Influence of counter-resistance training variables on elderly muscular strength: a systematic review with emphasis on dose/response relationships

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ABSTRACT

Muscular force is considered an important component of physical exercise programs. The results of this type of training depend on the combination of the number of repetitions, series, overload, sequence and intervals between series and exercises. However, it is still not very clear yet what the best combination of these variables for a good stimulus/response relationship in elderly people is. The objective of this study was to analyze the research on power-training for elderly people by means of systematic revision, with the intention to identify common trends in terms of effect of the training provoked by the manipulation of these variables. After definition of inclusion criteria, 22 cases were selected and grouped by treatment similarity (number of series; weekly frequency; intensity; intervals and order of the exercises). Techniques of descriptive statistics were used in order to determine possible trends in the stimulus/response relationship. Once identified, these trends were qualitatively analyzed. Among the variables revised, only for intensity of overload evidence that allows affirming that heavier loads would be more effective to induce force increase in this age group was found. Concerning the remaining variables, the results available in the literature do not support accurate inferences in terms of the best type of training program that connects effectiveness and safety. Therefore further studies should be conducted in order to experimentally compare the effects of the manipulation of these variables on muscular force in elderly people.

Keywords: Aging. Power-training. Prescribed exercises.

INTRODUCTION

Muscular strength may be defined as the maximal strength a muscle or muscular group can generate in a specific pattern of movement performed in a given velocity[1]. In the last decades, it began to be considered a crucial component of physical aptitude aimed at the maintenance of quality of life of individuals, being part of the majority of physical training programs dedicated to health[2-4].

The importance of the development of a strength training program for maintenance of work capacity has been increasing since as one ages, there is a tendency of progressive decline. For Macaluso and De Vito[5], the studies about the topic bring evidence that the muscle reaches its maximal strength between the second and third decades of one's life and shows a slow or unperceiving decrease until about 50 years of age, when it begins to decline approximately 12% to 15% per decade, with faster losses above 65 years of age.

The decrease of muscular strength brings consequences to the functional autonomy of older subjects[6-7]. Latham *et al.*[8], for instance, demonstrated that reduced levels of strength would be associated with lower gait velocity and inaptitude, which would cause increase in the risk of falls and fractures in older individuals. Generally, progressive losses of strength tend to make the elderly incapable of performing simple daily tasks, making them many times dependable on other people, which tends to greatly reduce the quality of life of these individuals[9-10].

Conversely, muscular strength can be improved in elders, as long as they are submitted to a training program with overloads. Studies as the one by Hunter *et al.*[2], Frontera *et al.*[11-12], Fiatarone *et al.*[13], Valkeinen *et al.*[14] and Latham *et al.*[15] reinforce this possibility, demonstrating that this kind of training improves muscle, articular and bone function and structure in any age. The accumulation of positive results in this direction explains the considerable increase of strength training programs aimed to older subjects indeed.

However, the benefits promoted by counter-resistance training depend on the manipulation of several factors; among them, intensity, frequency and training volume are highlighted. Such factors derive from the combination of number of repetitions, series, overload, sequence and intervals between series and exercises, as well as the velocity of the movements' performance imposed to training[16,18,22]. Nevertheless, it is not clear yet what the best combination of these variables for an optimum dose-response relationship is. Studies as the ones revised by Gomes and Pereira[17], for instance, show that different combinations may be equally efficient for reaching these goals. Even facing this uncertainty, a guideline usually followed by specialists in strength training for healthy young adults is the one suggested by the American College of Sports Medicine, which recommends 8 to 10 exercises with 3 series of 8 to 12 maximal repetitions (RM), in a 2 to 3 days weekly frequency as a starting point[18]. In its text, though, nothing is specifically recommended to older populations.

Pearson *et al.*[19] when publishing the basic guidelines of the *National Strength and Conditioning Association* (NSCA) for strength training for athletes, mention in the section dedicated to older athletes that no special recommendation could be given since there would not be studies supporting such situation. They even affirm that for older athletes the same recommendations given to young individuals could be applied. Since the recommendations by the NSCA refer closer to athletes, the guidelines by the ACSM have been more widely spread.

Within this context, if there are concerns about the methodological variables associated with strength training prescription for healthy young adults yet, the problem is even bigger when older

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subjects are considered. It is worth remembering that some time ago resisted exercises with important overloads were considered inadequate to this age group[20-21].

Conversely, due to the lack of data specifically with elders, recommendations of normative agencies (such as the ACSM) have been worldwide used for the prescription of strength training. In other words, it seems that there are no great concerns about training variables adaptation to the characteristics related to a senescent body. Such thinking raises the following issue: in terms of dose-response, which would be the most efficient training methodology for the development of muscle strength in older individuals?

One may think then, that further systematic review studies, seeking for the identification of common references concerning the methodological variables of the strength training for this population would be needed. Some studies were conducted with this purpose. However, the analyzed population was of apparently healthy young adults, as in the case of the study by Rhea *et al.*[22]. These authors performed a meta-analysis for the determination of the dose-response relationship concerning intensity, frequency and number of series of the counter-resistance training, concerning muscle strength gain. Another study was developed by Wolf *et al.*[16], with the aim to investigate the same relationship when comparing programs involving single and multiple series.

Concerning the elderly population, only one study that analyzed as a whole the results of the experimental studies available was found; namely, the meta-analysis performed by Latham *et al.*[8]. Nonetheless, the focus of the authors was more epidemiological, considering the training effects on aspects such as falls prevention and reduction of physical inaptitude. The study did not consider the methodological aspects of the proposed trainings and strength gain produced by them.

Therefore, in order to obtain more data concerning the isolated as well as combined role of the training variables for the strength gain in this age group, more investment in systematic reviews with emphasis on the dose-response relationships is justified. Thus, the aim of the present study is to analyze the research on strength training for older individuals through systematic review. The aim was to identify possible common trends concerning training effects caused by the manipulation of the following variables: workload; number of series; weekly frequency; recovery interval and order of the exercises.

METHODOLOGY

The study consisted of a systematic review. The following inclusion criteria were adopted in order to select the studies for analysis: a) experimental studies, in which only training with overload had been used; b) target population composed of apparently healthy individuals of both sexes, aged 60 years or older.

Only the studies published and found through electronic search on Medline, Lilacs and Sport Discuss participated in the selection. The following steps were used for the studies' prospection: a) search algorithms with recognition of specialized literature; b) reference lists of the found studies; c) manual search of the articles in magazines not virtually found.

166 studies were initially selected from which only 22 fulfilled the pre-set inclusion criteria. The following items were analyzed from the selected studies: a) interventions – training methodology (number of series; number of repetitions; weekly frequency; exertion intensity; order and interval between exercises series; b) the found results.

In order to analyze the found results, the 22 selected studies were grouped by treatment similarity (number of series; weekly frequency; intensity; intervals and exercises order) and their results concerning strength gain were summed and over the sum the mean was applied for determination of the dose-response of their treatments. The differences between the found means in each study group were qualitatively analyzed.

PRESENTATION AND DISCUSSION OF RESULTS

Number of series

The analysis of the 'number of series' variable revealed that within the 22 studies which fulfilled the selection criteria, only three presented as aim the comparison of its effect on the strength gain (chart 1). From these, only one had as aim to specifically investigate the different strength gains facing different number of series for the same muscle group; namely, the one developed by Harris *et al.*[23]. The other two, by Menkes *et al.*[24] and Treuth *et al.*[25], verified the difference in the strength gain between lower (LL) and upper limbs (UL), (1 series for UL and 2 series for LL). The results of these two kinds of studies are presented in chart 1. There was no significant difference between the training groups, which may suggest that the upper limbs would need greater work volume. However, no study compared the obtained results with an equal number of series for UL and LL. Another issue refers to possible differences of response in men and women, since the two studies were developed only with men.

CHART 1
Studies which compared strength gain in elders facing different number of series

Study	Sample	Treatment	Results (strength gain)
Harris *et al.*[23]	N 51 ♂♀ Lower and upper limbs	**2 ser** of 15RM **3 ser** of 9RM **4 ser** of 6RM 2x week/18 weeks	2 ser = 44% 3 ser = 51% 4 ser = 50% (Mean of 8 exercises)
Menkes *et al.*[24]	N 18 ♂ Lower and upper limbs	**1 ser** of 15RM for UL **2 ser** of 15RM for LL 3x week/16 weeks	1 ser = 43% 2 ser = 47% (Mean of 6 exercises)
Treuth *et al.*[25]	N 22 ♂ Lower and upper limbs	**1 ser** of 15RM for UL **2 ser** of 15RM for LL 3x week/16 weeks	1 ser = 39% 2 ser = 42% (Mean of 6 exercises)

Women and men participated in the study developed by Harris *et al.*[23]. Two series of 15RM; 3 of 9RM and 4 of 6RM were compared; however, no significant difference between groups was identified. This result could suggest that, in older ages, the number of series would not influence in the strength gains. Nonetheless, since it is the only study with such outline, any affirmation would be too early. Yet, the lack of data concerning the best number of series for the development of strength is not exclusive to training with elders. As illustration, in a recent review, Gomes and Pereira[17] demonstrated that there was not sufficient evidence to affirm that multiple series are better than single series when reviewing the studies available about training for young adults.

Although no strong evidence has appeared concerning the best number of series for the development of muscular strength in the elderly, the majority of the analyzed studies pointed to the utilization of three series in their treatment, totalizing thirteen studies. Only three adopted two series and two a single series (chart 2).

If a mean of the results in strength increase of all studies which used three series was possible, a result of 40% would be found. In the ones which used two series 37.3% would be found; and of the ones which used only one series, 58%. This kind of analysis is questionable, since the analyzed studies present different outlines (exertion intensity, weekly frequency, involved muscular groups and training duration). Conversely, concerning such restrictions, one cannot deny that the focus is illustrative in terms of the weak relationship of the number of series with effective strength gains in this population.

CHART 2
Studies considered for the calculation of the mean gains associated with different number of series

Study	Sample	Treatment	Results (strength gain)
Kalapotharakos *et al.*[3]	N 33 Lower and upper limbs	**3 series** 80% of 1RM 60% of 1RM 3x week/12 weeks	80% of 1RM = 41.82% 60% of 1RM = 30.37% (Mean of 8 exercises)
Hagerman *et al.*[4]	N 22 Lower limb	**3 series** 85-90% of 1RM 2x week/16 weeks	68,7% (Mean for knee extension, leg-press and squat)
Rhodes *et al.*[9]	N 38 Lower and upper limbs	**3 series** 86% of 1RM 3x week/12 months	53% (Mean of 6 exercises)
Judge *et al.*[10]	N 31 Lower limb	**3 series** 75-80% of 1RM 3x week/12 weeks	32% (Mean for knee extension)
Frontera *et al.*[11]	N 14 Lower limb	**3 series** 80% of 1RM 3x week/12 weeks	40% (Mean for knee extension)
Seynnes *et al.*[27]	N 22 Lower limb	**3 series** 80% of 1RM 40% of 1RM 3x week/10 weeks	80% of 1RM = 57.3% 40% of 1RM = 36% (Mean for knee extension)
Reeves *et al.*[28]	N 18 Lower limb	**3 series** 70-75% of 1RM 3x week/14 weeks	19% (Mean for knee extension and leg-press)
Miszko *et al.*[29]	N 39 Upper and lower limbs	**3 series** 50% to 70% of 1RM 80% of 1RM 3x week/16 weeks	80% of 1RM = 18.72% 50 to 70% of 1RM = 12.23% (Mean for bench press and leg-press)
Brandon *et al.*[30]	N 85 Lower limb	**3 series** 50%, 60% and 70% of 1RM 3x week/16 weeks	51.7% (Mean for knee extension and flexion and plantar flexion)
Taaffe *et al.*[31]	N 53 Lower and upper limbs	**3 series** 80% of 1RM 1, 2, 3x w./ 24 weeks	1x w. = 37.0% 2x w. = 41.9% 3x w. = 39.7% (Mean of 8 exercises)
Morganti *et al.*[32]	N 39 Lower limb	**3 series** 84% of 1RM 3x week/12 months	61.9% (Mean for knee extension, leg-press and hip adduction)
Judge *et al.*[33]	N 48 Lower limb	**3 series** 75% of 1RM 3x week/12 weeks	62% (Mean of 8 exercises)
Pika *et al.*[34]	N 14 Lower and upper limbs	**3 series** 70% to 75% of 1RM 3x week/52 weeks	62.39% (Mean of 12 exercises)
Hunter *et al.*[2]	N 36 Lower and upper limbs	**2 series** 80% of 1RM 50, 65 and 80% 1RM 3x week/25 weeks	80% of 1RM = 32.8% 50/65/80% of 1RM = 32.8% (Mean of 4 exercises)
Tsutsumi *et al.*[35]	N 42 Upper and lower limbs	**2 series** 75% to 85% of 1RM 55% to 65% of 1RM 3x week/12 weeks	75% to 85% of 1RM = 48.2% 55% to 65% of 1RM = 39.7% (Mean of 12 exercises)
Schlicht *et al.*[36]	N 22 Lower limb	**2 series** 75% of 1RM 3x week/8 week	27.5% (Mean of 6 exercises)
Vincent e Braith[37]	N 62 Lower and upper limbs	**1 serie** 50% of 1RM 80% of 1RM 3x week/24 weeks	50% of 1RM = 52.4% 80% of 1RM = 79.0% (Mean of 10 exercises)
Hurley *et al.*[38]	N 35 Lower and upper limbs	**1 serie** 15RM 3x week/16 weeks	43% (Mean of 6 exercises)

A single study found was not considered for the calculation of the mean gain mentioned: it is the study developed by Lamoureux *et al.*[26]. Such fact is due to its completely different outline from the others. The authors investigated the effect of the progressive increase of the workload as well as the number of series during six-month training, which led to an increase of 235% in the strength of the involved subjects. No other study with similar aim and methods was found, making a comparative analysis difficult.

Weekly frequency

Only one study was found with the concern to investigate the influence of the 'weekly frequency' variable in the muscular strength gain in older subjects. Taaffe *et al.*[31] developed a study with 53 individuals distributed in four groups: one which trained once a week; another which trained two times a week; a third which trained three times a week; and a fourth which was characterized as control group. The trainings lasted 24 weeks and the authors did not find significant differences among the experimental groups.

Despite the lack of comparative studies which support the hypothesis that routines involving three weekly sessions are better than those involving one or two sessions, 19 of the 22 analyzed studies used a frequency of three weekly times in their research (chart 3). Only one study used two sessions, while none conducted research with a single weekly training session.

Adopting the same mentioned outline for the number of series, when the mean of the obtained results in the 19 studies which used a training weekly frequency of three days is considered, an approximate value of 45.03% in strength gain in elders will be found. Harris *et al.*[23], in studies developed with application of only two weekly sessions found a very similar mean of 47.5%. Somehow, such fact tends to reinforce the findings by Taaffe *et al.*[31]. However, the analysis consistency is harmed due to the studies' distinct outlines.

It is worth mentioning once again that the study by Lamoureux *et al.*[26], was not considered for the determination of the mean strength gain due to its methodological characteristics completely different from the others. Besides applying a progressive increase of the workload intensity and the number of series during six months of training, the authors also varied the weekly frequency, beginning with a three-day frequency at the first three months and finishing with two weekly training sessions at the last three months. As previously mentioned, this variation in the subjects' treatment as well as not finding another similar study, do not lead to any further conclusions. The strength gains though, were fairly higher than the ones observed by the remaining studies.

Workload intensity

The workload intensity in the strength training, represented by the 1RM percentage or by the number of maximal repetitions that the individuals perform at each series developed in the counter-resistance program, is the variable which has taken the most space in the studies of the specialists of the field, comparing with the others.

From the 22 studies analyzed, six adopted as main topic the comparison between low and high intensities; among which, four found significant differences with advantage for the high workloads, most of the times established in a threshold of 80% of 1RM[3,27,37]. Only the study by Tisutisumi *et al.*[35] worked with loads which were kept between 75 and 85%. Generally, loads between 40% and 65% of 1RM are considered low, as can be seen in chart 4.

Considering the same approach used for the previous variables, the mean gains obtained by the individuals who trained with high intensity behaved steady at around 55.6%, while the ones who trained with low intensity were kept at around 39.9% (chart 5).

It is interesting to verify in chart 4 that two studies: Kalapotharakos *et al.*[3] and Seynnes *et al.*[27], presented a very similar outlin-

CHART 3
Studies considered for the calculation of the mean gains associated with different weekly frequencies

Study	Sample	Treatment	Results (strength gain)
Hunter *et al.*[2]	N 36 Lower and upper limbs	2 series 80% of 1RM 50, 65 and 80% of 1RM **3x week**/25 weeks	80% of 1RM = 32.8% 50/65/80% 1RM = 32.8% (Mean of 4 exercises)
Kalapotharakos *et al.*[3]	N 33 Lower and upper limbs	3 series 80% of 1RM 60% of 1RM **3x week**/12 weeks	80% of 1RM = 41.82% 60% of 1RM = 30.37% (Mean of 8 exercises)
Rhoofs *et al.*[9]	N 38 Lower and upper limbs	3 series 86% of 1RM **3x week**/12 months	53% (Mean of 6 exercises)
Frontera *et al.*[11]	N 14 Lower limb	80% of 1RM 3 series **3x week**/12 weeks	40% (Mean for knee extension)
Menkes *et al.*[24]	N 18 ♂ Lower and upper limbs	1 serie of 15RM for UL 2 serie of 15RM for LL **3x week**/16 weeks	1 serie = 43% 2 series = 47% (Mean of 6 exercises)
Treuth *et al.*[25]	N 22 ♂ Lower and upper limbs	1 serie of 15RM for UL 2 series of 15RM for LL **3x week**/16 weeks	1 serie = 39% 2 series = 42% (Mean of 6 exercises)
Seynnes *et al.*[27]	N 22 Lower limb	3 series 80% of 1RM 40% of 1RM **3x week**/10 weeks	80% of 1RM = 57.3% 40% of 1RM = 36% (Mean for knee extension)
Reeves *et al.*[28]	N 18 Lower limb	70-75% of 1RM 3 series **3x week**/14 weeks	19% (Mean for knee extension and leg-press)
Miszko *et al.*[29]	N 39 Upper and lower limbs	3 series 50% to 70% of 1RM 80% of 1RM **3x week**/16 weeks	80% of 1RM = 18.72% 50 to 70% of 1RM = 12.23% (Mean for bench press and leg-press)
Brandon *et al.*[30]	N 85 Lower limb	3 series 50%, 60% and 70% of 1RM **3x week**/16 weeks	51.7% (Mean for knee extension and flexion and plantar flexion)
Morganti *et al.*[32]	N 39 Lower limb	3 series 84% of 1RM **3x week**/12 months	61.9% (Mean for knee extension, leg-press and hip adduction)
Judge *et al.*[33]	N 48 Lower limb	3 series 75% of 1RM **3x week**/12 weeks	62% (Mean of 8 exercises)
Pika *et al.*[34]	N 14 Lower and upper limbs	3 series 70% to 75% of 1RM **3x week**/52 weeks	62.39% (Mean of 12 exercises)
Judge *et al.*[10]	N 31 Lower limb	3 series 75-80% of 1RM **3x week**/12 weeks	32% (Mean for knee extension)
Tsutsumi *et al.*[35]	N 42 Upper and lower limbs	2 series 75% to 85% of 1RM 55% to 65% of 1RM **3x week**/12 weeks	75% to 85% of 1RM = 48.2% 55% to 65% of 1RM = 39.7% (Mean of 12 exercises)
Schlicht *et al.*[36]	N 22 Lower limb	2 series 75% of 1RM **3x week**/8 weeks	27.5% (Mean of 6 exercises)
Vincent e Braith[37]	N 62 Lower and upper limbs	1 serie 50% of 1RM 80% of 1RM **3x week**/24 weeks	50% of 1RM = 52.4% 80% of 1RM = 79.0% (Mean of 10 exercises)
Hagerman *et al.*[4]	N 22 Lower limb	3 series 85-90% of 1RM **2x week**/16 weeks	68.7% (Mean for knee extension, leg-press and squat)
Harris *et al.*[23]	N 51 ♂♀ Lower and upper limbs	2 x 15RM; 3x 9RM; 4 x 6RM **2 x week**/18 weeks	2 series = 44%; 3 series = 51%; 4 series = 50% (Mean of 8 exercises)
Hurley *et al.*[38]	N 35 Lower and upper limbs	1 serie 15RM **3x week**/16 weeks	43% (Mean of 6 exercises)

CHART 4
Studies which compared strength gains in elders facing different load intensities

Study	Sample	Treatment	Results (strength gain)
Kalapotharakos *et al.*[3]	N 33 Lower and upper limbs	3 series/8 rep/**80%** of 1RM 3 series/15 rep/**60%** of 1RM 3x week/12 weeks	80% of 1RM = 41.82% 60% of 1RM = 30.37% (Mean of 8 exercises)
Tsutsumi *et al.*[35]	N 42 Upper and lower limbs	2 series/8-12 rep/**75-85%** of 1RM 2 series/12-16 rep/**55-65%** of 1RM 3x week/12 weeks	75% to 85% of 1RM = 48.2% 55% to 65% 1RM = 39.7% (Mean of 12 exercises)
Hunter *et al.*[2]	N 36 Lower and upper limbs	2 series x 10 rep. x **80%** of 1RM 2 series x 10 rep. x **50, 65 and 80%** of 1RM 3x week/25 weeks	80% of 1RM = 32.8% 50/65/80% 1RM = 32.8% (Mean of 4 exercises)
Vincent e Braith[37]	N 62 Lower and upper limbs	1 serie **50%** of 1RM **80%** of 1RM 3x week/24 weeks	50% of 1RM = 52.4% 80% of 1RM = 79.0% (Mean of 10 exercises)
Seynnes *et al.*[27]	N 22 Lower limb	3 series **80%** of 1RM **40%** of 1RM 3x week/10 weeks	80% of 1RM = 57.3% 40% of 1RM = 36% (Mean for knee extension)
Harris *et al.*[23]	N 51 ♂♀ Lower and upper limbs	**2 of 15RM; 3 of 9RM; 4 of 6RM** 2x week/18 weeks	2 series = 44%; 3 series = 51%; 4 series = 50% (Mean of 8 exercises)

ing when the weekly frequency was considered (3 x week), 1 RM percentage (80%) and training time (12 and 10 weeks, respectively). The other two studies, by Tisutsumi *et al.*[35] and Vincent *et al.*[37], worked with one and two series and training time of 24 and 25 weeks, respectively. It is worth mentioning that Vincent *et al.*[37], using the lowest number of series, found the highest strength gains with high load intensity (79%).

Two studies did not find significant differences in the strength increase of elders when trainings with high and low loads were compared. The one by Hunter *et al.*[2] compared a group which trained with two series at 80% of 1RM intensity with a group which trained one day a week at 50%; another day at 65%; and on the third day at 80%. The authors found a mean strength increase of 28.5% and 37.1% for upper and lower limbs respectively, for the first and second groups. However, it would not be possible to characterize the second group as trained only with low loads, but varied instead. There are no other studies which can aid in the discussion of the role of loads variation in the potential increase of strength in short and middle-term trainings. Nonetheless, one may think that the strength gains derived from coordinative adaptations, predominant in this kind of program, are the origin of the obtained results. Perhaps the neural component is sensitive to this kind of manipulation, once it is reflected in the recruitment pattern of the motor units[1-2]. Hence, the motor repertoire associated with the program is enriched, with possible effect on the contraction optimization in the proposed exercises[1].

The study by Harris *et al.*[23] did not find significant differences between different work intensities, comparing groups which trained with two series of 15RM; three series of 9RM and 4 series of 6RM. The gains observed by the authors, respectively for each group, were of 44.51 and 50% of the strength measured on the baseline. As the number of series also varied, the total work of the groups behaved similarly, which makes it difficult to conclude that the different intensities added to the number of maximal repetitions performed would have the same potential of strength development.

Therefore, generally speaking, there is evidence that the high intensity workloads cause a significantly higher increase in strength

CHART 5 Studies considered for the calculation of the mean gains associated with different intensities			
Study	**Sample**	**Treatment**	**Results (strength gain)**
Hagerman *et al.*[4]	N 22 Lower linf	**85-90%** of 1RM 3 series 2x week/16 weeks	68.7% (Mean for knee extension, leg-press and squat)
Rhoofs *et al.*[9]	N 38 Lower and upper limbs	**86%** of 1RM 3 series 3x week/12 months	53% (Mean of 6 exercises)
Frontera *et al.*[11]	N 14 Lower limb	**80%** of 1RM 3 series 3x week/12 weeks	40% (Mean for knee extension)
Miszko *et al.*[29]	N 39 Upper and lower limbs	**50% to 70%** of 1RM **80%** of 1RM 3 series 3x week/16 weeks	80% of 1RM = 18.72% 50 to 70% of 1RM = 12.23% (Mean for bench press and leg-press)
Taaffe *et al.*[31]	N 53 Lower and upper limbs	**80%** 1RM 3 series 1, 2, 3x w./ 24 weeks	1x w. = 37.0% 2x w. = 41.9% 3x w. = 39.7% (Mean of 8 exercises)
Morganti *et al.*[32]	N 39 Lower limb	**84%** of 1RM 3 series 3x week/12 months	61.9% (Mean for knee extension, leg-press and hip adduction)
Lamoureux *et al.*[26]	N 45 Lower limb	**85%** 1RM 2 to 5 series 3x week (3 months) 2x week (3 months) 24 weeks	235% (Mean of 5 exercises)
Judge *et al.*[10]	N 31 Lower limb	**75-80%** of 1RM 3 series 3x week/12 weeks	32% (Mean for knee extension)
Judge *et al.*[33]	N 48 Lower limb	**75%** of 1RM 3 series 3x week/12 weeks	62% (Mean of 8 exercises)
Pika *et al.*[34]	N 14 Lower and upper limbs	**70% to 75%** of 1RM 3 series 3x week/52 weeks	62.39% (Mean of 12 exercises)
Reeves *et al.*[28]	N 18 Lower limb	**70-75%** of 1RM 3 series 3x week/14 weeks	19% (Mean for knee extension and leg-press)
Schlicht *et al.*[36]	N 22 Lower linf	**75%** of 1RM 2 series 3x week/8 weeks	27.5% (Mean of 6 exercises)
Brandon *et al.*[30]	N 85 Lower limb	**50%, 60% and 70%** of 1RM 3 series 3x week/16 weeks	51.7% (Mean for knee extension and flexion and plantar flexion)
Menkes *et al.*[24]	N 18 ♂ Lower and upper limbs	1 of **15RM** for UL 2 of **15RM** for LL 3x week/16 weeks	1 series = 43% 2 series = 47% (Mean of 6 exercises)
Treuth *et al.*[25]	N 22 ♂ Lower and upper limbs	1x **15RM** for UL 2x **15RM** for LL 3x week/16 weeks	1 serie = 39% 2 series = 42% (Mean of 6 exercises)
Hurley *et al.*[38]	N 35 Lower and upper limbs	**15RM** 1 serie 3x week/16 weeks	43% (Mean of 6 exercises)

gains in elders than with lower workloads. These findings may be explained by the fact that the main factors which contribute to the strength increase due to training are the neural and hypertrophic adaptations[39]. In an early moment of the training, the neural development tends to be the preferential via for the improvement of the capacity to mobilize workloads, since a higher level of strength may be created through the increase of the frequency as well as the recruitment of motor units of the muscular groups involved in the movement[40-41]. Kraemer *et al.*[42], within this context, point that the recruitment of the motor units through the high intensity of the neural work may previously enable underused muscular fibers to be trained.

This possibility seems to be well-accepted by the literature: of the 16 studies found which did not have as aim to compare different training intensities over the strength gains, 12 used workloads above 75% of 1 RM in their treatments, while only four applied loads below this limit (chart 5). Once again, the expressive results obtained in the study by Lamoureux *et al.*[26] separately highlight: the authors found in response to high load training (85% of 1RM), an increase of 235% in strength in elders. Despite a very different outline from the remaining studies, such finding reinforces the evidence that intense loads generate higher strength increases comparing with reduced loads.

Intervals and exercises order

Since it has received less attention from the researchers, the 'interval between series and exercises' variable was not main object of investigation in any of the 22 studies included in this systematic review. Moreover, not all investigated studies described the interval time adopted in the treatment as part of the experimental procedures. Of the 22 analyzed studies, only 14 described the used intervals, which varied from one to three minutes. Regardless the intensity and volume of the series used in the training, the great majority (10 studies) adopted, even with no evidence that this is the ideal parameter for elders, the mean time of two minutes for recovery between series and exercises.

Concerning the exercises order, of all the variables involved in the counter-resistance training, this one seems to be the one with the least attention. Besides not having been aim of specific investigation in any of the 22 studies found, not even the used order in their treatments was reported. Thus, no inference or comment on the relative influence of this variable in the context of a dose-response relationship is possible.

It is interesting to note that Simão[39], when reviewing studies conducted with young adults, found the same difficulties to identify consensus concerning these training variables. In other words, although it is accepted that exercises involving large muscular groups should be placed at the beginning of training sessions, this recommendation does not seem to find support in several scientific evidences. The same episode occurred with the 'interval between series and exercises' variable – the author only found studies analyzing intervals in tests of maximal workload, but none which had focused them as study object in an exercises sequence.

FINAL CONSIDERATIONS

The benefits promoted by the counter-resistance training depend on the combination of variables with the number of repetitions, series, overload, sequence and intervals between series and exercises[16].

When reviewing the studies published so far with the aim to verify the existence of common trends concerning the methodological variables of strength training for elders (load intensity; number of repetitions; number of series; interval between series; exercises order and weekly frequency), the best combination of these variables for an optimum dose-response relationship was uncertain. Furthermore, it widely reproduces what is observed concerning the training of young adults. Therefore, the results found in the present review lead to a conclusion similar to that of the review study by Gomes and Pereira[17]: different combinations of the training variables may be equally efficient for strength development of elders.

Individually analyzed, the variables have not been widely investigated with the aim to determine the effects on the strength gain of this or that strategy when populations with older subjects were considered. Concerning the number of series and weekly frequency, only one study involving each of these variables was found. None presented significant differences between the results of the groups which worked with different manipulations, which tends to reinforce the idea that there are several obscure aspects concerning the dose-response relationships in strength training with elders. The results available in the literature; therefore, do not support the almost consensual choice of the analyzed studies: three series performed in a frequency of three weekly days for the designing of their training programs. It seems that this choice has been based only on the recommendations by the ACSM for the training of young adults, regardless the biological differences which may somehow influence the trainability potential of older subjects.

Concerning the exertion intensity, six studies compared strength gains in elders submitted to trainings with high and low intensities; four found significant differences, showing evidence that higher loads would be more efficient for the production of strength increase in this age group. These findings support the almost exclusive adoption high training intensities from the found studies. However, there are still obscure zones, specially concerning programs with varied load or the effects derived from short and long training periods – in other words, the manipulation of the work intensity and the magnitude of strength gains attributed to coordinative and hypertrophic adaptations in older subjects still raises concerns which deserve further investigation.

It was not possible to develop considerations concerning the manipulation of the variables associated with the intervals between exercises and series neither the exercises order. None of them was main objective of investigation in any of the 22 studies included in the present systematic review. Concerning the 'exercises order', besides not having been investigated, one can see that the studies did not even describe it. This fact is a gap to be explored, since the procedures usually adopted refer to the recommendations by the ACSM[18] when the exercises involving large muscular groups are performed prior to those which recruit smaller groups. Studies in our laboratory show that this is not always the most suitable procedure, depending on the training session's purpose as well as the fitness level of the practitioner[39]. Data on how older individuals respond to different acute and chronic exercises order were not found in the literature researched.

Thus, it can be concluded that further investigation is needed concerning different combinations of variables of strength training for the elderly. Within this context, we suggest that additional effort should be applied with the purpose to make them clearer, especially concerning the outline of training programs which combine effectiveness and safety.

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