Original Article

Effect of resistance and power training with walking in different directions on the serum concentrations of P3NP and CAF, the lower body muscle strength and motor function in elderly men

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ABSTRACT

Objective(s): Examine the effect of resistance and power training with walking in four directions on the N-terminal peptide of type III procollagen (P3NP), the C-terminal agrin fragment (CAF), the lower body muscle strength and motor function in elderly people. Materials and Methods*:* Thirty-one elderly men were selected and divided into three groups: control group (C); resistance training (RT) group, and power training (PT) group. RT was performed with 8–10 repetitions during 20–35 seconds of exercise and PT with 8–10 repetitions during 10–13 seconds of exercise. The exercise to which subjects were exposed to, in both resistance and power training groups, consisted in walking in four directions for 12 weeks (two sessions per week). Body mass index (BMI), functional tests, and lower body strength were also measured. The serum levels of P3NP and CAF were evaluated in all groups. Results*:* Lower body strength (leg press, plantar ankle flexion, knee extension, leg curl) and motor function (chair stand test, timed up and go, 6-minute walking), improved following the exercise, while no effect was found concerning the serum levels of P3NP and CAF. Conclusions: An increase in motor function and lower body strength was observed in both types of exercise programmes discussed in this paper, although the exercise should be done rapidly for a better result.
Keywords: Sport Medicine; Nutrition; Health; N-terminal peptide of type III procollagen (P3NP); C-terminal agrin fragment (CAF); Resistance training; Power training; Walking in four directions.

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INTRODUCTION

Sarcopenia and aging are classified as a muscle disease, which is associated with an increased risk of falling, with consequent fracture, disability, and illness, mainly due to a decreased muscle strength, muscle mass and physical function (Granacher et al., 2012). Functional capabilities are related to endurance, muscle strength, balance and coordination, and general health (Granacher et al., 2012; Larsson et al., 2018). Aging reduces the anabolic reactions and increases the catabolic reactions in the muscle cell structure and these physiological events can be associated with a decrease in the capacity of muscle cell regeneration, resulting in muscle cell apoptosis (Tudoraşcu et al., 2014). During muscle cell regeneration, collagen, which provides support for the regulation and growth of myoblasts, is also formed (Fragala et al., 2015). A third type of collagen in the skeletal muscle is actually synthesised from the procollagen III molecule by the N- and C-terminal peptides (Fragala et al., 2015). In the final phase of collagen synthesis, the N-terminal peptide of type-III procollagen (P3NP), which is poured into the blood circulation, can enhance the synthesis of type-III collagen and ultimately the biomarker of muscle quality (Fragala et al., 2015). High levels of P3NP in pathological conditions, such as congestive heart failure (Biolo et al., 2009; Franzen et al., 1995), high blood pressure (Díez et al., 1995), and coronary artery disease (Jensen et al., 1990), are also associated with abnormal collagen formation. In these diseases, inflammation is assumed to lead to the abnormal synthesis of collagen and to the fibrosis of soft tissues, which leads to an increase in P3NP levels (Sugimoto et al., 2009). The neuromuscular junction is also affected by aging (Fragala et al., 2014; Fragala et al., 2015). Agrin is a heparin sulphate proteoglycan that is synthesised in the motor neuron, transported along the axon and transmitted to the synaptic base laminate of the neuromuscular junction (NMJ), where the structure of the post-synaptic system, including clustering of acetylcholine receptors and pre-existing structures, is fixed (Stephan et al., 2008). The C-terminal agrin fragment (CAF) value has been suggested as a marker of muscle atrophy in human blood (Drey et al., 2013) and in the blood of animal subjects (Bütikofer et al., 2011). One of the factors of NMJ destruction is the increased generation of neurotrypsin (Bütikofer et al., 2011; Fragala et al., 2015). Neurotrypsin is effective in reducing muscle mass by destructing the agrin protein receptor with the subsequent destruction of the NMJ (Bütikofer et al., 2011). When agrin destruction occurs, the CAF concentration in the blood increases and the transmission of neural signals from the upper nervous system to the muscles is impaired. Failure to send nerve signals leads to less muscle activity, resulting in weakness and atrophy (Drey et al., 2013; Fragala et al., 2015; Stephan et al., 2008). Research works have reported that the CAF index increases because of aging (Drey et al., 2013; Fragala et al., 2014; Fragala et al., 2015; Stephan et al., 2008).

Training methods

Training and physical activity are a powerful and stimulating mechanism for the reconstruction and repair of the skeletal muscle (Egan & Zierath, 2013). Changes in the exercise load, number of repetitions, and contraction time are known as factors influencing the adaptations of post-resistance training, which can create different adaptation phenotypes, according to their combination. Some researchers have demonstrated that resistance exercises increase power and have little effect on performance (Foldvari et al., 2000; Miszko et al., 2003). In contrast, other findings suggest that resistance training, in addition to increasing muscle mass and strength, improves the performance of the elderly (improving the speed of chair stand and of climbing stairs) (Gomes et al., 2017; Straight et al., 2016). Power exercises can also increase muscle strength and improve performance, but the speed of performing these exercises is different between achieving optimal motor performance and increasing muscle strength, as has been reported by the literature (Munn et al., 2005; Ramírez-Campillo et al., 2014).

Some exercises involve power training as intense as resistance training but performed at a higher speed (up to fatigue) (Bernat et al., 2019), while the intensity is less in other exercises but with an increased speed of motion (Gomes et al., 2017). Six weeks of resistance training (8–15 repetitions with 70%–85% repetition maximum [RM]) were found to increase the serum levels of P3NP and CAF in elderly people (Fragala et al., 2014). Power training (2–3 seconds concentric, 2–3 seconds eccentric) and power training (high-speed concentric, 2–3 seconds eccentric) with supplementation of vitamin D, instead, reduced the CAF serum level (Drey et al., 2013). Eight weeks of resistance training (80% 1-repetition maximum strength [1RM] up to fatigue) at high speed, including leg flexion, extension and elbow flexion, and extension at maximum speed, increased the muscle strength variables (1RM), muscle thickness, and peak knee joint movement other than improving the motor function (balance). However, no difference was found between the two training groups (Bernat et al., 2019). Long-term (weekly for 2 years) power training (three sets of 8–13 repetitions with 60%–85% 1RM) increased the muscle strength (isometric contraction in opening and closing the knee) and improved performance (Berg Balance Scale, chair stand performance, and walking speed) in 182 elderly people (Aartolahti et al., 2019). The effect of lower body power and resistance training (foot press and leg extension) with two different intensities (three sets of 40% and 70% with 10 repetitions) was measured in 52 elderly subjects having the same speed of training (1 second concentric, 2 seconds eccentric). The frequency of maximal repetition and improved motor function (walking and chair stand performance) was reported to increase, while there was no difference between the two training groups (Reid et al., 2014). Two types of walking exercises (880 yards in the first session with an increase in steps in subsequent sessions based on individual power) and strength (two sets of 75% 1RM with 1–10 repetitions and 5% increase in 1RM after 10 repetitions at the foot press, knee opening and closing, and chest press) for 16 weeks improved performance and flexibility (Simons & Andel, 2006).

To the best of our knowledge, the studies conducted thus far on CAF and P3NP indices are insufficient and with fragmentary results that do not allow to obtain an general picture with definitive conclusions. The main limit of these studies was, in fact, the duration of the training courses, which was in the range of 6–8 weeks (Fragala et al., 2014; Santanasto et al., 2020), while neuromuscular adaptation requires more time compared to physiological variables and peptide changes (Conlon et al., 2017; Radaelli et al., 2014). Therefore, conducting research on a longer time frame could be crucial in terms of neuromuscular and physiological adaptation. There is a general disagreement on the method of training, which should be effective in preventing a fall caused by lower limb muscle weakness and imbalance (considered as one of the most important causes of mortality due to aging (Morello et al., 2019; Ylitalo et al., 2021)). Moreover, the results based on the serum peptide variables used in the studies conducted over a period of less than 10 weeks, performing resistance training as an effective intervention factor (Calvani et al., 2018; Fragala et al., 2014; Fragala et al., 2015), were inconsistent. We thus compared the two types of training (resistance and power) with walking in different directions for a longer time frame (12 weeks) to examine their effects on P3NP, CAF, and on the physical performance indices in older men.

MATERIALS AND METHODS

A total of 36 retired men was selected on a targeted basis and divided into three groups based on age and body mass index (12 subjects in each group). Five subjects left practice for various reasons, so were excluded from the dataset and the statistical analysis was performed on the final sample. Ten subjects with an average age of (63.40 ± 3.95) years old and average weight of (78.8 ± 8.3) kg were inserted in the control group; 10 subjects (average age = 63 ± 3.88 years old; average weight = 79 ± 8.3 kg) were placed in the resistance group and the remaining 11 individuals (average age = 63.50 ± 5 years old; average weight 76 ±

6.2 kg) formed the power group. The sampling method was determined based on the analysis of variance (α = 0.02, power = 80%) with.

Blood samples were taken from the participants twice. The first time between 7:00 and 8:30 am 48 h before training for a pre-test and the second time between 7:00 and 9:30 am 24 h after training for a post-test (see Figure 1 for more details). The test of motor function and muscle strength of the lower limbs was performed a week before the study and 24 h after training (Fig. 1). The following inclusion criteria in the study were considered: at least 61 years of age, lack of regular exercise, presence of cardio-pulmonary disease, and absence of chronic diseases, such as arthritis, high blood pressure, and diabetes. Exclusion criteria included: muscle damage, inability to exercise, lack of presence in more than three sessions, and quitting in between due to personal reasons. All participants filled the informed written consent form to participate in the research and the physical health questionnaire (with the approval of the physician). The research method was confirmed by the Ethics Committee of the Hakim Sabzevari University of Medical Sciences (Sabzevar, Iran) and was registered under the code of ethics (Ir.Medsab.Rec.1396.98).

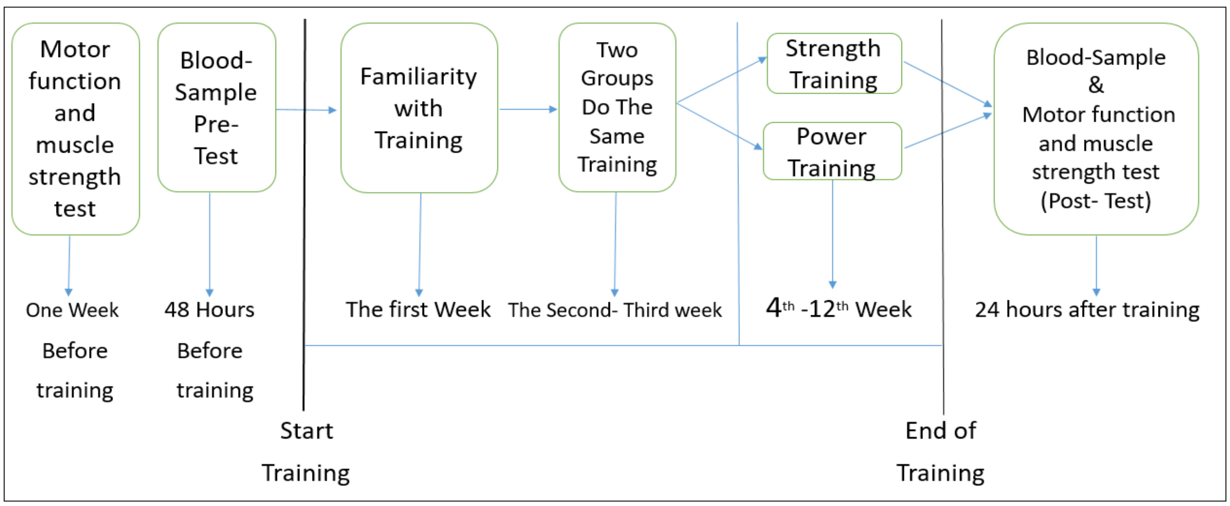

Figure 1. Diagram of the study design.

Motor function (including dynamic strength, dynamic balance, and cardio-respiratory endurance) was evaluated by chair stand (r = 0.97) (Hamilton & Haennel, 2000), timed up and go (r = 0.95) (Chan et al., 2017), and 6-minute walking (r = 0.95) (Bellet et al., 2012). Muscle resistance and the 1RM (One Repeated Maximum) test included maximum contraction in foot press, plantar ankle flexion, and knee extension and flexion, which were evaluated by an indirect method (Brzycki, 1993) (Formula 1):

Maximum of 1 repetition = weight / [(1–0.02) the number of repetitions] (Formula 1)

Blood sampling

The serum concentrations of P3NP and CAF were measured after 10–12 hours of fasting. Ten cc of blood was taken from the brachial ventricle of the subjects, centrifuged at 4000 rpm, and then kept in the fridge at –80°C. P3NP was measured with an amplitude of 75–2400 ng/L and sensitivity of 5 ng/L and CAF was measured with an amplitude of 1.5–48 pmol/L and sensitivity of 0.1 pmol/L by the ELISA method using a ZellBio (Germany) special kit according to the manufacturer's instructions.

Training Programme

During the first week of the study all participants were exposed to the exercises of the training programme to become familiar with the same and practice was carried out during weeks 2 and 3 in which the two groups performed the same kind of training (Fig. 1). From the fourth to the 12th week the participants were divided in the two experimental groups (resistance training and power training; Fig. 1). For both resistance training and power training, the exercises consisted of walking in 4 different directions (see Fig. 2 for more details). The resistance training programme in both groups included four stations (foot press, leg extension, leg curl, and toe stand pose), which were performed at a different speed and intensity. All participants, who were possibly exposed to weakness and injury, performed the training programme in two sets during the first 3 weeks and increased up to three or four sets in the last 3 weeks (see Tables 1 and 2 for more details).

Table 1. Resistance training programme.

Resistance training												
Week	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Sets	2	2	2	3	3	3	4	4	4	3	3	3
Interval	1-2 min											
Max rep	8-10	8-10	8-10	8-10	8-10	8-10	8-10	8-10	8-10	8-10	8-10	8-10
Time of set	20-35 sec											

Table 2. Power - resistance training programme.

Power training												
Week	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Sets	2	2	2	3	3	3	4	4	4	3	3	3
Interval	2-3 min											
Max rep	8-10	8-10	8-10	8-10	8-10	8-10	8-10	8-10	8-10	4-6	4-6	4-6
Speed	Arbitrary			Medium			Explosive			Explosive		
Time of set	Similar to the resistance training group			13-16 sec			11-13 sec			6-8 sec		

Whenever the number of repetitions exceeded the specified value, weights were increased (5%–15%) to maintain the number of repetitions.

Walking training

The following procedure was applied for each set of exercises:

Step 1 - Moving from the centre forwards to point (A), turning back, and then moving forwards to the central point again.
Step 2 - Moving from the centre backwards to point (B), turning back, and then moving backwards to the central point again.
Step 3 - Moving from the centre to the right to point (C), turning back, and then moving left to the central point again.
Step 4 - Moving from the centre to the left to point (D), turning back, and then moving right to the central point again.
All four steps are defined as a set. In all cases, the distance from the end of the route to the central point is 10 m (Figure 2).

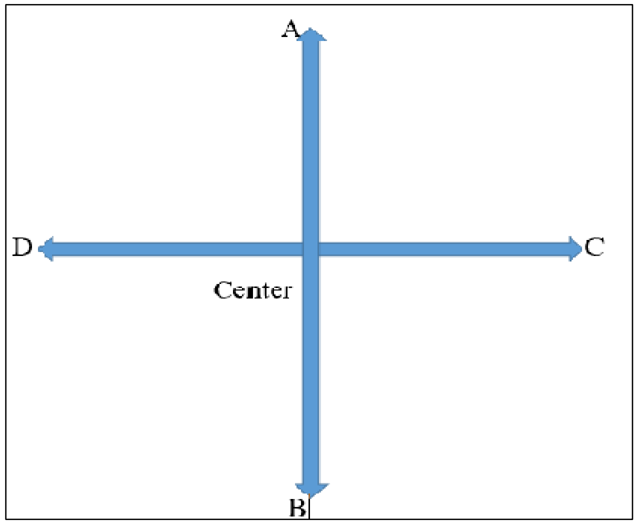

Figure 2. Walking method from the centre in four directions (ABCD).

This training programme was designed for both groups with the aim of increasing neuromuscular coordination and of balancing the lower body muscle activity in the anterior–posterior and internal–lateral parts of elderly patients (Table 3).

Table 3. Walking programme in four directions.

Weeks	Procedure
1st	% 60 HRM
2nd	% 60 HRM
3rd	1 set with 0.5 kg medicine ball at % 60 HRM
4th	Like 3rd week with % 65 HRM
5th	2 sets with 0.5 kg medicine ball at % 65 HRM
6th	Like 5th week with % 65 HRM
7th	2 sets with 1 kg medicine ball at % 70 HRM
8th	Like 7th week with % 70 HRM
9th	2 sets with 2 kg medicine ball at % 70 HRM
10th	Like 9th week with % 75 HRM
11th	Like 9th week with % 75 HRM
12th	Like 9th week with % 75 HRM

The intensity of walking activity based on the percentage of HRM was controlled by using Formula (2):

HRM (Heart Rate Maximum) = 211-(0.64*Age) (Nes et al., 2013) (Formula 2)

Descriptive statistics was used to describe the mean and standard deviation (Table 4) and coefficient of variation (Table 5), and repeated measures analysis of variance was used to analyse the data (Table 6). In the repeated measures design, the response data related to the same subjects was analysed more than once (i.e. an analysis of variance type 2 was applied). This test considers between-subject effects to analyse data and within-subject effects to examine the basic hypotheses. The Kolmogorov–Smirnov test with correction of Lilliefors was used to assess the normality of the groups before and after training, Levine's test was used to test the homogeneity of the groups in the pre-test/post-test, and the Box test was used to verify the constant error covariance matrix. Considering that the *p*-value in all of the above cases was greater than .05, the repeated measures analysis of variance was performed using the least-squares method. In variables with no assumptions of homogeneity and normality ($p < .05$), the weighted repeated measures analysis of variance was devised. The significance level was set at $p = .05$. SPSS software (version 20) was used to analyse all the data.

RESULTS

The statistical analysis showed that there was no significant difference between the P3NP and CAF indices of both groups. However, in line with previous results (Purath et al., 2009), a significant difference was observed between the two groups in terms of the leg press test, gastrocnemius strength, leg extension, leg curl and functional tests of dynamic balance, lower body muscle strength, and cardio-respiratory endurance (Table 6). The results of Turkey's test and the post hoc test showed that the aforementioned indices significantly improved ($p < .05$) in both training groups, although no significant difference emerged between the two groups with the only exception of the dynamic balance test. In fact, the power training group showed a significant improvement in dynamic balance ($p = .001$) and a better performance ($p = .02$) compared to the resistance training group. No difference was found between the two training groups in other tests. In addition, the results of the statistical analysis showed that the interaction of group and time was non-significant in terms of P3NP and CAF. Therefore, exercises had no effect on the selected serum factors. It should be noted that there was no significant correlation between the functional and muscle strength indices and the P3NP and CAF serum indices ($r > 0.4$ and $p > .05$). Therefore, the P3NP and CAF serum indices were shown to be insufficient to predict the results of the power and performance tests (Tables 4, 5 and 6).

DISCUSSION

In the present study, muscle strength and cardio-respiratory endurance increased in both training groups, although no statistical difference emerged between the two experimental groups. While the dynamic balance index demonstrated improvement in the performance of both training groups compared to the control group, the power group showed a better performance than the resistance group. Changes in serum P3NP and CAF were non-significant in both groups.

Previous research considered the intensity of resistance training as 65%–85% 1RM with 8–12 repetitions, which increased the maximum power (17, 20, 19), while in our study the maximum number of repetitions was 10 and the principle of overload was 5%–10%, likewise Simons and Andel (Simons & Andel, 2006) and Arnarson and co-workers (Arnarson et al., 2013). In the power and resistance training programmes, the research methods applied were different. For example, for some authors the intensity of the exercise was similar to the intensity of resistance training, although it was performed more quickly up to fatigue (Bernat et al., 2019). In other studies the intensity of training was less than the traditional resistance training (40%–60% 1RM), but, for concentric and eccentric contraction, a ratio of 1:2 was considered (1 second concentric and 2 seconds eccentric) (Miszko et al., 2003; Reid et al., 2014), which was also used in this study. However, in our case the total runtime of a set was evaluated with a stopwatch, and we attempted to run a set (according to age) at the minimum possible speed (Table 2). The results of power training improved in this research compared to the control group, although they did not differ from the traditional resistance group (Bernat et al., 2019; Reid et al., 2014). In contrast, as reported in other studies, differences were reported between the results of the power and resistance groups, with the power group having better results (Miszko et al., 2003; Orr et al., 2006).

Table 4. Descriptive indices of functional and power tests in the pre- and post-tests.

Groups	Control group			Resistance training			Power training		
	Before	After	Percent changes	Before	After	Percent changes	Before	After	Percent changes
Leg press (kg)	85.13 ± 6.7	85.70 ± 5.2	0.66	86.65 ± 7.4	104.5 ± 11.6	20	89.09 ± 4.82	107.51 ± 12.0	20.6
Gastrocnemius Strength (kg) (Pressing the toes to the ground)	11.84 ± 1.7	12.11 ± 1.8	2.2	11.63 ± 2.7	19.33 ± 3.2	66.2	12.06 ± 2.46	21.57 ± 3.19	78.8
Knee Extension (kg)	22.40 ± 2.3	22.54 ± 2.3	0.62	22.23 ± 3.7	28.02 ± 3.4	26	22.64 ± 2.23	33.43 ± 5.94	47.6
Leg Curl (kg)	24.37 ± 2.6	24.38 ± 2.8	0.04	24.07 ± 4.2	34.28 ± 5.2	42.4	24.81 ± 2.79	36.26 ± 5.83	46.1
Dynamic Balance (s) (Timed Up Go)	6.37 ± 0.27	6.24 ± 0.4	-2.1	6.42 ± 0.2	5.79 ± 0.2	-9.8	6.48 ± 0.19	5.46 ± 0.18	-15.7
Dynamic power (Number) (Chair Stand Test)	12.1 ± 1.2	12.00 ± 1.5	-0.82	12.10 ± 1.6	15.30 ± 1.2	26.4	12.64 ± 1.12	16.18 ± 1.88	28
Cardio-respiratory endurance (m) (6-Minute Walking)	783.5 ± 11.5	784.59 ± 11.01	0.13	785.82 ± 17.06	813.31 ± 11.6	3.5	789.0 ± 11.72	820.77 ± 11.29	4
P3NP (ng/L)	5.150 ± 1.16	4.82 ± 0.927	-6.4	4.920 ± 1.584	3.820 ± 1.796	-22.3	5.573 ± 0.936	5.25 ± 0.74	-5.7
CAF (pmol/L)	114.7 ± 31.2	111.2 ± 29.69	-3	118.9 ± 41.97	90.80 ± 45.40	-23.6	135.2 ± 17.18	127.55 ± 15.36	-5.6

Table 5. Coefficient of variation (CV).

	Control Group		Resistance Group		Power Group	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Leg press	%7.9	%6.1	%8.6	%11.2	%5.4	%11.2
Gastrocnemius Strength (Pressing the toes to the ground)	%14.7	%15	%23.4	%16.6	%20.4	%14.8
Knee Extension	%10.4	%10.2	%16.6	%12.3	%9.9	%17.8
Leg Curl	%10.8	%11.2	%17.4	%15.3	%11.3	%16.1
Dynamic Balance (Timed Up Go)	%4.4	%6.5	%3.2	%3.1	%2.9	%3.4
Dynamic power (Chair Stand Test)	%10.4	12.4	%13.6	%8.2	%7.7	%8.0
Cardio-respiratory endurance (6-Minute Walking)	%1.5	%1.4	%2.2	%1.4	%1.5	%1.4
P3NP	%22.5	%19.2	%32.2	%33	%16.8	%14.2
CAF	%27.2	%26.7	%21.1	%25.6	%12.7	%12.0

Table 6. Results of weighted and repeated measures analysis of variance of power, performance, P3NP and CAF (group effect, time effect, and group–time effect).

Variable	**Group effect**			**Time effect**			**Group time effect**		
	Stat	*p*-value	Effect Size	Stat	*p*-value	Effect Size	Stat	*p*-value	Effect Size
Foot press (kg)	46.91	.001	0.77	109.23	.001	0.79	16.45	.001	0.54
Gastrocnemius (kg) (Pressing the toes to the ground)	31.37	.001	0.69	289.55	.001	0.91	35.04	.001	0.71
Leg extension (kg)	61.06	.001	0.81	153.98	.001	0.84	21.00	.001	0.6
Leg curl (kg)	71.74	.001	0.83	175.57	.001	0.86	22.68	.001	0.61
Dynamic balance (s) (Timed Up Go)	9.63	.001	0.40	114.95	.001	0.80	22.85	.001	0.62
Dynamic power (Number) (Chair Stand Test)	58.08	.001	0.80	151.42	.001	0.84	39.61	.001	0.73
Cardio-respiratory endurance (m) (6-Minute Walking)	55.96	.001	0.8	150.55	.001	0.84	32.72	.001	0.7
P3NP ng/L	16.79	.001	0.545	4.21	.04	0.131	2.38	.110	0.14
CAF (pmol/L)	58.23	.001	0.8	5.59	.02	0.16	1.97	.157	0.12

In none of the previous studies was "*walking in four directions*" considered as a training method together with other methods; however, this method was considered as a separate method of training by Simons and Andel (Simons & Andel, 2006) or only walking backwards was considered by others (Dufek et al., 2009). Based on the increased strength and performance in both training groups, we can conclude that both types of exercise can be suitable for elderly people. On the other hand, there was a significant difference between the two training groups in terms of the dynamic balance test; in other words, the combination of walking and power training resulted in a better balance, leading to a reduced mortality resulting from falling due to imbalance in elderly people (Lelard & Ahmaidi, 2015; Steadman et al., 2003). The lack of differences in the other performance tests and maximum power between the two groups can be attributed to the low training time. By increasing the training period (more than 12 weeks), more favourable results should be obtained for power training.

The 12-week training conducted in this study reduced CAF, while none of the other training methods had a significant effect on the CAF serum concentration. Only a handful of studies have reported the effect of power training on the CAF concentration and the results are conflicting. For example, according to Fragala and co-workers (Fragala et al., 2014), 6 weeks of power training significantly increased the concentration of CAF, whereas others reported that even 2 months of power training had no effect on the CAF serum concentration (Bondoc et al., 2015). If both resistance and power training were combined in subjects receiving vitamin D as a food supplement, CAF was shown to decrease significantly (Drey et al., 2013). There are various reasons that may explain the ineffectiveness of training on the CAF serum concentration. In the first place, according to the mean age of the subjects (63.3 ± 4 years), probably, neurotrypsin did not start its malignant activity (Bütikofer et al., 2011). Primary CAF levels could also have been lower in the subjects under study. With higher primary CAF levels, exercise has shown to be more effective (Fragala et al., 2014; Reid et al., 2014) and vitamin D supplementation alongside exercise may play a major role (Drey et al., 2013), which was not experimented in this study. Because nerve cells and muscle fibres are highly metabolic, it is logical to assume that they may be affected by even minor mitochondrial dysfunction (Baines et al., 2014; Li et al., 2013). Therefore, the role of mitochondria at the end of the axon in the construction and processing of chemical transmitters and, consequently, in the improvement and strength of the structure of the NMJ is very important (Deschenes et al., 2010). Recent studies have shown that PGC1-α gene expression plays a key role in mitochondrial structure and, consequently, in NMJ stability (Gouspillou & Hepple, 2013; Liang et al., 2011). PGC1-α gene expression and mitochondrial function are improved by aerobic activity (Lee et al., 2006). Therefore, endurance training can be effective in reducing CAF due to its effect on PGC1-α gene expression and mitochondrial function. The difference in the type of exercise in the present study may have been effective in not changing this index.

In this study, the serum concentrations of P3NP were not affected by training, in contrast to previous research in which exercise determined the reduction in P3NP levels (Bhasin et al., 2009). Only Fragala and co-workers (Fragala et al., 2014) focused on the effect of power training on P3NP, obtaining results that were consistent with the present study. It has been reported that, in cases of injury and inflammation, the serum levels of P3NP increase (Babbs et al., 1988; Berry et al., 2013).

Therefore, compatibility may be due to improved anti-inflammatory conditions and a lack of change in the P3NP index is an indication of this condition (Sugimoto et al., 2009). The response of P3NP levels to exercise has been reported to vary according to the amount of testosterone and growth hormone (Erotokritou-Mulligan et al., 2007; Nelson et al., 2006). If the amount of growth hormone increases in response to exercise, the amount of P3NP will also increase (Erotokritou-Mulligan et al., 2009; Nelson et al., 2008).

Testosterone levels and anti-inflammatory markers were not evaluated in the present study assuming obviously lower testosterone levels for the age range of the subjects recruited for this study (Craig et al., 1989; Perrini et al., 2005). As has been previously demonstrated, a period of training at a given intensity has an effect only on the reduction in the destructive process and a higher intensity of resistance and power training is necessary for the synthesis of structural proteins (Bell et al., 2019). On the other hand, the increase in P3NP is dependent on the increase in procollagen 3, which contributes to the growth of myoblasts and muscle formation (Fragala et al., 2014). It is muscle hypertrophy and not the intensity of the exercises that is enough to increase the index. It may be argued that uncontrollable intervention factors, such as nutrition, motivational factors, and the level of possible physical activity, which were outside the scope of this research, may have affected the outcome of this research.

The observed improvement in performance seen in the subjects of this study appears to be due to neuromuscular adaptations, such as the accelerated transmission of neurotransmitters (Piasecki et al., 2016), the increased coherence of motor units (synchronisation) (Semmler, 2002), the improvement in muscle metabolism (Breen & Phillips, 2011), and increase in recruitment of motor units (Arnold & Bautmans, 2014). The change in the intrinsic properties of motor nerves may be responsible for the increased coherence of motor units invoked in resistance training. As previously reported, unit irritability is higher in trained athletes (Gabriel et al., 2006) and if exercise increases motor irritability, we may expect the motor nerve discharge frequency (fire rate) to increase with exercise (Gabriel et al., 2006), which can be one of the possible factors determining the increase in dynamic strength with training. As previously demonstrated, after 6 weeks of resistance training of a large muscle group (knee extensor) on the lateral muscle load rate, the load rate increased by 15% in the young and 49% in the elderly (Kamen & Knight, 2004). Thus, it is possible that the improvement in physical function in the subjects of this study was due to the improved coordination between the nerve and muscle.

The increased endurance performance in the present study could be related to the quadriceps muscle activity during exercise (Izquierdo et al., 2003). This can be caused by blockage of the blood vessels due to the rapid rate of muscle contraction (Marcinik et al., 1991), which is attributed to the increased capillary density and citrate synthetase activity in the quadriceps muscle as well as to the increase in lactate (Izquierdo et al., 2003). On the other hand, the training programme followed in the present study caused a significant improvement in the balance index and in the dynamic resistance in the training groups compared to the control group. To balance it out, information from the sensory receptors of the atrioventricular region (20%), sensory-somatic (70%) and visual (10%) regions needs to be processed and integrated (Peterka, 2002). A large network of cortical structures, such as the parieto-insular vestibular cortex (PIVC), superior temporal gyrus (STG), and insular cortex region have been identified as important factors determining an enhanced processing capability of the atrial and multisensory areas in the brain (Dieterich & Brandt, 2015). Changing directions during exercises, which was conducted in this study, may have invoked the necessary interaction required for the seamless communication between different parts of the brain. On the other hand, increasing dynamic power, which is an important indicator of maintaining balance, also had the double effect of maintaining a better balance in the individuals under study. It can be said that strength-speed training increased the efficiency of the nervous system in the aforementioned areas. In addition, the improvement of strength in the lower muscles could be explained by the increased co-activation of agonist muscles and consequent decreased co-activation of antagonist muscles (Aagaard et al., 2000) (Hortobágyi & DeVita, 2006; Kubo et al., 2004).

CONCLUSIONS

Power training along with walking can be used as an effective exercise programme to maintain dynamic balance, hence contributing to reducing the incidence of falls in the elderly. In addition, the use of light weights in performing these exercises has fewer risks. According to the results of this study, elderly people can use resistance and resistance-power training along with walking in different directions to prevent muscle weakness and improve their physical function. However, resistance-power training results in a better maintenance of balance in the elderly, hence preventing the risk of falling and the complications associated with it. Despite the promising results, further studies are needed to obtain results that can be generalised based on the indicators of this study.

AUTHORS CONTRIBUTIONS

MP was responsible for the writing of the manuscript, RA for the manuscript conceptualisation and MD for the data analysis. RA and MP was responsible authors.

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DISCLOSURE STATEMENT

The database maintained under the Iranian Longitudinal Study on Aging was made accessible for the project free of charge since it was part of a student-based thesis. The opinions expressed in this manuscript are the ones of the authors and do not reflect the views of the Iranian Longitudinal Study on Aging.

ETHICS APPROVAL

The research method was approved by the Ethics Committee of the Hakim Sabzevari University of Medical Sciences (Sabzevar, Iran) and was registered under the code of ethics (Ir.Medsab.Rec.1396.98).

INFORMED CONSENT

All participants were provided with information brochures and informed consent was obtained from them at various stages of the study. Formal consent was not required for this type of study.

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