THE EFFECT OF AGEING ON CONTRACTION TIME OF POSTURAL AND NON-POSTURAL SKELETAL MUSCLES IN MASTER ATHLETES

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Abstract

Normal aging is characterized by muscular atrophy and a loss of force-generating capacity. The goal of this research was to investigate the age and sport activity type on postural (vastus lateralis) and non postural (biceps femoris) muscles' contraction time in 170 master athletes (athletic events) and 51 non athletes. We found significant age effect in postural muscle ($P = 0.032$) and also in non postural muscle ($P < 0.001$). However, we found sport activity type effect significant just in non postural muscle ($P < 0.001$). The interaction effect of age * sport was significant in both observed muscles. Sprinters/jumpers deteriorate with age the most in postural muscle, while non athletes in non postural muscle. We could conclude that non postural muscle deteriorate the most without regular sport activity, while postural muscle have enough daily stimuli to be prevented from major deterioration.

Keywords: Ageing, Skeletal muscle, Sport Activity, Tensiomyography, Athletics, Contraction time

Introduction

Regular physical activity and healthy sports are essential for our quality of life, especially in older age. Appropriate physical activity and sports for all constitute one of the major components of a healthy lifestyle, along with healthy diet, tobacco free life and avoidance of other substances harmful to health (WHO, 2003).

Available experience and scientific evidence show that the regular practice of appropriate physical activity and sports provides people, of all ages and conditions, with wide range of physical, social and mental health benefits. Regular practice of physical activity and healthy sports interacts positively with strategies to improve diet, discourage the use of tobacco and other unhealthy habits, helps reduce violence, enhances functional capacity and promotes social interaction and integration.

Preservation of the mechanical output of the skeletal muscle seems to be dependent on their function and gravitational loading. To understand effect of regular physical activity, scientists propose to study the opposite – deconditioning as an effect of spaceflight (Antonutto et al. 1999) or ground-based models such as immobilisation (Sargeant et al. 1977), lower limb suspension (Berg et al. 1991), or bed rest (De Boer et al. 2008) simulating the effects of microgravity. The postural muscles such as the plantar flexors and knee extensors appear to be the most affected (De Boer et al. 2008; Di Prampero and Narici 2003). The most common and apparent adaptation of skeletal muscle with removal of weight bearing contributing to the decreased mechanical output is a loss of muscle mass reflected in a decreased muscle size (LeBlanc et al. 1995; Akima et al. 2000), muscle strength (Berg et al. 1991; Antonutto et al. 1999), reduced neural activation (Antonutto et al. 1999), muscle fibre specific tension (Larsson et al. 1996; Trappe et al. 2004), muscle tone (Pišot et al., 2008), and, recently, the stiffness of the in-series tendon (Kubo et al. 2000; Maganaris et al. 2006) have been shown to be associated with the loss of muscle function after disuse and unloading.

But there is reasonable doubt in generalising effects of simulating microgravity into effects of regular sport activity. Deconditioning after microgravity exposure is acute, exposure to deconditioning lasts for about 14 – 90 days and as such it is not the best model to understand the long-lasting effect of regular sport activity.

Our goal was to evaluate the age and sport activity type effect of postural and non postural skeletal muscles' contraction time in master athletes and non athletes. Master athletes continue their sportive career throughout life, often adhering to training regimes of 20 hours and more per week. Therefore, master athletes provide a unique opportunity to study the question pointed out (Rittweger et al. 2004).

Methods

MASTER ATHLETES: Altogether of 170 master athletes (99 males) were measured on 16th European Veterans Athletics' Championships Stadia in Ljubljana/Slovenia. Table 1 summarises the number of participants per gender, age and sport type. Three groups of sport activity type were defined as FAST (sprinting events up to 800 meters, jumping events, throwing events) and ENDURANCE (running events longer than 1500m, walking events), while the third group used as control group of non athletes.

NON ATHLETES: The group of 40 non athletes (27 males) were chosen from our previous study (Šimunič et al. 2005) and 11 (5 males) from yet unpublished data. Their age range was from 35 to 82.

Table 1: Number of participants per age, and sport activity type.

	35 – 44 years	**45 – 54 years**	**55 – 64 years**	**over 65 years**
FAST MASTER ATHLETES	27	29	21	29
ENDURANCE MASTER ATHLETES	18	16	15	15
NON ATHLETES	19	12	10	10

FAST: sprint, jump and throw events; ENDURANCE: middle and long distance events; NON ATHLETES: sedentary population.

CONTRACTION TIME MEASUREMENTS: Tensiomyographic data was assessed using TMG-ZD1 device (Furlan & Co., Slovenia) on two skeletal muscles. The measurement point in biceps femoris muscle was defined at the midpoint of the line between the fibula head and the ischial tuberosity, while in the vastus lateralis was defined at the lower third of its length from the distal insertion. Supramaximal single bipolar twitch stimulation (pulse width 1 ms) was applied to each muscle, separately. Self adhesive electrodes (Pals, AxelGaard Co., USA) were placed directly on the muscle belly: cathode was placed 5 centimetres distally, while anode 5 centimetres proximally from the measurement point. Knee joint was set appropriately for each muscle: for vastus lateralis was set in 30 degrees flexion (participant lying on his back) and for biceps femoris in 5 degrees flexion (participant lying on his front). Amplitude of the electrical stimulation was gradually increased to get maximal response where two maximal responses were saved on the computer for further analysis.

DATA PROCESSING: From two maximal responses amplitude a contraction time was calculated from 10% to 90% of maximal amplitude contraction. An average value was taken into account for further analysis. Furthermore, contraction time for each muscle was pilled in twelve different groups: age (4) x sport activity type (3), as presented in table 1.

STATISTICAL ANALYSIS: Statistical analyses were done using SPSS software version 12.0. All values are presented as mean values with standard deviation. The age and sport activity type effect were tested with two-way ANOVA design. Post-hoc Tukey test was used for establishing age effect in multiple comparisons. The level of significance was set at $^{*}P < 0.05$, and $^{\#}P < 0.001$.

Results

Table 2 presents the statistical output for each factor's main effect and between factor interactions:

- BICEPS FEMORIS: We observed significant age effect (P < 0.001) and ssignificant sport activity effect (P < 0.001). However, there was also significant interaction age * sport activity effect (P = 0.044).
- VASTUS LATERALIS: Age effect was significant (P = 0.032) but the deterioration was much lower than in biceps femoris. Interestingly, the sport activity type effect was not significant (P = 0.526). However, we found significant interaction age * sport activity type effect (P = 0.045).

Post hoc analysis revealed that biceps femoris contraction time deteriorated significantly in age group 55 – 64 years for 28% (P < 0.001), and in age group > 65 years for 49% (P < 0.001). Vastus lateralis contraction time deteriorated significantly in age group > 65 years for 8% (P = 0.012). In Figure 1 contraction time of biceps femoris and vastus lateralis is presented for all three sport activity types and four age groups. It is evident that biceps femoris changes are larger than in vastus lateralis. Furthermore, FAST athletes have shorter biceps femoris contraction time at age of 35 – 44 years than ENDURANCE athletes, while at age of > 65 the differences are no longer present. Contraction time in non athletes at age of 35 – 44 years have values in the middle regarding to FAST and ENDURANCE athletes. But later on contraction time consistently increase with age to the values higher than in both groups of athletes. In vastus lateralis muscle we can establish significantly shorter contraction time at age of 35-44 years but the effect of sport activity is not significant.

The interaction effect of age * sport was significant in both observed muscles (Table 2). In biceps femoris contraction time increase has larger slope in non athletes, than in FAST athletes, and least in ENDURANCE athletes. While in vastus lateralis age and sport effects were much smaller but anyway we could confirm that larger slope was observed in FAST athletes, than in ENDURANCE athletes and least in non athletes.

Table 2: Factors' main effect with their interactions on contraction times of biceps femoris and vastus lateralis.

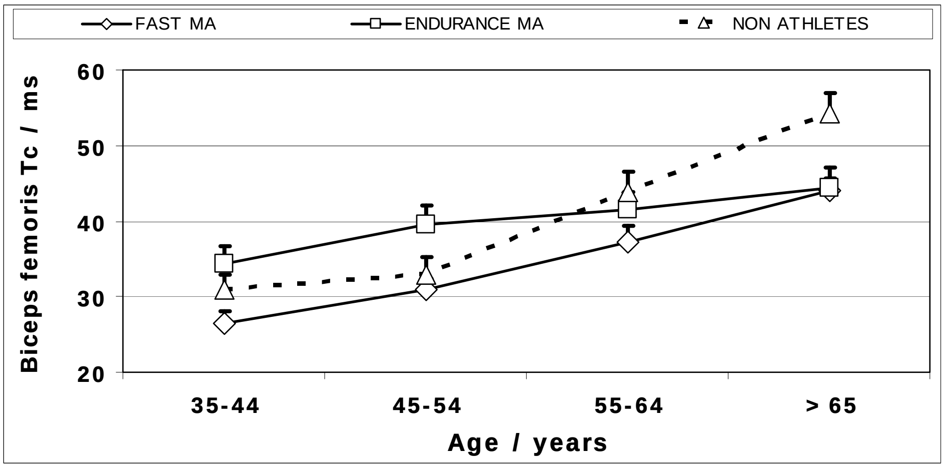
Factors / interactions	**Biceps femoris F / P**	**Vastus lateralis F / P**
Age	31.774 / 0.000 #	3.007 / 0.032 *
Sport	11.913 / 0.000 #	0.644 / 0.526
Age * Sport	2.210 / 0.044 *	2.199 / 0.045 *

** P < 0.05; # P < 0.001*

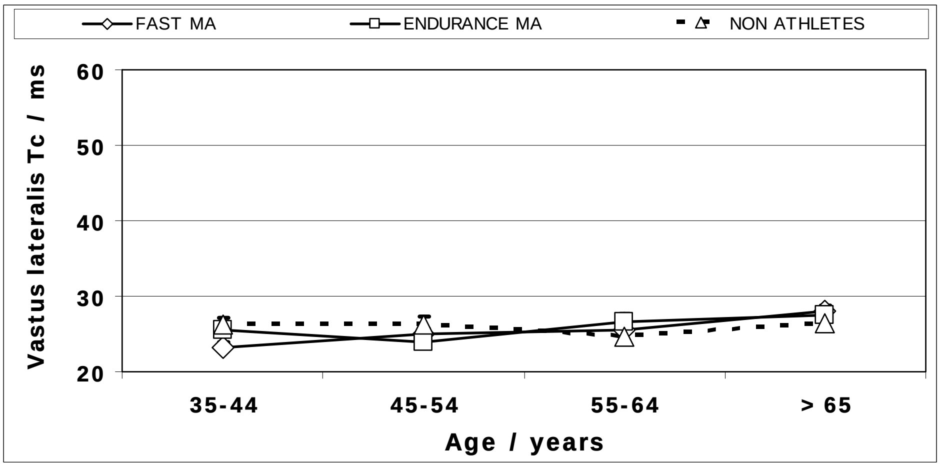
Conclusions

The major part of this study was performed on master elite athletes competing on European athletics championships 2008. The selection of athletes was done through advertisement in a brochure before the competition, posters at the stadium and oral invitations. Each athlete went through a registration phase for basic personal data collection, information on training habits, personal records, nutrition habits, and health status. Second part of this study was summed from our previous publication (Šimunič et al. 2005) where we presented muscle deterioration in non athletes. The data for the third part of this study have not been published yet.

Figure 1: Contraction time of biceps femoris (upper graph/table) and vastus lateralis (lower graph/table) with age and sport type.



Biceps femoris Tc ± SE / ms	35 – 44 years	45 – 54 years	55 – 64 years	> 65 years
FAST MA	26.5 ± 1.6	30.9 ± 9.4	37.3 ± 5.1	44.1 ± 9.8
ENDURANCE MA	34.4 ± 2.2	39.4 ± 2.5	41.6 ± 2.3	44.5 ± 2.5
NON ATHLETES	30.9 ± 1.9	32.9 ± 2.4	43.9 ± 2.7	54.2 ± 2.7



Vastus lateralis Tc ± SD / ms	35 – 44 years	45 – 54 years	55 – 64 years	> 65 years
FAST males	23.2 ± 0.7	25.0 ± 0.7	25.5 ± 1.0	28.1 ± 0.7
FAST females	25.6 ± 1.0	24.0 ± 1.2	26.7 ± 1.1	27.5 ± 1.2
ENDURANCE males	26.3 ± 0.9	26.3 ± 1.1	24.7 ± 1.2	26.5 ± 1.9

FAST – sprint, jump and throw events; ENDURANCE: middle and long distance events; NON ATHLETES: sedentary population.

We have found that biceps femoris muscle (non postural muscle) deteriorate in much greater scale than vastus lateralis muscle (postural muscle) with age. Furthermore, we observed sport activity type effect in biceps femoris, while not in vastus lateralis. Sprinters and jumpers have shorter contraction time in both muscles at age of 35 – 44 years and ageing brings them to the values equal of endurance athletes. This finding confirms that endurance type training could be useful at preserving physical fitness at old age. We could confirm also age * sport activity type interaction effect was significant in both muscles. Postural muscle deteriorates with age the most in fast athletes but we have to consider shorter contraction times in baseline at age of 35 – 44 years. In non postural muscle bigger age deterioration is in non athletes, even though their baseline contraction time is not the shortest.

We evaluated this with contraction time derived from mechanical response of muscle belly, using Tensiomyography. Tensiomyography was presented few times as a useful tool for non-invasive and selective detection of skeletal muscle contractile properties (Dahmane et al. 2000, 2005; Pišot et al. 2008). Authors explained contraction time as intrinsic contractile properties of muscle belly detected on the muscle belly and not on a distal limb (torque mechanical response). Such approach prevents integration of tendon properties, joint mechanics, and surrounding tissue effect on mechanical response deformation.

There is an undoubted loss of skeletal muscle mass and strength with age in humans. The atrophy of skeletal muscle with age appears to be due to a decline in the hormonal and nutritional status (combined with changes in many other systems), reduced exercise and muscle use, and a loss of muscle innervation. It is not clear whether the age related changes in muscle activity result in a lack of production of trophic factors by the muscle that are required to maintain healthy synaptic connections between the muscle and the nerve. Alternatively, the neurones themselves may manifest some age-related defect, resulting in an inability to correctly function and innervate the muscles. It would seem that the balance between these two scenarios remains to be unresolved.

Runge et al. (2004) has found that postural calf muscle anatomical cross sectional area does not correlate with age, neither in males nor females. Furthermore, the same authors found significant negative correlation in jumping power with age, for both genders. Functional but not geometrical loss within skeletal muscle indicated deterioration in skeletal muscle composition or neural drive. Lexell et al. (1988) showed that the ageing atrophy of the muscle begins around 25 years of age and thereafter accelerates. This is caused mainly by a loss of fibers, with no predominant effect on any fiber type, and to a lesser extent by a reduction in fiber size, mostly of type 2 fibers. Since our data was collected using transcutaneous electrical stimulation and not by voluntary contractions, we suggest that more neural drive than fibre type deterioration affect muscle function.

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References

1. Akima H, Kawakami Y, Kubo K, Sekiguchi C, Ohshima H, Miyamoto A, Fukunaga T. (2000) EVect of short-duration spaceflight on thigh and leg muscle volume. Med Sci Sports Exerc 32: 1743–1747.
2. Antonutto G, Capelli C, Girardis M, Zamparo P, di Prampero PE. (1999) Effects of microgravity on maximal power of lower limbs during very short efforts in humans. J Appl Physiol 86: 85–92.
3. Berg HE, Dudley GA, Haggmark T, Ohlsen H, Tesch PA. (1991) Effects of lower limb unloading on skeletal muscle mass and function in humans. J Appl Physiol 70: 1882–1885.
4. Dahmane R, Valenčič V, Knez N, Eržen I. (2000). Evaluation of the ability to make non-invasive estimation of muscle contractile properties on the basis of the muscle belly response. Med Biol Eng Comput 39: 51-55.
5. Dahmane R, Djordjevič S, Šimunič B, Valenčič V. (2005) Spatial fiber type distribution in normal human muscle histochemical and tensiomyographical evaluation. J Biomech 38(12): 2451-2459.
6. De Boer MD, Seynnes OR, di Prampero PE, Pišot R, Mekjavić, IB, Biolo G, Narici MV. (2008). Effect of 5 weeks horizontal bed rest on human muscle thickness and architecture of weight bearing and non-weight bearing muscle. Eur J Appl Physiol 104(2): 401-407.
7. Di Prampero PE, Narici MV. (2003) Muscles in microgravity: from fibres to human motion. J Biomech 36:403–412.
8. Fiatarone MA, Marks EC, Rya, ND, Meredith CN, Lipsitz LA, Evans WJ. (1990). High-intensity strength training in nonagenarians. Effects on skeletal muscle. JAMA; 263: 3029-3034.

9. Kubo K, Akima H, Kouzaki M, Ito M, Kawakami Y, Kanehisa H, Fukunaga T. (2000) Changes in the elastic properties of tendon structures following 20 days bed-rest in humans. Eur J Appl Physiol 83: 463–468.

10. Larsson L, Grimby G, and Karlsson J. (1979). Muscle strength and speed of movement in relation to age and muscle morphology. J Appl Physiol 46: 451–456.

11. Larsson L, Li X, Berg HE, Frontera WR. (1996) Effects of removal of weight-bearing function on contractility and myosin isoform composition in single human skeletal muscle cells. PXugers Arch 432: 320–328.

12. LeBlanc A, Rowe R, Schneider V, Evans H, Hedrick T. (1995) Regional muscle loss after short duration spaceflight. Aviat Space Environ Med 66: 1151–1154.

13. Lexell J, Taylor CC, and Sjöström M. (1988). What is the cause of the ageing atrophy? Total number, size and proportion of different fiber types studied in whole vastus lateralis muscle from 15- to 83-year-old men. J Neurol Sci 84: 275–294.

14. Maganaris CN, Reeves ND, Rittweger J, Sargeant AJ, Jones DA, Gerrits K, De Haan A. (2006) Adaptive response of human tendon to paralysis. Muscle Nerve 33: 85–92.

15. Pišot R, Narici MV, Šimunič B, De Boer M, Seynnes O, Jurdana M et al. (2008). Whole muscle contractile parameters and thickness loss during 35-day bed-rest. Journal of applied Physiology 104(2): 409-414.

16. Rittweger J, Kwiet A, Felsenberg D. (2004). Physical performance in aging elite athletes – Challenging the limits of physiology. J Musculoskel Neuron Interact 4(2):159-160.

17. Runge M, Rittweger J, Russo CR, Schiessl H, Felsenberg D. (2004). Is muscle power output a key factor in the age-related decline in physical performance? A comparison of muscle cross section, chair-rising test and jumping power. Clin Physiol Funct Imaging 24: 335–340.

18. Sargeant AJ, Davies CT, Edwards RH, Maunder C, Young A. (1977) Functional and structural changes after disuse of human muscle. Clin Sci Mol Med 52: 337–342.

19. Sato T, Akatsuka H, Kito K, Tokoro Y, Tauchi H, and Kato K. Age changes in size and number of muscle fibers in human minor pectoral muscle. Mech Ageing Dev 28: 99–109, 1984.

20. Šimunič B, Pišot R, Djordjević S, Kugovnik O. (2005). Age related changes of the skeletal muscle contractile properties. In: Milanović, D, Prot, F (Eds.). 4th International Scientific Conference on Kinesiology "Science and Profession - Challenge for the Future", Proceedings book, 570-573.

21. Tomonaga M. (1977). Histochemical and ultrastructural changes in senile human skeletal muscle. J Am Geriatr Soc 25: 125–131.

22. Trappe S, Trappe T, Gallagher P, Harber M, Alkner B, Tesch P. (2004) Human single muscle Fibre function with 84 day bed-rest and resistance exercise. J Physiol 557: 501–513.

23. WHO – World Health Organisation (2003). Health and Development Through Physical Activity and Sport. WHO/NMH/NPH/PAH/03.2.