eJBio

Electronic Journal of Biology, 2016, Vol.12(3): 222-228

Aged Garlic Supplementation Improves Muscle Performance Properties in Untrained Male

Zekine Punduk*

Physical Education and Sport, University of Balikesir, Balikesir, Turkey.

*Corresponding author. Tel: +90 266 243 6447; Fax: +90 266 239 0285 E-mail: zkn1938@gmail.com

Citation: Punduk Z. Aged Garlic Supplementation Improves Muscle Performance Properties in Untrained Male. Electronic J Biol, 12:3

Received: April 06, 2016; **Accepted:** April 26, 2016; **Published:** May 03, 2016

Research Article

Abstract

Background: Aged garlic extract (AGE) is a dietary supplement and is reported have numerous health benefits including protection against fatigue. Recently, aged garlic extract (AGE) has been promoted as a nutritional supplementation against fatigue. However, the effects of AGE on muscle strength contraction properties have not been clearly defined in humans. The aim of this study was to investigate the anti-fatigue role of AGE in isokinetic muscle contraction in sedentary men.

Methods and findings: Six male subjects participated in this study and were tested during the isokinetic concentric/concentric protocol involving 6 maximal repetitions at the 60 and 180 degrees/sec on dominant knee for extensor and flexor muscles. Subsequently, the concentric muscle fatigue test with 30 maximal repetitions at 180°/sec was performed. After baseline test, the subjects were supplemented daily with AGE (5 ml) for 10 days. The performance tests were evaluated at baseline, after 10 days of post-supplementation and 10 days after the end of the study. AGE increased the extensor and flexor muscle function of the peak work, peak work/ body weight, average and total work in the post-supplementation period. Flexor peak torque, peak power, average power values were increased in the post-supplementation whereas no effect was observed on the extensor functions regarding these parameters.

Conclusion: AGE supplementation enhanced isokinetic knee muscle work parameters in the post-supplementation period in untrained men.

Keywords: AGE supplementation, Isokinetic muscle strength, Muscle work.

1. Introduction

The role of nutritional supplements in enhancing performance and recovery from injury has been investigated in a wide variety of sports. Most of the studies have investigated the effects of natural products and phytochemicals and their potential to enhance recovery of muscles from exercise induced damageand have reported positive results with cherry [1], blueberry [2] or pomegranate- based drinks [3-5]. The consumption of pomegranate juice improved the recovery of elbow flexor [4,5], knee extensor [5] and muscle strength properties in sedentary men. However, intake of polyphenols or grape juice did not affect the recovery of elbow flexor muscles strength [6]. On the other hand, long term supplementation with vitamin D3 and quercetin alone or their combination did not produce regulation of muscle strength in physically active male [7]. Thus, the effectiveness of supplementation in muscle strength or recovery of the normal muscle function, appears to be been influenced by different factors, including muscle contraction type (concentric or eccentric), muscle group, exercise protocol, daily amount of supplementation, and training status of participants.

Garlic (*Allium sativum*) is a herb and a nutraceutical and displays several biological benefits against oxidative stress, inflammatory, and dyslipidemia [8]. It is also available commercially in different formats and once popular preparation is the aged garlic extract. This differs from other garlic varieties in that it has less stimulative and pungent properties than cooked and raw garlic, and it contains more gamma-glutamyl cysteine, S-allyl cysteine, S-allylmercaptocysteine, and S-methyl cysteine than those found in cooked or raw garlic also [9]. AGE has been investigated widely both in vitro and in vivo and is reported to improve plasma lipid concentrations and oxidative stress, inflammatory cytokines [10,11] and reduced the fat tissue in obese rat [12]. Moreover, limited studies provide that AGE and exercise interventions have protective effects against high fat diet induced insulin resistance in obese rats [13]. In general, studies have focused on the effect of AGE garlic on physical fatigue in mice and human subjects and but did not report on the effect of AGE on muscular performance parameters.

Ushijima et al. [14] have examined the effect of raw garlic juice, heated garlic juice, dehydrated garlic powder and AGE on physical strength and recovery from fatigue [14]. They found that raw garlic and AGE prolonged the treadmill running time of mice and enhanced the speed of recovery time [14]. Recently, limited clinical studies have investigated the effect of AGE garlic supplementation. In Regard, Verma et al. [15] investigated six weeks of garlic oil administration on cardiac performance and exercise tolerance in 30 patients with coronary artery disease. They showed that garlic significantly improved exercise tolerance and reduced the work load on heart [15]. Moreover, the AGE ameliorated the subjective symptoms caused by fatigue and enhanced reflex function and leg muscle strength [16]. Moreover, many clinical studies of garlic product containing AGE have reported that they exert significant effects against systemic fatigue accompanying the common cold or unidentified complaints [17,18]. Another study showed that AGE elevated succinate dehydrogenase (SDH) levels in rat skeletal muscle, indicating that AGE improves the metabolic pathway of the aerobic glucose efficiency in skeletal muscle during exercise [19]. However, the authors did not provide any evidence on the effect of the AGE on aerobic running performance. Recently, one study has reported that the garlic supplementation slightly increased maximal oxygen consumption (VO_2 max) in trained young men [20]. On the other hand, garlic consumption had no effect on peripheral blood pressure, VO_2 max, blood oxygen saturation, heart rate response, or exercise performance in hypoxia in human, only ergogenic effects on pulmonary hypertension were observed [21]. However, information regarding the effects of AGE supplementation on exercise performance is not clear, also isokinetic muscle strength properties have not yet been elucidated. Therefore, in this study, we hypothesized that AGE supplementation may affect the isokinetic muscle strength properties in healthy untrained man.

2. Method

2.1 Participants and procedure

Six sedentary healthy male volunteers (Mean age 30.2 ± 2.9 year, height 175.6 ± 2.8 cm) participated in this study. The study complied with the principles of the Declaration of Helsinki and was approved by the School of Medicine Balikesir University Ethics committee and informed written consent was obtained from each participant (Ethic prot. number 2014/61). The participants who informed that they were taking any medicine, had any medical history of disease, taking any antioxidant or other dietary supplementation, had a history of allergy to supplementation, or any injuries were excluded from the study. Subjects were instructed to avoid food containing very high sugar and fatty foods any other supplements. The isokinetic muscle performance test protocol was applied at the beginning of the study (baseline), post-10 days supplementation (post-supplementation), then 10 days after the end of the study (washout period). During the performance test sessions, the participants underwent an isokinetic knee concentric/concentric maximal muscle strength and muscle fatigue test. Isokinetic muscle strength parameters were assessed and compared to baseline values. All tests were conducted at the same time of the day to minimize any effect of circadian variance.

2.2 Body composition measurement

Body composition parameters namely BMI, percentage of fat percent, fat mass and fat free mass measured by using the Tanita BC 418 MA (Tanita Corporation, Japan). Tanita BC 418 MA is a monofrequency bioelectric impedance analyzer measurement system, which covers the frequency of 50 kHz with eight electrodes integrated in the handles and the stepping platform for transmission of electric current into the body.

2.3 AGE supplementation

The supplementation with AGE was carried out essentially as described previously by Dillon et al. [22]. The AGE is prepared by soaking sliced raw garlic (*A. Sativum*) in 15-20% aqueous ethanol for up to 20 min at room temperature. The extract is then filtered and concentrated under reduced pressure at low temperature. The content of water-soluble compounds is relatively high, whereas that of oil-soluble compounds is low. The AGE used in this trial contained 305 g/L extracted solids; *S*-allyl cysteine, which is a water-soluble organo-sulfur compound present in AGE, at a concentration of 1.47 g/L. After the baseline test, subjects consumed 5 mL of AGE (taken in a small volume of fruit juice) daily for 10 d between 0700 and 0900 h; otherwise, subjects followed their usual diet and lifestyle, excluding alcohol intake. This dose of AGE is that recommended as a dietary supplement by the manufacturers and was used in previous study, which showed inhibition of ADP-induced platelet aggregation [23].

2.4 Isokinetic muscle performance test

Isokinetic knee extensor and flexor muscles performance assessments were assessed using by isokinetic dynamometer (Isomed 2000 Basic). A week before the tests, the subjects attended the laboratory and were instructed about the exercise tests and performed one familiarization exercise session. The subjects were instructed to consume a light meal about 2 hours before the tests to avoid dramatic alterations in blood glucose. The subjects were seated on a computer controlled isokinetic dynamometer and with the backrest at 90° C and were instructed to grip the sides of the seat during the test and the thigh, pelvis and trunk of the subjects were stabilized with straps. An adjustable arm was attached to the leg by padded cuff just proximal to the lateral malleolus of the ankle and the axis rotation of the dynamometer arm was positioned just lateral to the lateral femoral epicondyle. The torque values were calculated and corrected for gravity by the use of dedicated software. Before the isokinetic maximal muscle strength test, subjects performed a moderate warm-up of 5-8 muscle actions at 60°/sec. Following by the warm-up the subjects rested for 3 minutes and then followed a knee extensor and flexor concentric/concentric protocol of 6 maximal repetitions at the angular velocity of 60 degrees and 180°/sec with dominant leg. Subsequently, after ten minute rest, subjects performed muscle fatigue test with 30 maximal-effort concentric/concentric repetitions at 180°/sec angular velocity. The range of motion was standardized from 10 degrees to 90° C during the test. Two other tests were performed post-AGE supplementation and washout period.

2.5 Muscle fatigue

For each subject, the highest consecutive five repetitions were determined by the values attained from the two repetitions immediately prior to, and following, the single highest repetition value. For subjects who attained their single highest repetition value within the first three repetitions, the first formula was used to calculate their F.I. Although the reliability of the F.I. has been questioned in previous studies [24,25], it was calculated to examine decreases in the isokinetic variables, independent of the magnitude of the absolute values. The fatigue index (FI) was determined by the following formula to yield a percent decrease for each isokinetic variable:

Formula I: *Percent decrease = 100-[(last 5 repetitions /first 5 repetitions) X100].*

In order to account for variable repetitions in which different subjects attained their single highest repetition value for each isokinetic variable, a second FI was calculated:

Formula II. *Percent decrease = 100-[(last 5 repetitions/highest consecutive 5 repetitions) X100]*

2.6. Statistical methods

All calculations were performed using SPSS software (SPSSInc, Chicago, Illinois, USA). The repeated measured analysis of variance (ANOVA) was used with pairwise comparisons. Significant differences between pre- and post-supplementation within the group was analyzed by using paired-samples *t* test. Data are expressed as means ± SD and the level of significance was set at p< 0.05.

3. Results

Ten day garlic administration significantly elevated the weight (p=0.011), BMI (p=0.012), fat percent (p=0.013), fat mass (p=0.003) in the washout with compared the post supplementation period, however AGE supplementation had no effect on fat free mass (Table 1). Isokinetic knee extensor and flexor muscle function of the peak work, peak work/body weight, average work and total work increased in the post-supplementation period at 60^0/ sec velocity (p<0.001) (Table 2). Flexor peak torque, peak power, average power values were increased in the post-supplementation period whereas garlic supplementation had no effect on these parameters

Table 1. Effect of garlic supplementation on physical characteristics of the subjects.

	Pre-Supp Test 1	Post-Supp Test 2	Washout Test 3	F	P	Significant difference
Weight (kg)	73.86 (5.52)	73.76 (5.68)	75.10 (5.85)	8.48	**0.011**	Test 2-3
Body Mass Index (kg/m²)	24 (1.92)	23.98 (1.94)	24.52 (1.95)	8.08	**0.012**	Test 2-3
Fat Percent (%)	11.18 (3.95)	12.10 (3.70)	14.02 (3.17)	7.80	**0.013**	Test1-3
Fat Mass (kg)	9.02 (3.71)	9.70 (3.58)	11.22 (3.41)	13.80	**0.003**	Test 1-3
Fat Free Mass	64.8 (5.51)	64.1 (5.69)	63.8 (6.12)	1.44	0.290	

Values are expressed as mean (SD), (n=6). A significant difference was found by repeated measures by ANOVA. Significant differences were observed between post-supplementation and washout period in experimental sessions.*P<0.05, **P<0.001. Pre-Supp:Pre-supplementation, Post-Supp: Post supplementation.

Table 2. Effect of garlic supplementation on knee extensor and flexor muscle function of the subjects at 60°/sec velocity.

Extensor muscle function						
	Pre-Sup Test 1	**Post-Sup Test 2**	**Washout Test 3**	**F**	**P**	**Significant difference**
Peak torque (Nm)	212.4 (11)	201.6 (7.5)	198.8 (10.8)	3.23	0.093	
Peak torque/weight (Nm/kg)	2.46 (0.83)	2.36 (0.82)	2.33 (0.84)	2.58	0.136	
Peak torque at knee angle (⁰)	66.4 (1.32)	64.2 (2.22)	69.8 (0.73)	2.44	0.149	
Peak torque flex/ext ratio	0.54 (0.05)	0.78 (0.04)	0.74 (0.06)	105.28	**0.000**	1-2, 1-3
Average peak torque (Nm)	197.8 (11.05)	181.6 (9.09)	186.2 (10.5)	2.24	0.171	
Peak work (J)	182.2 (8.06)	160.6 (4.68)	157.2 (6.31)	18.92	**0.001**	1-2, 1-3
Peak work/weight (J/kg)	2.50(0.38)	2.21(0.36)	2.13 (0.40)	26.42	**0.000**	1-2,1-3, 2-3
Average work (J)	170.5 (7.4)	149.5 (3.4)	146.7 (5.9)	13.36	**0.003**	1-2, 1-3
Total work (J)	1022 (45)	897 (20)	880 (34)	13.16	**0.003**	1-2
Peak work flex/ext ratio	0.69 (0.07)	0.97(0.05)	0.97 (0.08)	33.87	**0.000**	1-2, 1-3
Peak power (W)	131(8.47)	122 (3.45)	121 (6.14)	2.11	0.183	
Average power (W)	119.6 (7.7)	113.6 (15.45)	112.6 (6.02)	1.07	0.387	
Range of motion	79.8 (0.66)	75.6 (3.20)	77.6 (0.77)	5.426	**0.032**	1-2
Flexor muscle function						
Peak torque (Nm)	116.2(16.5)	158.2 (13.34)	148 (7.76)	55.93	**0.002**	1-2, 1-3
Peak torque/weight (Nm/kg)	2.93 (0.60)	2.79 (0.49)	2.70 (0.54)	3.55	0.079	
Peak torque at knee angle (⁰)	46.6 (3.28)	35.8 (3.27)	41.4 (3.23	4.02	0.062	
Average peak torque (Nm)	107 (12.9)	145(7.77)	138.6 (6.82)	3.55	0.079	
Peak work (J)	125.8 (7.2)	157.8 (8.5)	153.6 (10.4)	50.5	**0.000**	1-2, 1-3
Peak work/weight (J/kg)	1.74 (0.40)	2.17 (0.42)	2.08 (0.44)	22.97	**0.009**	1-2,1-3
Average work (J)	116.4 (6.4)	147.9 (15.8)	142.7 (9.7)	23.13	**0.009**	1-2, 2-3,3-1
Total work (J)	698 (38.2)	886 (42.5)	856 (58.5)	23.94	**0.008**	1-2, 1-3 2-1, 3-1
Peak power (W)	(81.6 ± 6.2)	114.2 (6.17)	111.8 (6.5)	33.64	**0.004**	1-2, 1-3
Average power (W)	(74.4 ± 5.8)	104.4 (4.8)	100.6 (6.6)	25.45	**0.007**	1-2, 1-3

Values are expressed as mean (SD), (n=6). A significant increase in the post-supplementation period according to Pre-Supp P<0.05, P<0.001, analyzed by repeated measures by ANOVA. Pre-Supp: Pre-supplementation, Post-Supp: Post supplementation.

of the extensor muscle function. Moreover, peak torque flexion/extension ratio and peak work flexion/ extension ratio was altered in the post-supplementation period (p<0.001, Table 2).

The angular velocity of the 180°/sec extensor and flexor peak work, peak work/ body weight and total work were significantly elevated in the post-supplementation period. Flexor group of muscles function parameters of the peak torque, peak torque/body weight, average peak torque, peak power and average power were increased by using AGE supplementation (p<0.001) whereas, the AGE supplementation had no effect on these parameters of the extensor muscles function (Table 3). Furthermore, the peak torque and work ratio of the flexion/extension had affected by using supplementation in this velocity (180°/sec, Table 3). Interestingly, muscles of the extensor and flexor fatigue properties were not significantly affected by AGE supplementation in this study (Table 4).

4. Discussion

The preliminary results indicate that ten days of AGE supplementation (5 ml/day) significantly affected isokinetic knee concentric-concentric extensor and flexor muscles contractile properties at the different velocity (60 and 180°/sec) in the sedentary human subject. This is the first study investigating the effects of AGE supplementation on isokinetic muscle contractile properties in healthy human subjects. Therefore, these results are novel and to the best of our knowledge, no data exists concerning the acute effect of AGE administration on isokinetic muscle contraction properties. In literature, the most of the studies reported that amino acid, protein and creatine supplementation modestly increase muscle strength, recovery and muscle fiber repair [26-28]. In addition different kind of herbal/botanical supplementation have been found to have a beneficial effect on muscle strength, balance and muscle function [29-31] or had no significant effects on muscle function [32]. Thus, limited studies have been reported on anti-fatigue effect using garlic supplementation in animal or patients. Regarding the previous study Ushijima et al. [14] investigated three kinds of garlic preparations namely: the effect of raw garlic juice, heated garlic juice, dehydrated garlic powder

Table 3. Effect of garlic supplementation on knee extensor and flexor muscle function of the subjects at 180°/sec velocity.

Extensor muscle function						
	Pre-Supp Test 1	Post-Supp Test 2	**Washout Test 3**	**F**	**P**	**Significant difference**
Peak torque (Nm)	147.8 (12.6)	140.6 (9.38)	138.2 (6.82)	0.62	0.56	
Peak torque/weight (Nm/kg)	2.02 (0.45)	1.94 (0.29)	1.88 (0.38)	0.80	0.48	
Peak torque at knee angle (⁰)	61.8 (0.86)	67.2 (2.03)	64.6 (1.96)	2.86	0.11	
Peak torque flex/ext ratio	0.60 (0.10)	0.96 8 (0.18)	0.90 (0.17)	16.19	0.002	1-2,1-3
Average peak torque (Nm)	139.4 (10.8)	129.6 (9.11)	125.4 (7.19)	2.48	0.14	
Peak work (J)	132.8 (8.32)	110.4 (6.02)	108 (5.82)	7.74	**0.01**	1-2, 1-3
Peak work/weight (J/kg)	1.81 (0.30)	1.52 (0.27)	1.47 (0.31)	9.91	**0.007**	1-2,1-3
Average work (J)	124.4 (7.90)	100 (6.67)	97.5 (6.57)	10.55	**0.006**	1-2
Total work (J)	746.8(47.55)	599.2(40.18)	584.8 (39.5)	10.50	**0.006**	1-2
Peak work flex/ext ratio	0.64 (0.13)	1.10 (0.25)	1.12 (0.22)	28.01	**0.000**	1-2,-3
Peak power (W)	227.2 (0.38)	205 (19.4)	200 (19)	2.56	0.138	
Average power (W)	211.4(16.07)	182.4 (10.4)	174.6 (9.7)	5.43	**0.032**	
Range of motion	80.6 (0.24)	78.4 (0.50)	80 (1.00)	3.59	0.077	
Flexor muscle function						
Peak torque (Nm)	90 (4.42)	133.8 (17.5)	124.4 (7.94)	40.72	**0.000**	1-2,1-3, 2-3
Peak torque/weight (Nm/kg)	1.29 (0.21)	1.83 (0.33)	1.67 (0.27)	34.67	**0.000**	1-2, 1-3, 2-3
Peak torque at knee angle (⁰)	32 (5.52)	27.6 (2.87)	36.8 (9.33)	1.44	0.291	
Average peak torque (Nm)	80 (5.20)	117.60 (5.14)	111 (6.27)	32.40	**0.002**	1-2,1-3, 3-1
Peak work (J)	90 (5.85)	119.6 (17.25)	119.6 (6.32)	63.94	**0.000**	1-2, 1-3
Peak work/weight (J/kg)	1.30 (0.25)	1.66 (0.40)	1.62 (0.35)	11.75	**0.004**	2-3
Average work (J)	124.4 (7.90)	100 (6.67)	97.58 (6.57)	29.92	**0.002**	1-2, 1-3
Total work (J)	463.8 (33.23)	639 .8 (39.4)	646 (29.68)	28.74	**0.000**	1-2, 1-3
Peak power (W)	139.6 (8.47)	217 (15.6)	211 (13.63)	44.33	**0.000**	1-2, 1-3
Average power (W)	118.6 (8.76)	188.2 (11.89)	180 (13.48)	37.60	**0.000**	1-2, 1-3

Values are expressed as mean (SD) (n=6). A significant increase in the post-supplementation period according to Pre-Supp $P<0.05$, $P<0.001$, analyzed by repeated measures by ANOVA. Pre-Supp:Pre-supplementation, Post-Supp: Post supplementation.

Table 4. Effect of garlic supplementation on knee extension and flexion fatigue index values [percent decline, mean (SD) for peak torque, work, and power for subjects across 30 maximal effort isokinetic contractions, using Eq.1: (%=100-[last 5 repetitions/first five repetitions x100%, and Eq. 2 (%=100 – [last 5 repetitions/highestconsecutive five repetitions)·100%]).

180°/san Extensor muscle function			
	Pre-Supp	**Post-Supp**	**Washout**
Eq.1			
Peak torque (Nm)	36.98 (14.56)	30.32 (21.52)	40.86 (10.39)
Peak power (W)	50.06 (12.94)	48.51 (13.44)	52.11 (6.95)
Eq.2			
Peak torque (Nm)	38.54 (14.22)	39.17 (12.69)	42.29 (9.76)
Peak power (W)	50.29 (12.71)	48.51 (13.44)	52.37 (6.66)
Flexor muscle function			
Eq.1			
Peak torque (Nm)	25.02 (4.92)	22.84 (5.95)	23.20 (3.40)
Peak power (W)	35.40 (4.63)	33.67 (5.90)	31.92 (3.32)
Eq.2			
Peak torque (Nm)	24.83 (4.17)	22.54 (5.96)	22.99 (2.79)
Peak power (W)	35.41 (2.93)	34.16 (5.60)	32.72 (3.13)

Values are expressed as mean (SD) (n=6). No significant differences were observed between pre-supplementation and post-supplementation or washout period in experimental sessions. $P> 0.05$ Pre-Supp:Pre-supplementation, Post-Supp: Post supplementation.

and AGE only significantly improved swimming performance by 82.3% and 90% at a dosage of 2 and 4 ml/kg in mice [14]. Moreover, the running time of the mice given heated garlic juice and garlic powder did not significantly improve, however AGE significantly improved the running time from 929 s to 1611 s [14].

Verma et. al have reported the effects of garlic oil supplementation for six weeks on cardiac performance and exercise tolerance in 30 patients with coronary artery disease [15]. After the baseline treadmill stress test, the subjects consumed AGE for 6 weeks, after which the treadmill stress tests were repeated. AGE significantly reduced the heart rate at peak exercise, and the work load of the heart, was improved after exercise when compared to the baseline test values. Exercise tolerance was also improved by approximately 1.24 min after 6 week garlic oil supplementation.

Ushijima's study suggested that AGE prevents acute physical fatigue and various types of damage during moderate exercise, thus improving lifestyle-related problems and enhancing physical strength. Evidently, our present study showed that AGE administration enhanced the isokinetic muscle strength; it specifically affected concentric extensor and flexor work properties. However, we did not found any favourable or unfavourable effect on muscle fatigue index. This was an unexpected result, because most of the studies have indicated that AGE increases exercise tolerance with physiological and psychological anti-fatigue effects. In particular, Morihara et al. [19] study reported that the AGE administered to rats 30 min before exercise, Succinate dehydrogenase (SDH) activity and superoxide dismutase (SOD) activity, nitric oxide (NO) metabolites in the gastrocnemius and soleus muscles, and lactic acid concentration in plasma were up regulated as biomarkers of physical fatigue [19]. SDH activity was enhanced 2-4-fold by repeated endurance exercise in comparison with untrained rats, and AGE further up-regulated SDH activity by 40%. Moreover, the SOD activity was increased 5-fold. Levels of NO levels were slightly decreased, whereas AGE enhanced NO levels about 2-fold [19] moreover, lactic acid concentration was similar in both groups. These results indicate that AGE may facilitate the modulation of aerobic glucose metabolism, reduce oxidative stress, and support oxygen supply based on vasodilatation, suggesting that AGE improves the various damages associated with physical fatigue. To clarify the mechanism underlying the anti-fatigue effect and active component of AGE, further studies are warranted in human subjects.

Speculatively, during acute exercise, energy is produced either aerobically or anaerobically depending on the intensity of the exercise, its load or muscle contractile type (concentric, eccentric and concentric/eccentric). With regard to supplementation, nutrients such as glucose and protein that cause an insulin response [33] these can directly activate mTOR through PI3K-Akt signalling [34]. Furthermore, AGE improves skeletal muscle oxidative enzyme activity and promotes oxygen supply via NO production [19], indicating that AGE contributes to the enhancement of physical strength. This may suggest that AGE stimulates energy metabolism, although the mechanism is not yet understood. An unexpected finding of the present study was that fat mass significantly increased during the experimental period and the reasons for this need to be investigated. We correlated muscle strength and body weight, and these did not influence the muscles parameters measured.

5. Conclusion

The present findings indicate that AGE supplementation increases the knee isokinetic muscle flexor and extensor contractile properties in different velocity. In addition, AGE enhanced muscle work properties in both flexor and extensor muscle group than the torque values, and it had more favourable effect on flexor muscles group than the extensor group in both velocity in untrained healthy human knee. Limitations to the present study include: 1) daily nutrition level and metabolism was not followed and may have had a significant effect on the muscle strength values.

Acknowledgements

This work was supported by the Balikesir University Scientific Research Project with Grant No. 2014/68, Turkey. No other organization or institution cofinanced this research. The author would like to thank Prof.Dr.Khalid Rahman, School of pharmacy and Biomolecular Sciences, Liverpool John Moores University for providing AGE supplementation. The author wishes to thank Master Degree student Cenk Biryol for organizing the study volunteers.

Competing interests

None declared.

References

[1] Connolly DA, McHugh MP, Padilla-Zakour OI, et al. (2006). Efficacy of a tart cherry juice blend in preventing the symptoms of muscle damage. *Br J Sports Med*. **40**: 679-683.

[2] McLeay Y, Barnes MJ, Mundel T, et al. (2012). Effect of New Zealand blueberry consumption on recovery from eccentric exercise induced muscle damage. *J Int Soc Sports Nutr*. **9**: 19.

[3] Trombold JR, Barnes JN, Critchley L, et al. (2010). Ellagitannin consumption improves strength recovery 2 to 3 days after eccentric exercise. *Med Sci SportsExerc*. **42**: 493-498.

[4] Trombold JR, Reinfeld AS, Casler JR, et al. (2011). The effect of pomegranatejuice supplementation on strength and soreness after eccentric exercise. *J Strength Cond Res*. **25**: 1782-1788.

[5] Machin DR, Christmas KM, Chou TH, et al. (2014). Effects of differing dosages of pomegranate juice supplementationafter eccentric exercise. *Physiol J*. **27**: 1959.

[6] O'Connor PJ, Caravalho AL, Freese EC, et al. (2013). Grape Consumption'seffects on fitness, muscle injury, mood and perceived health. *Int J SportNutr Exerc Metab*. **23**: 57-64.

[7] Scholten SD, Sergeev IN, Song Q, et al. (2015). Effects of vitamin D and quercetin, alone and in combination, on cardiorespiratory fitness and muscle function in physically active male adults. Open Access J Sports Med. **24:** 229-239.

[8] Banerjee SK, Maulik SK. (2002). Effect of garlic on cardiovascular disorders: A review. *Nutr J.* **1**: 4.

[9] Amagase H, Petesch BL, Matsuura H, et al. (2001). Intake of garlic and its bioactive components. *J Nutr.* **131**: 955S-962S.

[10] Yeh YY, Yeh SM. (1994). Garlic reduces plasma lipids by inhibitinghepatic cholesterol and triacylglycerol synthesis. *Lipids*. **29**:189-193.

[11] Zare A, Farzaneh P, Pourpak Z, et al. (2008). Purified aged garlic extract modulates allergicairway inflammation in BALB/c mice. *Iran J Allergy AsthmaImmunol*. **7**: 133-141.

[12] Seo DY, Lee S, Figueroa A, et al. (2012). Aged garlic extract enhances exercise mediated improvement of metabolic parameters in high fat diet-induced obese rats. Nutr Res Pract. **6:** 513-519.

[13] Seo DY, Kwak HB, Lee SR, et al. (2014). Effects of aged garlic extract and endurance exercise on skeletal muscle garlic extract and endurance exercise on skeletal muscle FNDC-5 and circulating irisin in high-fat-diet rat models. Nutr Res Pract. **8:** 177-182.

[14] Ushijima M, Sumioka I, Kakimoto M, et al. (1997). Effect of garlic and garlic preparations on physiological and psychological stres in mice. Phytooher Res. **11:** 226-230.

[15] Verma SK, Rajeevan V, Jain P, et al. (2005). Effect of garlic (Allium sativum) oil on exercise tolerance in patients with coronary artery disease. *Indian J Physiol Pharmacol*. **49**: 115-118.

[16] Kawashima Y, Ochiai Y, Shuzenji H. (1986). Anti-fatigue function of aged garlic extract for athletic club student. *Clinical Rep*. **20**: 8229-8245.

[17] Nakasawa S, Tsukamoto Y, Okada M, et al. (1983). Clinical study of aged garlic extract preparation (KYOLEOPIN): Recovery action from fatigue. *J New Remed Clinic*. **32**: 208 -219.

[18] Kawashima Y, Ochiai Y, Itou K, Fuzisaki I, et al. (1985). Clinical study of KYOLEOPIN (KLE): Clinical examination for a cold syndorome with a systemic fatigue symptom. *Med Consult N Remed*. **22**: 3012-3024.

[19] Morihara N, Ushijima M, Kahimoto N, et al. (2006). Aged garlic extract ameliorates physical fatigue. *Biol Pharm Bull*. **29**: 962-966.

[20] Womack CJ, Lawton DJ, Redmond L, et al. (2015). The effects of acute garlic supplementation on the fibrinolytic and vasoreactive response to exercise. *J Int Soc Sports Nutr*. **12**: 23.

[21] Morris DM, Beloni RK, Wheeler HE. (2013). Effects of garlic consumption on physiological variables and performance during exercise in hypoxia. *Appl Physiol Nutr Metab*. **38**: 363-367.

[22] Dillon SA, Lowe GM, Billington D, et al. (2002). Dietary supplementation with aged garlic extract reduces plasma and urine concentrations of 8-Iso-prostaglandin $F_{2\alpha}$ in smoking and nonsmokin men and women. *J* Nutr. **132**:168-171.

[23] Vang O, Ahmad N, Baile CA, et al. (2011). What is new for an old molecule? Systematic review and recommendations on the use of resveratrol. *Plos one*. **6:** e19881.

[24] Gross MT, Hoffman GM, Phillips CN, et al. (1991). Intramachine and intermachine reliability of the Biodex and Cybex II for knee flexion and extension peak torque and angular work. *J Orthop Sports Phys Ther*. **13:** 329-335.

[25] Pincivero DM, Gear WS, Sterner RL. (2001). Assessment of the reliability of high-intensity quadriceps femoris muscle fatigue. *Med Sci Sports Exerc*. **33**: 334-338.

[26] Maltais ML, Perreault-Ladouceur J, Dionne IJ. (2015).The effect of resistance training and different sources of post-exercise protein supplementationon muscle mass and physical capacity in sarcopenic elderly men. *J Strength Cond Res*. **7**.

[27] Naclerio F, Larumbe-Zabala E. (2016).Effects of Whey Protein Alone or as Part of a Multi-ingredient formulation on strength, fat-free mass, or lean body mass in resistance-trained individuals: A Meta-analysis. *Sports Med*. **46**:125-137.

[28] Candow DG, Vogt E, Johannsmeyer S, et al. (2015). Strategic creatine supplementation and resistance training in healthy older adults. *Appl Physiol Nutr Metab*. **40**: 689-694.

[29] Jeong JW, Shim JJ, Choi ID, et al. (2015). Apple pomace extract improves endurance in exercise performance by increasing strength and weight of skeletal muscle. *J Med Food*. **18**:1380-1386.

[30] Promthep K, Eungpinichpong W, Sripanidkulchai B, et al. (2015). Effect of kaempferia parviflora extract on physical fitness of soccer players: A randomized double-blind placebo-controlled trial. *Med Sci Monit Basic Res*. **21**: 100-108.

[31] Tsai CC, Chou YY, Chen YM, et al. (2014).Effect of the herbal drug guilu erxian jiao on muscle strength, articular pain, and disability in elderly men with knee osteoarthritis. *Evid Based Complement Alternat Med.* 2014: 297458.

[32] Furlong J, Rynders CA, Sutherlin M, et al. (2014). Effect of an herbal/botanical supplement on strength, balance, and muscle function following 12-weeks of resistance training: a placebo controlled study. *J Int Soc Sports Nutr.* **28**: 11-23.

[33] Gannon MC, Nuttall FQ. (2010). Amino acid ingestion and glucose metabolism–a review. *IUBMB Life*. **62**: 660-668.

[34] Nave BT, Ouwens M, Withers DJ, et al. (1999). Mammalian target of rapamycin is a direct target for protein kinase B: identification of a convergence point for opposing effects of insulin and amino-acid deficiency on protein translation. *Biochem J*. **344**: 427-431.