]	Plantar flexors”	−5.5[8]	1.6[8]	−7.1[7]	n.s.
		Plantar flexion	Maximal effort	EMG$_{RTD}$ (%) [@]	Tibialis anterior	.6[8]	−1.9[8]	2.5[7]	n.s.
		Single-leg stance	n/a	mV [α]	Plantar flexors”	.1[8]	0[8]	.08	p = .030
		Single-leg stance	n/a	mV [α]	Tibialis anterior	0[8]	−.2[8]	.22	n.s.
LaRoche et al. (2008)	24	Knee extension	Maximal effort	%pEMG	Biceps femoris	−12.5*	16#[8]	−28.5	p < .05
		Knee extension	Maximal effort	%pEMG[ɣ]	Rectus femoris	85.4†	92.7†	n/a	n.s.
		Knee extension	Maximal effort	%pEMG·s^{-1} [&]	Rectus femoris	1079†	1152†	n/a	n.s.
		Knee extension	Maximal effort	ms ‘	Rectus femoris	95†	94†	n/a	n.s.

VM = vastus medialis; *VL* = vastus lateralis; *RF* = rectus femoris; *BF* = biceps femoris; *ST* = semitendinosus; * = significant difference from baseline; [8] = calculated value (Δ=Mpost−Mpre); [7] = calculated value (Δ=ΔMT−ΔMC); ° = constant stride frequency of 35/min; [$] = quadriceps (VM + VL + RF) vs. hamstrings (BF + ST); *%Q/H ratio* = quadriceps-to-hamstrings; † = only baseline values reported in the study; ‘ = motor time: defined as the delta between neural activation onset (beginning of the EMG burst) and force development; ” = combined activity of gastrocnemius medialis; gastrocnemius lateralis and soleus; [@] = root mean square value of the trial with the highest PT and RTD within the first 250 ms; α = root mean square values for each muscle calculated in the time window of 5–25 s from the onset of the trial with longer standing time; [#] = estimated from graph; [&] = rate of EMG rise (s^{-1} %); [ɣ] = onset EMG (%); [£] = normalized to maximal EMG signal during maximal voluntary contraction; *n/a* = not applicable

3.4.6 Physical Performance Parameters

Six studies of 17 included in this systematic review assessed physical performance parameters after a power training intervention. As mentioned above, some studies performed multiple arm studies, thus, data from eight intervention groups were compared to control groups. For details, see Table 8 below. Overall, data from 208 participants were collected with eighteen different tests after intervention periods ranging from six to 22 weeks. Sañudo et al. (2016), being the only study to investigate a period of six weeks of power training intervention, is followed by Pazit et al. (2016), which conducted an eight-week intervention. Furthermore, only one study investigated a ten-week intervention period (Richardson et al., 2019), while two studies performed a 12-week intervention (Sayers et al., 2016; Webber & Porter, 2010). However, Henwood et al. (2008), being the only study to investigate physical performance parameters after an eight- and 22-week intervention, showed mixed results. While five studies conducted functional testing with a chair such as: 30-second Sit-to-Stand Test ($n = 48$), Timed Up and Go Test ($n = 94$), chair rise ($n = 34$) and 8-foot Up and Go Test ($n = 30$). Three studies assessed walking tests such as: usual six-meter walk ($n = 34$), fast six-meter walk ($n = 34$), 400-m walk ($n = 34$), backward walk ($n = 34$), six-minute walk ($n = 30$), habitual gait speed ($n = 42$), and maximal gait speed ($n = 42$). Furthermore, two studies used testing with stairs, such as the stair climb test ($n = 34$), and the timed stair climb test ($n = 18$). In addition, Henwood and colleagues (2008) performed a test which involved rising from a lying position to standing, the floor rise-to-standing test ($n = 34$). The functional reach test ($n = 34$), performed to assess static balance while standing behind a line and reaching across a measuring tape as far as possible, and a proprioception test ($n = 18$), was performed by one study each. The Short Physical Performance Battery ($n = 42$), consisting of a gait speed, standing balance, and chair rise test, was performed by Sayers et al. (2016). For details on which test was performed by which study, see Table 8 below. In the following, the results of performance tests performed with a chair are presented. Two studies reported a significant difference compared to the control for the Timed Up-and-Go Test (Pazit et al., 2018, *MD* = –1.8 s, 95% CI [0.16, 3.48], *p* = .03; Sañudo et al., 2019, *MD* = –0.67 s, 95% CI [–1.25, –0.98], *p* = .023), and one study could not show an effect after a power training for the Timed Up-and-Go Test (Sayers et al., 2016, *MD* = –0.37 s, 95% CI not reported, *p* = *n.s.*). However, the significant improvements in the 30-second Sit-to-Stand test demonstrated by Pazit et al. 2018 (*MD* = 5 s, 95% CI [–9.94, –0.05], *p* = .04) could not be replicated by Richardson et al. (2019), while two parallel intervention arms performed the intervention (Richardson et al., 2019a, *MD* = 1 repetition, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = 1 repetition, 95% CI not reported, *p* = *n.s.*). It should be noted that the same test was called differently in both studies. Pazit et al. (2018) called the test: 30-Second Sit-to-Stand test, while Richardson et al. (2019) referred to the test as 30-second Chair-Stand Test. Henwood et al. (2008) reported significant improvements in the chair raise test after eight weeks (*MD* = –1.6 s, 95% CI not reported, *p* = .004) and twenty-two weeks (*MD* = –2 repetition, 95% CI not reported, *p* ≤ .001). It must be emphasized that Pazit et al. (2018) and Richardson et al. (2019) performed the chair raise test for 30 seconds, whereas Henwood and colleagues instructed the participants to perform five repetitions of chair raises and measured the time. Lastly, Richardson et al. (2019) reported no significant changes compared to the control for the 8-Foot Up-and-Go Test for both parallel intervention groups (Richardson et al., 2019 a, *MD* = –0.4 s, 95% CI not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = –0.6 s, 95% CI not reported, *p* = *n.s.*). Participants started in a sitting position for the 8-Foot Up-and-Go Test. After getting up, they walk around a cone which is eight feet away and walk back to the chair, while the time is measured until they sit down (Rikli & Jones, 1999). As mentioned above, three studies conducted walking tests in different variations, while Richardson et al. (2019) investigated two parallel intervention groups, thus, four groups were compared to the control after the power training intervention with regard to walking ability. Richardson et al. (2019) and Henwood et al. (2008) performed long-distance walking tests, while Richardson and colleagues conducted a six-minute walk test (Richardson et al., 2019a, *MD* = 8 m, 95% *CI* not reported, *p* = *n.s.*; Richardson et al., 2019b, *MD* = 26 m, 95% CI not reported, *p* = *n.s.*), whereas Henwood and colleagues performed a 400-m walking test eight weeks post-intervention (*MD* = –14.5 m, 95% CI not reported, *p* = *n.s.*) and 22 weeks post-intervention (*MD* = –16.4 m, 95% CI not reported, *p* = *n.s.*), with both studies showing no significant differences compared to the control. In contrast, short-distance walking tests were investigated by Sayers et al. (2016) and Henwood et al. (2008), while Henwood et al. (2008) assessed a six-meters walk and Sayers et al. (2016) a ten-meter walk. In fast walking, Sayers and colleagues reported no significant differences (*MD* = 0.04 $m \cdot s^{-1}$, 95% CI not reported, *p* = *n.s.*) and Henwood and colleagues reported no significant differences for the 8-weeks (*MD* = 0.1 s, 95% CI not reported, *p* = *n.s.*), however, after 22 weeks, a significant difference was reported (*MD* = –0.3 s, 95% CI not reported, *p* ≤ .001). In contrast, Henwood and colleagues reported no significant differences for habitual gait speed for both: eight weeks (*MD* = –0.2 s, 95% CI not reported, *p* = *n.s.*) and 22 weeks (*MD* = –0.12 s, 95% CI not reported, *p* = *n.s.*) post intervention. In addition, Sayers et al. (2016) did not demonstrate significant differences for habitual gait speed either (*MD* = 0.0 m·s^{-1}, 95% CI not reported, p = *n.s.*). Lastly, only Henwood and colleagues assessed backward walking time over six meters with no significant differences after eight (*MD* = 0.12 s, 95% CI not reported, p = *n.s.*) and 22 weeks (*MD* = –2.3 s, 95% CI not reported, p = *n.s.*) were shown compared to the control. In addition, physical performance in the form of stair climbing was assessed by two studies with three intervention groups. Henwood et al. (2008) conducted a stair rise test consisting of eleven stairs with a height of sixteen centimeters per stair without using the hands (Henwood & Taaffe, 2006), whereas Pazit and colleagues instructed the participants to complete ten stairs with a height of fourteen centimeters per stair. However, Henwood et al. (2008) reported significant differences compared to control for the timed stair climb test after eight-weeks (*MD* = –0.62 s, 95% CI not reported, p = .004), but no significant differences after 22 weeks (*MD* = –0.47 s, 95% CI not reported, p = *n.s.*). Furthermore, Pazit et al. (2018) did not demonstrate significant differences for the timed stair climb (*MD* = 36.7 W, 95% CI [–83.87, 10.49], p = *n.s.*). Being the only study to investigate the ability to rise from a lying position on the floor to a standing position, Henwood et al. (2008) reported no significant differences after eight weeks (*MD* = –0.19 s, 95% CI not reported, p = *n.s.*) and 22 weeks (*MD* = –0.25 s, 95% CI not reported, p = *n.s.*) of power training compared to the control. In addition, Henwood and colleagues performed the functional reach test and reported no significant differences after eight (*MD* = 3.6 cm, 95% CI not reported, p = *n.s.*) and 22 weeks (*MD* = 3.8 cm, 95% CI not reported, p = *n.s.*). As mentioned above, the effect of power training on proprioception was investigated by Pazit et al. (2018). Pazit and colleagues reported no significant differences in knee proprioception (*MD* = –0.1°, 95% CI not reported, p = *n.s.*) after the power training intervention compared to control. Furthermore, Webber and Porter (2010) showed no significant improvements in the rapid movement test for both intervention groups compared to the control (Weber & Porter 2010a: *MD* = 6 m·s^{-1}, 95% CI not reported, p = *n.s.*; Weber & Porter 2010b, *MD* = 10 m·s^{-1}, 95% CI not reported, p = *n.s.*). The rapid movement test consists of reacting to a stimulus by moving one foot from one pedal to another pedal. Moreover, Sayers et al. (2016), being the only study to assess the Short Physical Performance Battery, consisting of balance, timed walking, and repetitive chair raises, reported significant differences compared to control after the power training intervention (*MD* = 1 (Score: 0-12), 95% CI not reported, p = .01).

Table 8: *Physical Performance Parameters*

Authors (year)	Population	Performance test	Unit	Change from baseline to post (SD) Training	Control	Difference	Significance [95% CI]
Henwood et al. (2008)[1]	34	Floor Rise to Standing	Duration (s)	.1[8]	.3*[8]	–.2[7]	n.s.
		Stair Climb	Duration (s)	–.4*[8]	.3[8]	–.6[7]	p = .004
		Usual 6 m Walk	Duration (s)	–.2[8]	.1[8]	–.3[7]	n.s.
		Fast 6 m Walk	Duration (s)	–.2*[8]	.1[8]	–.3[7]	n.s.
		Backward 6 m Walk	Duration (s)	–1.3[8]	–1.4[8]	.1[7]	n.s.
		Chair Rise	Duration (s)	–1.5*[8]	.1[8]	–1.6[7]	p = .004
		Functional Reach	Distance (cm)	2.2[8]	–1.4[8]	3.6[7]	n.s.
		400 m Walk	Duration (s)	–8.6[8]	5.9[8]	–14.5[7]	n.s.
Henwood et al. (2008)[2]	34	Floor Rise to Standing	Duration (s)	.1[8]	.3*[8]	–.3[7]	n.s.
		Stair Climb	Duration (s)	–.3[8]	.2[8]	–.5[7]	n.s.
		Usual 6 m Walk	Duration (s)	.1[8]	.2[8]	–.1[7]	n.s.
		Fast 6 m Walk	Duration (s)	–.1[8]	.2[8]	–.3[7]	$p \leq .001$
		Backward 6 m Walk	Duration (s)	–2.9[8]	–.6[8]	–2.3[7]	n.s.
		Chair Rise	Duration (s)	–1.5*[8]	.5[8]	–2[7]	$p \leq .001$
		Functional Reach	Distance (cm)	2.7*[8]	–1.1[8]	3.8[7]	n.s.
		400 m Walk	Duration (s)	–19.4*[8]	–3[8]	–16.5[7]	n.s.
Pazit et al. 2018	18	30–Second Sit–to–Stand	Repetitions	4.5*[8]	–.6[8]	5	p = .04 [–9.94, –0.05]
		Timed Up and Go (TUG)	Duration (s)	–1.2	.6[8]	–1.8	p = .03 [0.16, 3.48]
		Timed Stair Climb	Power output (W)	11.1[8]	–25.5[8]	36.7	n.s. [–83.87, 10.49]
		Knee Proprioception	Degree (°)	.3[8]	.4[8]	–.1[7]	n.s.
Richardson et al. (2019)a	20	8-Foot Up–and–Go	Duration (s)	–.3[8]	.1[8]	–.4[7]	n.s.
		30-Second Chair Stand	Repetitions	1*[8]	0[8]	1[7]	n.s.
		6–Minute Walk	Distance (m)	3[8]	17[8]	8[7]	n.s.
Richardson et al. (2019)b	20	8–Foot Up–and–Go	Duration (s)	–.5*[8]	.1[8]	–0.6[7]	n.s.
		30-Second Chair Stand	Repetitions	1*[8]	0[8]	1[7]	n.s.
		6–Minute Walk	Distance (m)	4[8]	17[8]	26[7]	n.s.
Sañudo et al. (2019)	34	Timed Up and Go (TUG)	Duration (s)	–.9*[8]	–.2[8]	–.7[7]	p = .023 [–1.25, –0.98]
Sayers et al. (2016)	42	Habitual Gait Speed	Velocity ($m \cdot s^{-1}$)	.03 ± .16	.03 ± .08	0[7]	n.s.
		Maximal Gait Speed	Velocity ($m \cdot s^{-1}$)	−.02 ± .17	−.06 ± .10	.1[7]	n.s.
		Timed Up and Go (TUG)	Duration (s)	−.50 ± 1.23	−.13 ± 1.14	–.4[7]	n.s.
		SPPB”	Score (0-12)	1.04 ± .19	.00 ± .82	1[7]	p = .01
Webber & Porter (2010)a	33	Rapid Movement $	Velocity $m \cdot s^{-1}$ (%)	8	2	6[7]	n.s.
Webber & Porter (2010)b	33	Rapid Movement $	Velocity $m \cdot s^{-1}$ (%)	12*	2	10[7]	n.s.

* = statistically significant difference from baseline; ” = Short Physical Performance Battery (SPPB); [8] = calculated value (Δ=Mpost−Mpre); [7] = calculated value (Δ=ΔMT−ΔMC); $ = measured as movement time: defined as the interval between activation of the “gas” switch and depression of the “brake” switch; [1] = post-intervention, measured after 8 weeks; [2] = post-intervention, measured after 24 weeks; *(%)* = relative to baseline

3.5 Results of Syntheses

Dynamic muscle strength was assessed as one-repetition maximum, three-repetition maximum, peak torque, peak power, and mean power output. While 15 studies measured muscle strength with 585 participants, the average PEDro score of these studies was 4.8. Moreover, the ability of muscle activation was measured by derived electromyographic signals, rate of force development and rate of torque development in six studies with 208 participants. These six studies scored an average PEDro score of 4.5. Lastly, neuromuscular outcome measures, assessed as physical performance parameters, were investigated by six studies with 208 participants with an average PEDro score of 5.6. Among dynamic muscle strength outcome parameters, one-repetition maximum and three-repetition maximum were assessed by nine studies, in contrast peak torque, which was measured by eight, peak power eight as well and mean power output by one study. It must be noted that, Caserotti et al. (2008) conducted the power training intervention with the youngest (Caserotti et al., 2008a, age = 62.7 ± 2.2) and oldest (Caserotti et al., 2008b, age = 81.8 ± 2.7) population among all studies assessing one-repetition maximum and three-repetition maximum. Of the nine remaining studies investigating one-repetition maximum and three-repetition maximum, five investigated a population under 70 (de Vos et al., 2005; Lopes et al., 2014, 2016; Pazit et al., 2018; Richardson et al., 2019), thus four over 70 (Henwood et al., 2008; Reid et al., 2008; Sayers & Gibson, 2010, 2014). Since, Caserotti et al. (2008) although assessed peak power and mean power output, they reported results for the youngest and oldest population for this outcome as well. In contrast to one-repetition maximum and three-repetition maximum, peak power and mean power output were assessed by an older population on average. Thus, five studies investigated a population with an average age older than 70 (Henwood et al., 2008; Reid et al., 2008; Sayers & Gibson, 2010, 2014; Webber & Porter, 2010) and two studies under 70 (de Vos et al., 2005; Lee et al., 2011) except Caserotti et al. (2008) since they included a training arm under 70 and one over 70. For peak torque, the included eight studies presented a homogenous average age in contrast to one-repetition maximum and three-repetition maximum or peak power and mean power output. The average age of the included participants ranged from 64 (Lopes et al., 2014) to 74 (Weber & Porter, 2010). Training duration in one-repetition maximum and three-repetition maximum for all studies ranged between eight to twelve weeks, except Henwood et al. (2008) who prolonged the intervention for 22 weeks. Richardson et al. (2019)a being the only study with a training frequency of once a week, five studies each conducted a training frequency of three times per week (Lopes et al., 2014, 2016; Reid et al., 2008; Sayers & Gibson, 2010, 2014), and two times per week (Caserotti et al., 2008; de Vos et al., 2005; Henwood TR et al., 2008; Pazit et al., 2018; Richardson et al., 2019). In peak power and mean power output, de Vos and colleagues conducted the shortest training period with eight weeks of training. As Henwood et al. (2008) investigated peak power and mean power output, with a training duration of 22 weeks, this study investigated the longest training duration. Therefore, the remaining six studies conducted training periods of a duration of twelve weeks (Caserotti et al., 2008; Lee et al., 2011; Reid et al., 2008; Sayers & Gibson, 2010, 2014; Webber & Porter, 2010). In addition, five studies conducted training frequencies of two times per week (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; Webber & Porter, 2010), while three studies performed training frequencies of four times per week (Lee et al., 2011; Reid et al., 2008; Sayers & Gibson, 2010, 2014). In contrast, five studies that assessed peak torque conducted a power training intervention of twelve weeks (Holsgaard-Larsen et al., 2011; Lee et al., 2011; Lopes et al., 2014, 2016; Webber & Porter, 2010) with three studies assessing shorter training periods. Kobayashi and colleagues investigated a four-week training intervention, while de Vos et al. (2005) and LaRoche et al. (2008) performed an eight-week intervention. It must be noted that de Vos et al. (2008) performed an eight-to-twelve-week intervention. Four of the eight studies investigating peak torque used training frequencies of twice per week (de Vos et al., 2005; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; Webber & Porter, 2010), while the remaining four studies performed training frequencies of three times per week (LaRoche et al., 2008; Lee et al., 2011; Lopes et al., 2014, 2016). Moreover, training intensities of the studies assessing dynamic muscle strength can be categorized as follows. Studies that assessed one-repetition maximum and three-repetition maximum consist of fourteen intervention groups, since some studies mentioned above conducted interventions with multiple parallel arms. Four of the fourteen intervention groups, which measured dynamic muscle strength as one-repetition maximum and three-repetition maximum, performed the power training with intensities over 70% of one-repetition maximum (Caserotti et al., 2008; de Vos et al., 2005; Reid et al., 2008) with seven intervention groups reaching intensities over 40% one-repetition maximum (de Vos et al., 2005; Henwood et al., 2008; Lopes et al., 2016; Richardson et al., 2019; Sayers & Gibson, 2010, 2014). Thus, the remaining three groups trained with intensities under 40% of their one-repetition maximum (de Vos et al., 2005; Lopes et al., 2014; Pazit et al., 2018). It must be noted that some studies trained with a wider range of training intensities, for example Lopes et al. (2016) with 40-80% of one-repetition maximum. Similar heterogeneous training intensities were used during the power intervention of the thirteen groups which were assessed for peak power and mean power output. Thus, six of the thirteen intervention groups trained with training intensities over 70% of one-repetition maximum (Caserotti et al., 2008; de Vos et al., 2005; Reid et al., 2008; Webber & Porter, 2010). While six studies instructed the participants to train with intensities between 40-69% one-repetition maximum (de Vos et al., 2005; Henwood et al., 2008; Lee et al., 2011; Sayers & Gibson, 2010, 2014), only one group of participants in de Vos et al. (2005) performed their intervention with intensities under 40%. It must be mentioned, that Henwood et al. (2008) performed the intervention with 45-75% and Lee et al. (2011) reported dailed settings of the resistance device, which was equivalent to 50-75% one-repetition maximum. Therefore, both studies were categorized into the 40-69% category of one-repetition maximum. Studies assessing peak torque as an outcome conducted the power training intervention with twelve intervention groups. Four groups each out of the twelve intervention groups performed the power training intervention with intensities over 70% (de Vos et al., 2005; Holsgaard-Larsen et al., 2011; Webber & Porter, 2010) and 40 to 69% one-repetition maximum (de Vos et al., 2005; Lee et al., 2011; Lopes et al., 2016). While two intervention groups used intensities under 40% of one-repetition maximum (de Vos et al., 2005; Lopes et al., 2014). In addition, Kobayashi et al. (2016) performed isometric power training with a self-regulated resistance hydraulic device. Kobayashi and colleagues instructed participants to plantarflex "as fast and hard es possible". Therefore, Kobayashi et al. (2016) can be categorized into the over 70% one-repetition maximum group. In addition, LaRoche et al. (2008) reported training intensities with angular velocities of a dynamometer. Since low velocity and high load ($45°\cdot s^{-1}$) to high velocity and low load ($200°\cdot s^{-1}$) were used over the intervention period, this study cannot be categorized in only one category. For more details, see Table 1. All studies that assessed dynamic muscle strength with one-repetition maximum and three-repetition maximum shared the characteristic that the included population were community-dwelling elderly who had not participated in resistance training for at least the past six months. Whereas Henwood et al. (2008) and Pazit et al. (2018) excluded participants who had performed structured resistance training in the past twelve months. Furthermore, Pazit and colleagues included only participants in their study with diagnosed osteoarthritis in the knee joint who had experienced a fall in the past twelve months. Although independently living elderly were included in all studies, participants with preexisting limitations in physical functioning (Reid et al., 2008), some limitations in function or mobility (Sayers & Gibson, 2010) or participants who were mobile with an assistive device were included as well (Sayers &

Gibson, 2014). Similar populations participated among the studies that assessed peak power and mean power output. Webber & Porter (2010) need to be mentioned since this study included mobility-limited elderly women who were unable to walk one mile at moderate peace. Furthermore, similar populations were included in the studies investigating peak torque. Four studies out of ten that assessed one-repetition maximum or three-repetition maximum scored a four points on the PEDro scale (Caserotti et al., 2008; Henwood et al., 2008; Lopes et al., 2016; Sayers & Gibson, 2010). In addition, four more studies scored a five points on the PEDro scale (Lopes et al., 2014; Pazit et al., 2018; Richardson et al., 2019; Sayers & Gibson, 2014). A PEDro score of six points was fulfilled by de Vos et al. (2005) and Pazit et al. (2018), simultaneously being the studies with the highest PEDro score for one-repetition maximum and three-repetition maximum measures. No study was categorized as "poor", and thus no study scored three points or less. Besides de Vos et al. (2005) and Pazit et al. (2018), which fall under the category of "good" according to their PEDro score with six points, the remaining studies are considered to be "fair" since they scored four or five points (Caserotti et al., 2008; Henwood et al., 2008; Lopes et al., 2014, 2016; Pazit et al., 2018; Richardson et al., 2019; Sayers & Gibson, 2010, 2014). Since no study was categorized as "poor", the PEDro scores varied from 4-6 points. In addition, further characteristics according to the comparability of the included studies must be mentioned. Richardson et al. (2019)a, being the only study to train once a week among those who assessed one-repetition maximum and three-repetition maximum. Furthermore, it must be mentioned that a wide range of training intensities across these studies was a limitation for comparability. Moreover, Pazit et al. (2018), being the only study to analyse 18 participants, whereas the remaining studies included 20 or more participants, considering that Pazit and colleagues investigated a population with osteoarthritis and particular inclusion criteria. With an average PEDro score of five, the studies measuring peak power and mean power output was higher than the average PEDro score of those that assessed one-repetition maximum and three-repetition maximum. While three studies scored four on the PEDro scale (Caserotti et al., 2008; Henwood et al., 2008; Sayers & Gibson, 2010), three studies scored a five points (Lee et al., 2011; Reid et al., 2008; Sayers & Gibson, 2014) and two studies scored six points (de Vos et al., 2005; Webber & Porter, 2010). Besides de Vos et al. (2005) and Webber & Porter (2010), which were categorized as "good" according to the PEDro evaluation, the remaining studies are categorized as "fair". In comparing the studies that assessed peak power and mean power output to the studies that assessed one-repetition maximum and three-repetition maximum, it can be stated that they display a more homogeneous methodological quality and lower risk of bias. Therefore, the studies show a similar training frequency and duration. Furthermore, the lowest number of participants among the studies measuring peak power and mean power output is 25 (Sayers & Gibson, 2010) and is higher compared to studies investigating one-repetition maximum, three-repetition maximum, and peak torque. Except one training arm of de Vos et al. (2005), the remaining studies conducted training intensities between 40% and 80% one-repetition maximum. It must be noted that Webber & Porter included participants without the ability to walk 1 mile at a moderate speed, while the remaining studies investigated independently living community-dwelling elderly individuals. Since the mobility abilities of this population are not quantified as Webber & Porter (2010) did, it could not be stated with certainty that both populations have the same mobility abilities. Similarly, peak power and mean power output, the average PEDro score of the studies assessed peak torque as outcome is five. With two studies scoring four points on the PEDro scale (Holsgaard-Larsen et al., 2011; Lopes et al., 2016) and four studies reaching five points (Kobayashi et al., 2016; LaRoche et al., 2008; Lee et al., 2011; Lopes et al., 2014). Thus, six studies are categorized as “fair” under the PEDro score evaluation system. Lastly, the remaining two studies reaching a PEDro score of six and being categorized as “good” under PEDro evaluation (de Vos et al., 2005; Webber & Porter, 2010). In comparison to the studies measuring peak power and mean power output, studies assessing peak torque are more heterogeneous in methods. The range of training duration varies from four to 22 weeks with three intervention groups training with intensities under 40% of the one-repetition maximum (de Vos et al., 2005; LaRoche et al., 2008; Lopes et al., 2014). Similarly to one-repetition maximum and three-repetition maximum outcome measures, the lowest number of participants included in one training group is 19 for peak torque (Holsgaard-Larsen et al., 2011). As mentioned above, muscle activation ability was assessed by six studies with three outcome variables such as; rate of force development, rate of torque development and electromyographic assessment of neuromuscular activation. As mentioned above, since Caserotti et al. (2008) conducted a training intervention with two parallel training arms, assessing participants with an average age of 62.7 years and 81.8 years, it investigated the youngest and oldest population among those who assessed rate of force and rate of torque development. While Lopes et al. (2014, 2016) included participants under 70 years of age, Kobayashi et al. (2016) and LaRoche et al. (2008) investigated populations over 70 years. Training duration varied from four weeks (Kobayashi et al., 2016) to twelve weeks (Caserotti et al., 2008; Lopes et al., 2014, 2016), with LaRoche and colleagues assessing an eight-week training period. Two studies each conducted training intensities over 70% one-repetition maximum (Caserotti et al., 2008; Kobayashi et al., 2016) and under 40% of one-repetition maximum (LaRoche et al., 2008; Lopes et al., 2014), while Lopes et al. (2016) performed intensities from 40-80%. Similar heterogeneous training duration was demonstrated by the studies measuring electromyographic signals. While training duration varied from four to twelve weeks, training frequency was twice or three times per week for all studies in these three outcome measures. Since only three studies measured electromyographic signals, the average age varied from 69.7 to 72.5 years. All three outcome measures included similar participants as community-dwelling elderly with no structured training at least for the past six months. Furthermore, all studies scored four or five points on the PEDro scale. Therefore, all included studies assessing rate of force development, rate of torque development and electromyographic signals are evaluated with “fair” study quality. It must be stated that among all six studies assessing these three outcome measures of muscle activation, one study included fewer than 20 participants (Holsgaard-Larsen et al., 2011) and three studies fewer than 25 participants (LaRoche et al., 2008; Lopes et al., 2014, 2016). In addition, it must be considered that this heterogeneous variety of training duration and intensity could be a limitation for comparability. Moreover, LaRoche et al. (2008), being the only study to blind the assessor, a further limitation in comparability due to differences in study quality is evident. Lastly, physical performance parameters as outcome were investigated by six studies (Henwood et al., 2008; Pazit et al., 2018; Richardson et al., 2019; Sañudo et al., 2019; Sayers et al., 2016; Webber & Porter, 2010), while eight intervention groups were assessed in total. It needs to be mentioned that Henwood and colleagues measured eight and 22-weeks post-intervention. In addition, Sayers et al. (2019) and Webber & Porter (2010) investigated a period of 12 weeks. While Richardson et al. (2019) assessed ten weeks, Pazit et al. (2018) eight and Sañudo et al. (2019) a period of six weeks. Six intervention groups (Henwood et al., 2008; Pazit et al., 2018; Richardson et al., 2019; Webber & Porter, 2010) performed two training sessions per week, with one group each performing one training session (Richardson et al., 2019) and three training sessions per week (Sayers et al., 2016). However, Sañudo and colleagues reported training frequencies of two to three times per weeks. The average age of the included population assessed in physical performance parameters varied from 65.3 to 75.5 years, with four intervention groups having an average age under 70 years and five groups over 70 years. However, only Webber and Porter (2010)a performed power training with intensities at 80% one-repetition maximum. While Pazit et al. (2018) hit intensities of 80% at the end of the training period, the participants started with 20% initially. In addition, Henwood et al. (2008) conducted a power training intervention with increased resistance, with a range of 45-75% of one-repetition maximum over their 22-week training period. However, three intervention groups performed power training at 40% of one-repetition maximum. Since Sañudo and colleagues used a flywheel device for their power training intervention, they reported the resistance as a moment of inertia ranging from 0.0025 to 0.05 $kg \cdot m^{-2}$ during the six-week intervention. Lastly, Webber & Porter (2010) conducted a power training intervention with an elastic band as resistance. Furthermore, the populations investigated for physical performance parameters can be categorized as independently living elderly assessed by three studies (Henwood et al., 2008; Richardson et al., 2019; Sañudo et al., 2019), independently living elderly with limitations in mobility abilities due to distance or due to the use of an assistive device (Sayers et al., 2016; Webber & Porter, 2010), and Pazit et al. (2018) investigating a population diagnosed with osteoarthritis of the knee and having experienced a fall incident in the past twelve months. With an average PEDro score of 5.6, the studies assessing physical performance parameters achieved the highest PEDro score among all outcome parameters in this systematic review. Thus, this outcome parameter is associated with the lowest risk of bias. The study of Henwood et al. (2008) scored 4 points and is categorized as fair according to the PEDro rating, while all remaining studies scored 6 points and are categorized as “good”. Besides the low risk of bias compared to other outcomes in this systematic review, the comparability between the studies assessing physical performance parameters is limited due the large variation in training intensities and duration. Furthermore, the investigated populations show a variety in inclusion and exclusion criteria, which is not necessarily a limitation. As mentioned above, Pazit and colleagues investigated a sample size of 18, while they assessed a specific population. However, the remaining studies investigated populations of over 30 people.

Across all outcome parameters, heterogeneous effects of power training were shown. The result of this systematic review tends to demonstrate major improvements in dynamic muscle strength. However, small improvements were reported for physical performance parameters. Furthermore, muscle activation tends to improve little to not at all after the power training intervention. Eight studies demonstrated significant improvements in eleven intervention groups showing significant improvements in one-repetition maximum and three-repetition maximum strength after the power training intervention (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; Lopes et al., 2014; Pazit et al., 2018; Reid et al., 2008; Sayers & Gibson, 2010, 2014). While two studies reported no significant changes for most of the exercises investigated in one-repetition maximum and three-repetition maximum strength (Lopes et al., 2016; Richardson et al., 2019). Most trials used training frequencies of 2-3 times per week with training durations from 8-12 weeks, besides Richardson et al. (2019)a, who conducted a training frequency of once per week with no significant improvements in one-repetition maximum, and Henwood et al. (2008) performed power training over 22 weeks. Furthermore, Lopes et al. (2016) and Richardson et al. (2019), being the only study to not demonstrate significant changes compared to control, performed the power training intervention with the same training intensities compared to those who demonstrated significant improvements. Similar positive effects of power training on improvements in peak torque were demonstrated across the included studies. Five studies demonstrated significant improvements in peak torque in eight intervention groups for most investigated exercises (de Vos et al., 2005; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; Lee et al., 2011; Lopes et al., 2016). In contrast, three studies with four intervention groups could not show significant changes in peak torque compared to the control (LaRoche et al., 2008; Lopes et al., 2014; Webber & Porter, 2010). It should be noted that LaRoche and colleagues reported a p-value of 0.06, which indicated a trend towards significance. Training frequencies varied from 2-3 sessions per week with training durations from 4-12 weeks. Training duration of 4 weeks was only used by Kobayashi et al. (2016). Thus, the remaining 11 intervention groups trained eight or 12 weeks. However, Kobayashi and colleagues reported significant improvements in peak torque despite training for four weeks. In addition, a wide range of training intensities of 20-80% one-repetition maximum was used. However, de Vos et al. (2005)a conducted a power training with 20% one-repetition maximum and showed significant improvements. In contrast, Webber and Porter (2010)b conducted power training with elastic bands, ergo at lower intensities, and demonstrated no significant improvements for peak torque. Furthermore, Webber and Porter (2010)a performed power training with 80% one-repetition maximum as did de Vos et al. (2005)c, while only de Vos et al. (2005) showed significant improvement compared to control. Across all studies, independently living elderly were investigated without participation in structured resistance training for the past 6 months at least, except for Webber & Porter (2010), who included participants that were mobility limited, defined as being unable to walk one mile at moderate pace. Webber & Porter (2010), although they excluded participants who had participation in structured strength training in the past six months. Given that differences in the investigated population, Webber and Porter are one of the three studies reporting no significant changes in peak torque after power training intervention. For more details, see

Table 4 above. The majority of the studies investigating dynamic muscle strength as one-repetition maximum, three-repetition maximum, and peak torque showed significant changes compared to the control, while a minority of studies could not demonstrate any improvements after power training, which is conflicting. However, the strongest effect of the power training intervention was demonstrated on peak power and mean power output. Across eight included studies with thirteen training groups, seven studies with eleven intervention groups demonstrated significant improvements for peak power or mean power output (Caserotti et al., 2008; de Vos et al., 2005; Henwood et al., 2008; Lee et al., 2011; Reid et al., 2008; Sayers & Gibson, 2010, 2014). It should be mentioned that, only eight exercises out of 49 reported no significant improvements in peak power or mean Power output. As shown in peak torque, Webber and Porter (2010) and Reid et al. (2008) included slightly mobility-impaired participants compared to the other studies. While Webber and Porter (2010) reported no significant changes after the intervention for all exercises, Reid et al. (2008) reported no significant changes for leg press but significant improvements for knee extension. Training durations and frequencies were heterogeneous, except for Henwood et al. (2008), who conducting a training period of 22 weeks. Training intensities varied from 20-80% one-repetition maximum. In addition, the youngest intervention group, with an average age of 62.7 years, demonstrated no significant improvements in mean power for leg extension, while peak power and mean power output in the countermovement jump were significantly improved by this group (Caserotti et al., 2008a). While Caserotti et al. (2008)b included the oldest population with an average of 81.8 years, the average age of the remaining intervention groups ranged from 68 to 75.5 years. It should be mentioned that the number of participants assessed in peak power or mean power output was 402 and was higher than the number of participants investigated for one-repetition maximum and three-repetition Maximum (n = 330) and peak torque (n = 343). In contrast, outcome parameters measuring muscle activation such as electromyographic assessment of muscle contraction, rate of force development and rate of torque development showed small improvements after the power training intervention compared to dynamic muscle strength outcome parameters. Caserotti et al. (2008) assessed rate of force development and showed significant changes in leg press for both intervention groups. Furthermore, Kobayashi and colleagues demonstrated significant improvements in rate of torque development in plantar flexion. While these two studies reported significant improvements, three studies reported no significant changes in rate of torque development in hip, knee and plantar joint testing, each in flexion and extension (LaRoche et al., 2008; Lopes et al., 2014, 2016). Despite having the shortest training period of 4 weeks, Kobayashi et al. (2016) demonstrated significant improvements compared to the control group, while LaRoche et al. (2008) conducted a training intervention over 8 weeks and showed no significant improvements. The remaining studies performed a power training intervention over 12 weeks and reported conflicting results. It must be noted that all three studies that performed three training sessions per week reported no significant changes in rate of torque development, while all studies with significant improvements trained their participants twice per week. In addition, Caserotti et al. (2008) and Kobayashi et al. (2016), being the only studies to show significant improvements, conducted a power training intervention with intensities over 75% one-repetition maximum. Thus, Lopes et al. (2014) trained with lower intensities throughout the full period, while LaRoche et al. (2008) and Lopes et al. (2016) increased the intensity at the end of the training period. Moreover, the average age of participants across all studies varied from 62.7 – 81.8 years. Although all participants were independently living, LaRoche et al. (2008) included inactive elderly, while Kobayashi et al. (2016) included physically active elderly. It must be mentioned that all studies excluded participants who had participated in structured resistance exercise. Rate of force development and rate of torque development were investigated by a total number of 188 participants. In comparison, electromyographic assessments of muscle activation were investigated by a total number of 99 participants in three studies (Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008). Across all studies, small effects of decreased antagonist muscle activation after power training were demonstrated. Holsgaard-Larsen and colleagues recorded electromyographic signals of muscle activation during stair climbing and could demonstrate a significantly decreased activation of the antagonist in the semitendinosus among 24 measures in total. In addition, Kobayashi et al. (2016) could not demonstrate significant changes in the plantar flexors and the tibialis anterior during plantar flexion. However, during one-leg standing, significantly decreased activity in the plantar flexors was reported, while no changes in derived signals of the tibialis anterior were observed. Consistent with these findings, LaRoche et al. (2008) reported decreased antagonist activation during knee extension, with no changes in the activity of the rectus femoris. Besides the small number of participants across all studies measuring electromyographic signals, training duration was different in every study ranging from 4 to 12 weeks. However, high training intensities were matched across all studies, except LaRoche et al. (2008) who started with lower intensity during the first half of the training period. In addition, the average age of the populations across all studies varies from 69.7 to 72.5 years and is although good matching. It must be mentioned that all three studies performed different exercises for testing, which is a limitation in comparability. Finally, power training interventions tended to show a small effect on physical performance parameters since 8 physical performance tests out of 33 showed significant improvements compared to the control group. While Richardson et al. (2019) and Webber and Porter (2010) reported no significant changes in any of their tests for physical performance parameters, the remaining four studies reported significant improvements for the minority of their tests (Henwood et al., 2008; Pazit et al., 2018; Sañudo et al., 2019; Sayers et al., 2016). The comparability of the results is limited, since 18 different tests were conducted by the included studies consisting of walk tests, stair climb tests, balance tests and test batteries. However, only the Timed Up and Go test and the 30-second sit-to-stand test was performed by multiple studies. The Timed Up and Go test was conducted by three studies with 158 participants in total (Pazit et al., 2018; Sañudo et al., 2019; Sayers et al., 2016). While Pazit et al. (2018) and Sañudo et al. (2019) demonstrated significant improvements in Timed Up and Go test, Sayers et al. (2016) reported no significant changes. However, Sayers and colleagues conducted an additional testing of the Short Physical Performance Battery and demonstrated significant improvements. Furthermore, the 30-second sit-to-stand test was performed by Pazit et al. (2018) and Richardson et al. (2019), while Richardson and colleagues conducted a two-parallel-arm study and performed the 30-second sit-to-stand test with two intervention groups. Whereas Pazit and colleagues demonstrated significant improvements for the 30-second sit-to-stand test, Richardson et al. (2019) reported no significant changes for both groups. It must be noted that Henwood et al. (2008) measured physical performance parameters after 8 and 22 weeks of power training intervention and reported conflicting results for the same tests. After eight weeks of intervention, significant improvements for stair climb and chair rise tests were reported. Although, after 22 weeks of intervention, chair rise testing and additionally the fast 6-m walk test were significantly different compared to the control, but the stair climb test was not significantly different compared to control. Despite the highest average PEDro score and lowest risk of bias across all studies categorized for each outcome, training duration, frequencies, intensities and populations are heterogeneous for the six studies considered for physical performance parameters. Training duration varied from six to 22 weeks and training frequencies of 1-3 sessions per week were conducted across all studies. Furthermore, training intensities ranged from low intensities such as 20% of one-repetition maximum or resistance with elastic bands to 80% of one-repetition maximum. The characteristics of included populations among the studies included for physical performance can be described as follows: Henwood et al. (2008), Richardson et al. (2019) and Sañudo et al. (2019) included community-dwelling elderly without mobility limitations. As mentioned above, Pazit et al. (2018) investigated elderly with diagnosed osteoarthritis and a fall incident in the past 12 months. Furthermore, Sayers et al. (2016) and Webber and Porter (2010) included community dwellers with slight limitations in mobility such as using an assistive device or being not able to walk 1 mile at a moderate pace. Furthermore, the average age of the participants across all included studies for this outcome was spread over 10 years. A population of 208 people were investigated for physical performance parameters in total. It must be noted that no sensitivity analysis was performed, since no meta-analysis was conducted. Thus, this systematic review narratively synthesized the included studies by their investigated outcome parameters.

4 Discussion

This systematic review aimed to investigate the effects of a power training intervention conducted with elderly in their neuromuscular performance. Across five databases and 6,143 papers, 17 studies satisfied the inclusion criteria which were grouped according to their investigated outcome parameters. Neuromuscular performance parameters were assessed as dynamic muscle strength, muscle activation, and physical performance parameters. Dynamic muscle strength was measured as peak power, mean power output, peak torque, one-repetition maximum and three-repetition maximum. Furthermore, muscle activation ability was assessed by derived electromyographic signals from muscles, rate of torque development and rate of force development. Lastly, physical performance parameters were assessed due to the performance of defined physical performance tests. Overall, power training has demonstrated strong effects on dynamic muscle strength parameters, while muscle activation parameters and physical performance parameters showed conflicting results. Across dynamic muscle strength parameters, power training demonstrated the strongest positive effects on peak power and mean power output followed by the majority of the studies reporting significant improvements in peak torque, one-repetition maximum and three-repetition maximum. These findings are consistent with the findings of Bandeira-Guimarães et al. (2023). Bandeira-Guimarães and colleagues investigated the effects of different power training intensities on neuromuscular parameters in the elderly. It must be mentioned that Bandeira-Guimares and colleagues included studies that performed power training with “maximal velocity during the concentric phase of each repetition”, which is important since power training was assessed accurately, which is relevant for validity. Power training intensities were categorized into groups of low intensity (≤ 49% of 1RM), moderate intensity (50-69% of 1RM) and high intensity (≥ 70% of 1RM), while outcome parameters such as dynamic muscle strength, muscle power, and muscle hypertrophy were measured. Despite only including three studies in their meta-analysis, Bandeira-Guimarães et al. (2023) demonstrated significant improvements in power output gains for all intensity categories, with the strongest effect in the high-intensity category. The increase in power output parameters across all intensity categories is in line with the results of this systematic review, however, the more significant increase in power output parameters with higher training intensity could not be demonstrated across all outcome parameters of this review. For example, Webber & Porter (2010) conduced a power training intervention with two parallel arms, one with lower intensities using elastic bands and one with 80% one-repetition maximum using machine training. Furthermore, de Vos et al. (2005) performed a three-arm parallel intervention in which training groups were categorized according to their training intensities of 20%, 50% and 80% one-repetition maximum. De Vos et al. (2005) and Webber and Porter (2010) reported no significant results when comparing their intervention groups to the control group. In contrast to a systematic review by Rice and Koegh (2009), where strong effects of power training interventions on physical performance parameters were reported, this systematic review demonstrated moderate effects of power training interventions on physical performance parameters of the elderly population. Rice and Koegh (2009) included twelve studies in their review, with ten studies showing significant improvements in physical performance parameters. As mentioned above, physical performance parameters were assessed by six included studies in this review with eight intervention groups. While 33 physical performance tests were conducted across all included studies, only eight tests in total showed significant improvements. Rice and Koegh did not report any details on their definition of power training besides the inclusion criteria: "included a high-velocity power training group who trained for at least eight weeks". It is not possible to evaluate the definition of power training used for inclusion, which is a limitation for comparison. In addition, nine of the twelve included studies in Rice´s and Koegh´s review had parallel training arms with a traditional strength training intervention. Rice & Koegh (2009) reported for four studies out of nine with using traditional strength training significant improvements in physical performance parameters. These results indicate a stronger effect for power training compared to traditional strength training. These findings are conflicting with the results of this systematic review when considering only physical performance parameters. Seven of the included 17 studies used a parallel training design with a power training intervention group and a traditional strength training intervention group (Henwood et al., 2008; Lopes et al., 2014, 2016; Reid et al., 2008; Richardson et al., 2019; Sayers & Gibson, 2010, 2014). Across all traditional intervention groups, the concentric phase of the exercises was slow-speed execution of about 2 seconds or more. While Lopes et al. (2016) trained the traditional strength training group at intensities of 60% one-repetition maximum, the remaining six studies trained at intensities over 70%. Henwood et al. (2008) and Richardson et al. (2019) were the only studies to measure physical performance parameters in power training and traditional strength training and reported conflicting results. Henwood et al. (2008) demonstrated significant improvements for both training groups compared to the control while no differences between the groups were demonstrated. However, Richardson et al. (2019) reported the most beneficial improvements for the low-velocity and high-load twice-weekly group in physical performance parameters. By comparing traditional strength training with power training across all seven studies included across all outcome parameters, the results indicate that both training methods show similar results across all outcome parameters with some additional beneficial effects for power training. For example, Henwood et al. (2008) and Lopes et al. (2014, 2016) showed additional superiority for power training regarding efficiency. Thus, power training demonstrated the same effects as traditional strength training with less workload. In addition, Reid and colleagues demonstrated stronger effects in leg press peak power for the power training group. However, Richardson et al. (2019) demonstrated greater strength improvements for traditional strength training compared to the power training group. It must be mentioned that Richardson and colleagues performed traditional strength training at 80% one-repetition maximum and power training only with intensities at 40% one-repetition maximum. Furthermore, Sayers and Gibson (2010) reported stronger effects for power training in peak power velocity and peak velocity, while Sayers and Gibson (2014) showed superiority for power training for shifting peak power at lower external loads and traditional resistance training was superior in increasing the external force. Lastly, Lopes et al. (2016) reported that only power training increased the rate of force development compared to the control. These findings are consistent with previous research by Tschopp et al. (2011) and El Hadouchi et al. (2022) where both meta-analyses have demonstrated a small superiority for the power training intervention compared to traditional strength training in the elderly population.

Overall, the average PEDro score of all included 17 studies in this systematic review is 5.18 on the PEDro scale. While the lowest PEDro score across all included studies is 4 and the highest score is 6. Thus, the average PEDro score of 5.18 is categorized as fair and provides an acceptable risk of biases. It is important to note that the included studies performed power training interventions with a large variability in training equipment, intensity, and duration. Besides Richardson et al. (2019), all studies used training frequencies of 2-3 times per week. Training duration ranged from four to 22 weeks, with 12 out of 17 studies performing a 12-week intervention. Furthermore, training intensities conducted during the power training interventions varied from 20-80% one-repetition maximum. It must be mentioned that Webber and Porter (2010) performed a training intervention with resistance bands, Sañudo and colleagues used a flywheel for training, or Lopes et al. (2014) used, among others, bodyweight training. Thus, this heterogeneity is a limitation for the comparability of the studies. Furthermore, all studies included small sample sizes, limiting the statistical power of the results. Most studies included community-dwelling elderly with no limitations in mobility. In contrast, Webber and Porter (2010) and Sayers et al. (2016) included still-independently-living elderly but with mobility limitations. For example, Webber and Porter (2010) included participants without the ability to walk 1 mile at a moderate pace, which was self-reported, not assessed. Sayers et al. (2016), for example, included a population that was ambulatory without distinguishing whether assistive devices were used or not. In addition, Pazit et al. (2018) included elderly diagnosed with osteoarthritis and a falling incident in the past 12 months. Some studies tolerated the use of medication, while others included participants who did not use any medication. The heterogeneity is a result of the investigated elderly population but is a potential risk for further biases. Further limitations in comparability arise from the training protocols used across the studies. Despite all studies using an adaptation period, approximately half of the studies trained with the same intensity over the training period, while the other half increased the intensity of the training over the training period. For example, Pazit et al. (2018) trained with 20 to 40% one-repetition maximum during the first two weeks of the training period and increased the intensity from week 3–5 to 40 - 60% one-repetition maximum. During week 6–8, the training intensity was set at 60 - 80% one-repetition maximum. It must be noted that despite the training intensity, the execution of the exercises was performed "as fast as possible" and was in line with the definition of power training. For more details on the definition of power training for this systematic review, see methods above. Further limitations arise from the inconsistencies in the outcome measures. While one-repetition maximum and three-repetition maximum measures were grouped according to the exercises used for measurement, different machines were used to assess the one-repetition maximum and three-repetition maximum. For example, de Vos et al. (2005) and Reid et al. (2008) used pneumatic machines, while Richardson et al. (2019) performed testing with weight-stacked machines. In addition, for peak torque measures, different contraction types were used during testing. An isometric testing protocol was used by six studies (de Vos et al., 2005; Holsgaard-Larsen et al., 2011; Kobayashi et al., 2016; LaRoche et al., 2008; Lopes et al., 2014, 2016), while kinetic testing was conducted by Lee et al. (2011) and isokinetic testing by Webber and Porter (2010). For the peak power and mean power output testing, potential limitations arise due to the use of different exercises and machines, as well as the defined intensities during testing. Caserotti et al. (2008) conducted countermovement jumps with bodyweight, while Reid et al. (2008) tested the leg press and knee extension at 40% and 70% one-repetition maximum. Furthermore, de Vos et al. (2005) performed testing at 20 - 80% one-repetition maximum and Sayers and Gibson (2010; 2014) at 40 - 90%. In contrast, Lee and colleagues, performed only testing at one lower and higher intensity. It must be mentioned that Henwood et al. (2008) only reported the sum of five exercises for one-repetition maximum and peak power, while the remaining studies reported single measures.

This systematic review was written according to the PRISMA statement by one author. However, to satisfy the PRISMA guidelines, a second author is needed for the selection process. In addition, a third person is required in case of disagreement regarding the inclusion or exclusion of papers. Therefore, this systematic review is biased since only one author has conducted the selection process. Although five databases such as PubMed, Web of Science, Sports Discus, CINAHL, and Scopus were screened for relevant studies, there is a limitation since not all databases such as Google Scholar, EMBASE, PEDro, or the Cochrane Central Register of Controlled Trials were retrieved, and potentially relevant studies could be overlooked. Furthermore, unpublished literature in terms of publication bias is not assessed, which represents an additional limitation. This review was based only on studies written in English, which excludes studies in other languages which might lead to a selection bias. Since no limitations were defined according to publication date, there is no time-based selection bias. Further filters were used for Scopus and Web of Science, where document type was filtered to articles only. Evidence generated from this review is applicable to healthy community-dwelling elderly with an age over 60 years without mobility limitations. However, Pazit et al. (2018) investigated elderly with diagnosed osteoarthritis in the knee and a fall incident in the past 12 months, while two studies included populations with mobility impairments. Webber and Porter (2010) investigated participants without the ability to walk 1 mile at a moderate pace and Reid et al. (2013) assessed participants with Short Physical Performance Battery scores above 9, thus including elderly with mild to moderate limitations. Thus, the results might not be generalized for elderly with significant mobility impairments or clinical populations. Furthermore, the generated knowledge is not applicable for a very old population, since the oldest population was on average 81.8 years (Caserotti et al., 2008). The second oldest population assessed in this review was 75.5 years on average. As mentioned above, the selection process was performed by the author without a second reviewer. Since the effectiveness of a power training intervention on neuromuscular performance in an elderly population was assessed, the definition of power training interventions is important for inclusion or exclusion of trials. For this systematic review, power training was defined. An intervention was accepted as a power training intervention, when the execution of the exercises was explicitly performed "as fast as possible". Hruda and colleagues performed a muscle power training in older adults to gain improvements in physical functioning but did not mention that the exercises were performed "as fast as possible". Thus, the study was excluded. Furthermore, Bårdstu et al. (2020) described the performed power training as, "…encouraged to train with high intentional velocity during concentric phase...", which is not "as fast as possible". This study was excluded as well. In addition, Lee et al. (2020) was excluded since they performed a one-second concentric phase in a high-speed power training intervention on neuromuscular and gait functions. Despite a one-second concentric phase might reach the intensity of a power training intervention for some participants, this study was considered not eligible according to the definition of power training. Moreover, Saeterbakken et al. (2018) was excluded for describing the execution of the concentric phase as "fast explosive concentric phase" or as "high velocity execution" as mentioned by Wallerstein and colleagues, which also resulted in exclusion. These mentioned studies could potentially have conducted a power training intervention, which was excluded from this review due to the strict definition of power training, resulting in potential bias. Home-based studies were excluded from this review, since the correct execution of power training is not guaranteed without a supervisor. While many studies used combined training interventions, for example the combination of power training with balance exercises or slow resistance exercises, combined training interventions were excluded because of confounding factors. For example, Gaemelke et al. (2024) conduced a power training intervention with an additional mesocycle of resistance and balance exercises, or Gray et al. (2018) performed a classical resistance training during the first 24 weeks of the intervention with an additional power training period for another 24 weeks. Many studies used an initial resistance training period with an additional power training period (Häkkinen et al., 2002; Miszko et al., 2003). Other combinations of training methods were also excluded, for instance Zubac et al. (2019) performed a plyometric training with additional gymnastics, balance, coordination movements, and active stretching. Across all studies, adaptation periods of a few sessions were used, since it is important to consider training status and the age of the investigated population to prevent injuries. Filho et al. (2022) performed a two-week familiarization period with an additional six weeks of adaptation period, which was evaluated as too long and as a combined training method. It must be mentioned that only randomized controlled trails were included in this systematic review, which increases the level of evidence and internal validity of the findings. However, the review might have benefited from high-quality clinical trials which were not randomized but strong in methodological design. Furthermore, the synthesis of this systematic review was synthesized narratively without conducting a meta-analysis. Therefore, deriving strong quantitative conclusions is limited.

Overall, power training is an effective method to increase neuromuscular functioning in the elderly. This review has demonstrated that a power training intervention has strongly significant effects on mean power, peak power, rate of torque development and 1-repetition maximum or three-repetition maximum. Furthermore, moderate effects were demonstrated after the power training intervention on muscle activation parameters and physical performance parameters. These findings are consistent with further meta-analyses which show even stronger effects of power training on physical performance parameters. Moreover, power training showed similar or slightly stronger effects compared to traditional strength training with less training load for the performing participants. Reduced training load is important, since the interventions are conducted with older populations. It is important to include power training interventions in the health system and mass sports to tackle the demographic changes with older populations. The results indicate that it is effective to combine an intervention with power training and traditional strength training elements. Future research should use standardized training protocols with standardized testing. Furthermore, testing for physical performance parameters should be standardized and mimic daily living conditions and tasks.

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