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TITLE:

Chronic Exercise preserves lean muscle mass in Masters Athletes

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ABSTRACT:

Aging is commonly associated with a loss of muscle mass and strength, resulting in falls, functional decline and the subjective feeling of weakness. Exercise modulates the morbidities of muscle aging. Most studies, however, have examined these changes in sedentary aging adults. This leaves the question of whether the changes commonly associated with muscle aging actually reflect the true physiology of aging muscle or are a picture of disuse atrophy. This study evaluated whether high levels of chronic exercise prevents the loss of lean muscle mass and strength witnessed with sedentary aging. A cross-section of 40 high level recreational athletes (train 4-5 times per week), age 40-81, underwent tests of health/activity, body composition, quadriceps peak torque and an MRI of bilateral quadriceps. Mid-thigh muscle area (TMA), quadriceps area (QA), subcutaneous (SCAT) and intramuscular adipose tissue (IMAT) were quantified in MRIs using MIPAV image analysis. One way ANOVA were used to examine age group differences. Relationships were evaluated using Spearman correlations. IMAT ($p=.31$) and lean mass ($p=.15$) did not increase with age and were significantly related to retention of TMA ($p=<.0001$). This is despite an increase in total body fat (%) ($p=.003$) with age. TMA ($p=.12$), QA ($p=.17$) and quadriceps peak torque did not decline with age. Specific strength (strength per QA) did not decline significantly with age ($p=.06$). As muscle area increased the peak torque increased significantly ($p=.008$). There was no significant relationship between IMAT ($p=.71$) or lean mass ($p=.4$) and peak torque. This study contradicts the common observation that muscle mass and strength decline as a function of age alone. Instead, these declines may signal the effect of chronic disuse and not muscle aging. Evaluation of high-level recreational athletes removes disuse as a confounding variable in the study of lower extremity function and loss of lean muscle mass. This maintenance of muscle mass and strength may decrease or eliminate falls, functional decline, and the lost independence commonly seen with aging.

Key words: lean muscle mass, active aging, disuse atrophy, masters athlete

INTRODUCTION:

Americans are living longer and more sedentary lives. Advances in medical technology, nutrition and public health lead to the average lifespan rising dramatically in the last century. With the aging of the “baby boomer” generation, the proportion of people greater than 65 years old in the United States will represent 20% of our total population by the year 2030. At the same time, our lifestyles changed from an active agrarian culture to more sedentary jobs and recreation. Living longer does not necessarily mean living well as fully one-third of aging Americans become disabled.

The good news, however, is that many of the diseases and infirmities commonly ascribed to aging alone are more accurately contributed to the ravages of sedentary living. Sedentary seniors decline twice as fast as their active counterparts and their highest level of conditioning effects their overall level of decline[1].

A growing subset of elders has maintained higher functional capacity and quality of life through exercise. Exercise improves quality of life by decreasing body fat, obesity, increasing muscle strength, improving balance, gait and mobility, decreasing the likelihood of falling, improving psychological health, reducing arthritis pain and reducing the risk of developing coronary heart disease, hypertension, osteoporosis, cancer and diabetes.

Feeling weak is often cited as one of the worst parts of aging. Between the ages of 40 and 50 we can lose more than 8% of our muscle mass. This loss accelerates to more than 15% per decade after age 75 (Figure 1). This loss of muscle mass is often accompanied by loss of strength and functional decline. The reasons for this decline are unclear. In a longitudinal study of aging skeletal muscle, Frontera [2] found a 14.7% decline in muscle cross-sectional area in men over a 12 -year period. Several authors[3-5] have documented increased fat infiltration into muscle with age. Although there is a clinical impression that the composition changes and muscle mass loss is associated with a functional decline, results have been inconsistent in the literature. Visser[6], in conjunction with the NIH Health ABC study, recently documented an association between lower leg muscle mass and greater fat infiltration in the muscle with poorer lower extremity performance in older men and women. Baumgartner[7] found that elders with low muscle mass were 3-4 times more likely to report disability, have balance abnormalities and use an assistive device for ambulation.

Goodpaster[8] found that high fat infiltration into muscle was associated with poor knee extensor strength, decreases muscle contractility, muscle fiber recruitment and muscle metabolism. A greater muscle fat content has also been associated with glucose intolerance and diabetes mellitus[9,10].

Although the Health ABC study is examining the physical changes associated with aging in healthy 70-79 year olds, there is a relative paucity of research examining ways to slow or arrest the seemingly inevitable decline from vitality to disability that accompanies aging. The study of senior athletes may provide vital answers to this question. This group continues to exhibit high levels of functional capacity as well as quality of life throughout their lifespan. Evaluation of this group removes disuse as a confounding variable in the study of lower extremity function and loss of lean muscle mass in aging adults.

MATERIALS AND METHODS

Study Population

Forty masters athletes, 20 men and 20 women, were recruited for this study. All subjects were over 40 years old and trained regularly for fitness and sports competition. Many were age group winners for their sport. Test subjects were primarily comprised of runners/track and field, bikers and swimmers. Five men and 5 women were recruited into each 10-year age category 40-49, 50-59, 60-69 and over 70. The subjects were recruited from individuals seeking treatment for sports injuries at the University of Pittsburgh Medical Center, participants in UPMC PRIMA (Performance and Research Initiative for Masters Athletes) programs, flyers in local bike shops as well as races and other competitive events in Pittsburgh, Pennsylvania and the surrounding areas. The University of Pittsburgh Institutional Review Board approved the protocol. All volunteers gave written consent.

Subject Testing

The masters athletes completed a survey capturing health history and details of their activity level and competition.

Lower Extremity Performance was measured bilaterally through a maximum voluntary isometric quadriceps torque test using an isokinetic dynamometer (Biodex System 3 Pro, Shirley, NY) with the force-sensing arm secured to the ankle, and the knee positioned at 75 degrees of flexion. Subjects were asked to exert as much force as possible while extending the knee against the force-sensing arm of the dynamometer. Each subject performed several warm-up repetitions at varying intensities followed by three maximum voluntary contractions. Lower extremity performance was tested bilaterally.

Body composition, including the masters athletes' body volume and body density were measured with the Bod Pod Body Composition System (Life Measurement Instruments, Concord, CA). This system uses air-displacement plethysmography to determine body fat percentage (BF), fat mass (FM) and lean mass (LM). Subjects removed all jewelry and wore minimal clothing while sitting in the device, such as a bathing suit or spandex shorts and a sports bra for females, as well as a swim cap. Initially, two measurements of body volume were recorded, followed by a third measurement conducted with a breathing tube to calculate lung volume. Body fat percentage was calculated using three different equations, depending on the subject's gender and ethnicity: Siri was used for all Caucasians, Ortiz for African-American females and Shutte for African-American males. Intrasubject reliability within the laboratory demonstrated an interclass correlation coefficient (ICC) of 0.98 and standard error of measurement of 0.47 body fat.

A bilateral magnetic resonance imaging (MRI) of both thighs was conducted. MRI scans were performed on a 3.0 Tesla scanner (Siemens Trio, Germany) using the whole body transmit/receive coil, T2 fat images were acquired at mid-thigh (acquisition parameters: 5 slices, TR = 1500ms, TE = 5ms, flip angle = 90, FOV = 20). Mid-thigh total muscle area (TMA), quadriceps area (QA), subcutaneous (SCAT) and intra-muscular adipose tissue (IMAT) were determined from the MRI using MIPAV software (Medical Imaging Processing, Analysis and Visualization, NIH, Bethesda, MD). Examples of thigh MRI scans are presented in figure 2.

Statistical Analysis

One-way ANOVAs were performed to examine group differences. If assumptions were not met, comparisons between groups were performed with the Welch adaptation to the ANOVA test. Post hoc tests were performed with the Tukey-Kramer honestly significant adjustment. Pairwise correlations were performed with the Spearman rho correlation. The alpha level was set a priori to 0.05. Statistical analyses were performed using JMP 5.0.1.2 for Macintosh.

RESULTS:

Subject characteristics

As described in the methodology, a total of 40 volunteers (20 women and 20 men) were enrolled in this cross-sectional analysis. Mean age was 60.1 ± 11.5, with a range from 40 to 81 years old. Subject characteristics detailed by age group are presented in table 1.

Differences between age groups

Per design, age was significantly different between groups. Although these did not differ in body weight, BMI tended to be higher in the 70+ group compared to the 40-49 years old. The 70+ groups had a higher BF content and FM (table 1). LM was not significantly different across the age groups (p=0.15) (figure 3).

TMA was not different between age groups (p=0.12). QA was ~20% lower in the 70+ group compared to the 40-49 and 50-59 years old (p=0.03). SAT and IMAT were not significantly different among groups (p=0.41 and p=0.31 respectively) (figure 4).

Peak torque (PT) from the dominant leg was significantly different between the groups (p=0.0002). While the 40-49 years old group was not statistically significant from all other groups, the group 50-59 was higher than the 60-60 and 70+. The two later groups were not different among each other (figure 5).

Specific peak torque, computed as the ratio of peak torque divided by the quadriceps area (PT/QA) followed the same pattern the PT, thus was significantly higher in the 50-59 compared to the 60-69 and 70+ ($p=0.01$)(figure 6). The ratio of peak torque divided by IMAT (PT/IMAT) was not significant between groups.

Gender differences

Men were heavier then women ($p<0.001$), but did not differ in BMI. Women had more BF ($p<0.001$) and tended to have more FM ($p=0.05$) than men. Men had more LM than woman ($P<0.001$)(figure 3).

Men had greater TMA and QA than women (both $p<0.001$). Women had more SAT than men ($p<0.001$). Neither IMAT nor PT differ between gender (figure 4 and 5). PT/QA was significantly higher in women than men ($p=0.04$)(figure 6), but not PT/IMAT.

Correlations

When all subjects were pooled together, age was significantly correlated with BMI, BF, TMA, QA, PT, PT/IMAT, PT/QA and tended to be correlated with LM and SAT (table 2). As TMA and QA increased PT increased significantly. There was no significant relationship between IMAT or LM and PT.

DISCUSSION:

It is commonly believed that with aging comes an inevitable decline from vitality to frailty. This includes feeling weak and often the loss of independence. These declines may have more to do with the lifestyle choices we make, including sedentary living and nutrition, than the absolute potential of musculoskeletal aging. This study, and those discussed here, shows we are capable of preserving both muscle mass and strength with life-long physical activity.

In this study, chronic intense exercise preserved muscle mass and prevented fat infiltration of muscle in masters athletes. Although changes in body composition were observed, including increased total body fat, there was no decline in absolute muscle mass and the fat infiltration of muscle itself, IMAT, was not increased. These findings are in contrast with studies done in well-functioning men and women between the ages of 70 and 79 y who are not considered masters athletes. These aging adults, in the study by Del Monico[11], were reported to have experienced an age-related increase in fatty infiltration of mid-thigh skeletal muscle in both men and women. The preservation of muscle mass and lack of fatty infiltration in the muscles of our subjects is dramatically illustrated in figure 2.

More important perhaps than mere retention of muscle mass and integrity, was the retention of muscle strength in our group. We studied masters athletes ages 40-81 and observed no difference in quadricept peak torque until participants entered the 60-69 age group. There was no significant difference in PT in the 60, 70, 80 year old groups. Thus, although PT did decline beginning around age 60, the decline did not significantly increase with further aging. This observation was also true with examination of specific strength per muscle area. Our data are consistent with those of McCrory [12] who measured the thigh muscle strength in senior athletes > 60yo. When compared to healthy controls they found the athletes' were significantly stronger than the sedentary controls and their strength did not decline with age. McCrory's[12] study observed no decline in strength in the oldest age group when compared to the 60-69yo. This is consistent with our findings that the significant change in peak torque did not occur until the beginning of the 60-69yo age-group and there was no further significant decline after age 60. These findings are of significant importance, especially when considered in context with findings from the Health ABC study of participants age 70-79 showing that older adults with reduced muscle strength have higher mortality[13]. The ability to retain muscle mass and strength in the upper decades of life, via the simple modality of chronic exercise, bodes well for our ability to intervene and prevent the functional declines experienced with sedentary aging.

Chronic exercise is prophylactic against age related functional decline as exercise at any age stimulates protein synthesis, increased muscle mass and strength. [14,15] Work underway in our labs, under the direction of F. Ambrosio, finds that the initiation of exercise in aging animals reverses the age associated declines in muscle stem cell function, growth factor production and WNT signaling and allows aging muscle to function like their younger counterparts. Multiple human interventional studies have born out the remarkable adaptive capability of aging muscle. Trappe[15] observed a more than 50% increase in the knee extension strength of aging men with 6 months of resistance training. Our study, and that of McCrory[12], documents the effect of lifelong exercise. Aging muscle is thus capable of not only getting stronger with short term interventions initiated in the upper decades but is able to maintain its strength and integrity across the lifespan with chronic exercise.

Interestingly, the effects of maintenance of muscle strength and function observed with chronic exercise are borne out in the athletic performance literature. Wright [16] found no significant decline in the running performance times of top senior athletes, (at all race lengths, 100m – 10000m) until age 75. Tanaka[17] made this observation in swimmers. These finding are supported by several other studies of senior athletes and suggests that lifestyle factors such as disuse and disease incur a significant influence on functional capacity and if minimized or eliminated by active aging, seniors should be able to remain functionally independent until the upper decades of life.

Maintaining lean muscle mass and strength as we age is more than about athletic competition. As we have previously noted, the health care and social costs of loss of lean muscle mass, weakness and senior disability are staggering. According to Janssen [18,19] $18.5 billion in health care costs are were directly attributable to sarcopenia in 2000. This accounted for approximately 1.5% of all health care expenditures for the year. Broken down into individual dollar costs, this represented $800-900 per sarcopenic person. With the aging of the American population these individual and societal costs will only rise. It

is imperative we assuage the wave of senior disability by all means accessible. Harnessing the benefits of acute resistance training intervention or chronic exercise to maintain and build muscle mass and strength, thus preventing loss of independent function and disability is not only logical but becomes a social imperative.
A mere reduction of 10% in sarcopenia prevalence would result in savings of $1.1 billion (dollars adjusted to 2000 rate) per year in U.S. healthcare costs.

CONCLUSION:

The loss of lean muscle mass and the resulting subjective and objective weakness experienced with sedentary aging imposes a significant but modifiable personal, societal and economic burden. As sports medicine clinicians and the gatekeepers of mobility, we must encourage people to become or remain active at all ages. This study, and those reviewed here, document the possibility to maintain muscle mass and strength across the ages. Simple chronic interventions, such as exercise, not only saves mobility but by decreasing disability and disease can save lives.

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TABLE 1
Subjects Characteristics, body composition and physical fitness

Age group	40-49	50-59	60-69	70+	P-Value
N	10	10	10	10	
Gender (M/F)	5/5	5/5	5/5	5/5	
Age (years)	45.9±3.1^{A}	54.4±3.5^{B}	65.2±2.5^{C}	75.4±3.4^{D}	<0.001
Weight (lbs)	136.3±18.1	144.2±25.2	134.8±21.7	135.7±19.18	0.75
BMI (kg/m^2)	20.3±1.3	21.9±2.8	21.6±2.2	22.9±1.5	0.07
Body fat (%)	15.5±7.2^{A}	17.9±4.9^{A}	21.9±8.7	28.4±2.3^{B}	0.003
Fat mass (lbs)	20.6±9.0^{A}	25.9±8.5	29.3±12.5	38.0±10.6^{B}	0.01
Lean mass (lbs)	115.6±21.1	118.3±21.3	106.0±21.6	97.6±6.8	0.15

Notes:
Data presented as mean±SD
^{A,B,C,D} denote significant differences between groups (one-way ANOVA)

TABLE 2
Pairwise correlations

	BMI	BF	LM	TMA	QA	SAT	IMAT	PT	PT/IMAT	PT/QA
Age	0.45*	0.54*	-0.31#	-0.32*	-0.42*	0.30#	0.26	-0.60*	-0.45*	-0.37*
BMI		0.57*	0.07	0.20	0.05	0.38*	0.34*	-0.06	-0.36*	-0.07
BF			-0.65*	-0.54*	-0.62*	0.86*	0.30#	-0.38*	-0.45*	0.01
LM				0.82*	0.85*	-0.69*	0.10	0.43*	0.11	-0.08
TMA					0.93*	-0.55*	0.09	0.47*	0.11	-0.10
QA						-0.58*	0.003	0.46*	0.19	-0.15
SAT							0.25	-0.24	-0.37*	0.18
IMAT								0.01	-0.91*	0.02
PT									0.36*	0.79*
PT/IMAT										0.26
PT/QA										

Correlations are Spearman's Rho, * $p<0.05$, #$p<0.01$

BF=body fat (%), LM=lean mass (kg), TMA=thigh muscle area(mm^2),

QA=quadriceps area (mm^2), SAT= tight superficial adipose tissue (mm^2),

IMAT=inter-muscular adipose tissue (mm^2), PT=peak torque

FIGURES:

Figure 1: Muscle loss with age. Reproduced from Abbott Labs

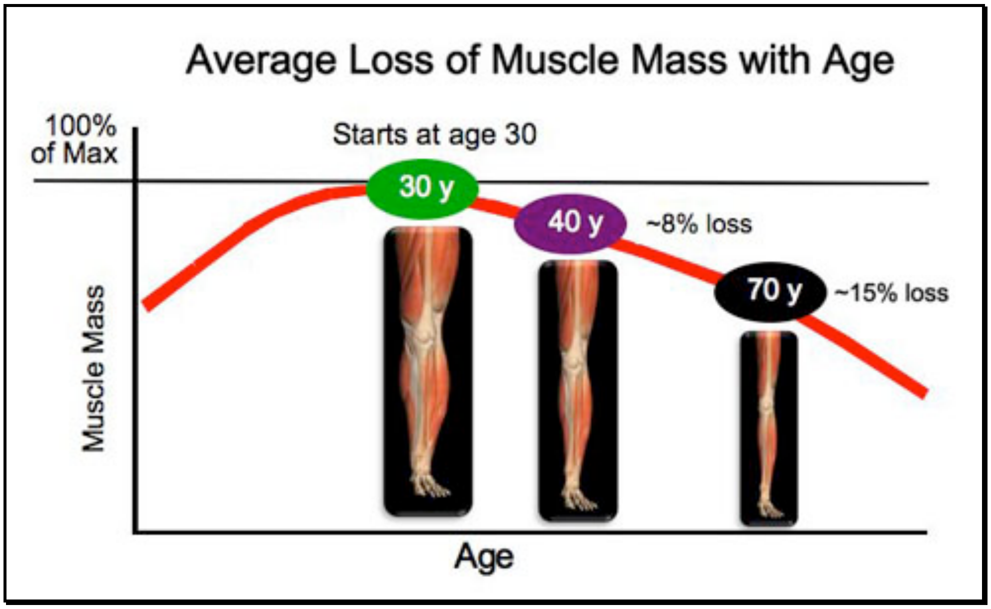
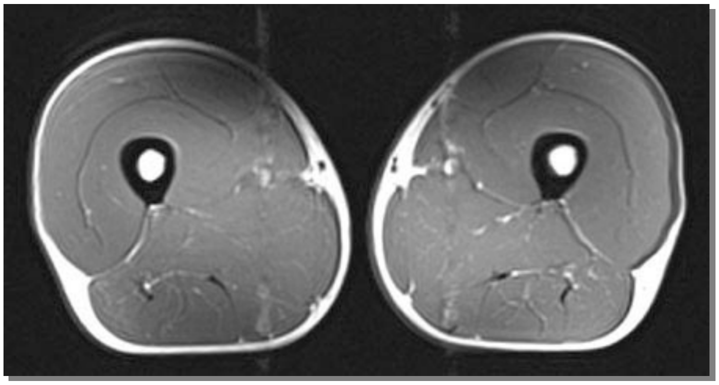
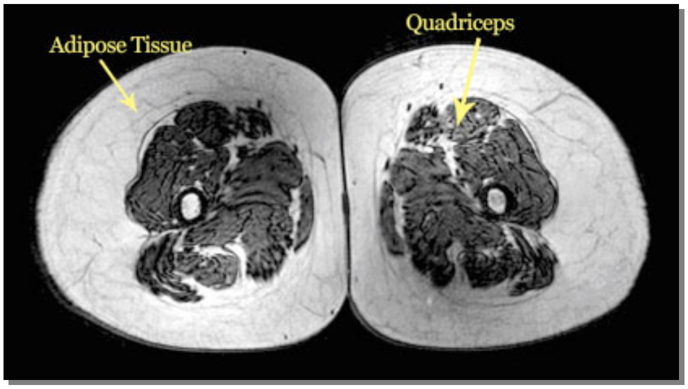


Figure 2: Typical Quad MRI of 40yo triathlete compared to the quad MRI of a 70yo triathlete and 74yo sedentary male. Note the significant visual difference between the SAT and IMAT of the sedentary versus masters athletes.

40 year old tri-athlete



74 year old sedentary man



70 year old tri-athlete

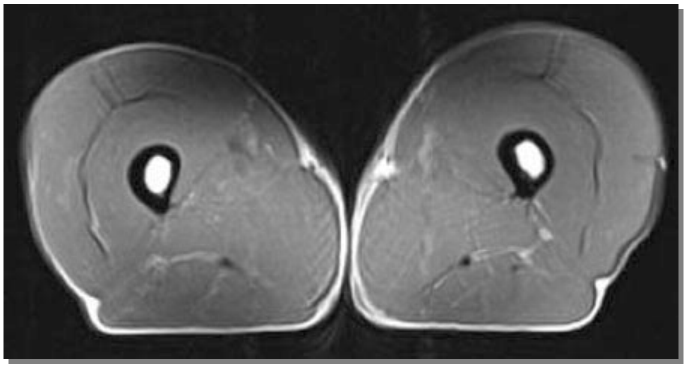


Figure 3: Lean Mass by age group and sex. LM was not significantly different between groups (p=0.12). Group mean represented by the dot, median as a line inside the box which corresponds to 50% of the distribution.

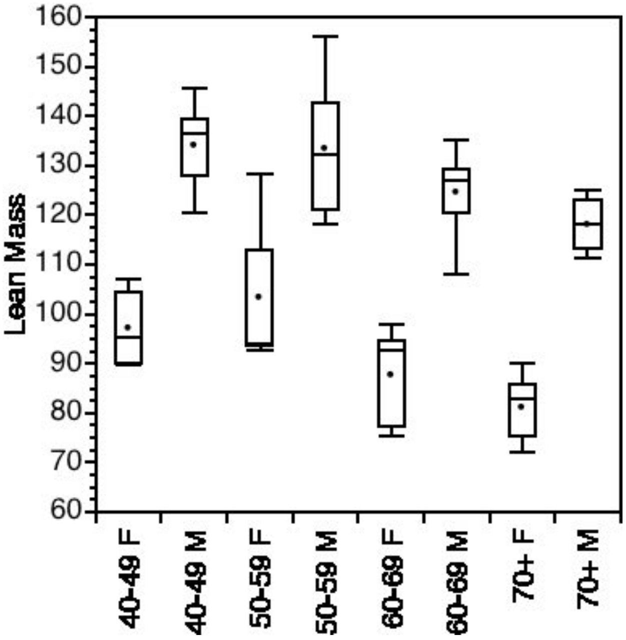


Figure 4: IMAT by age group and sex. IMAT was not significantly different between groups (p=0.31). Group mean represented by the dot, median as a line inside the box which corresponds to 50% of the distribution.

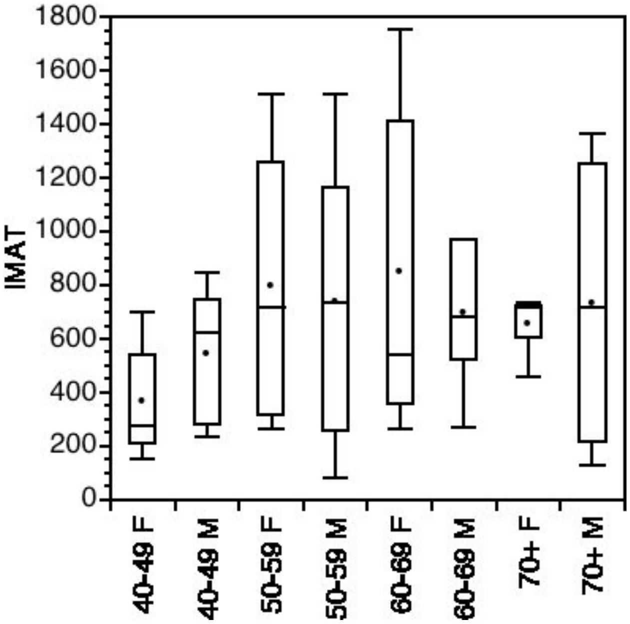


Figure 5: Peak Torque by age group and sex. PT changed significantly after age 60. There was no significant difference between athletes older than 60. Group mean represented by the dot, median as a line inside the box which corresponds to 50% of the distribution.

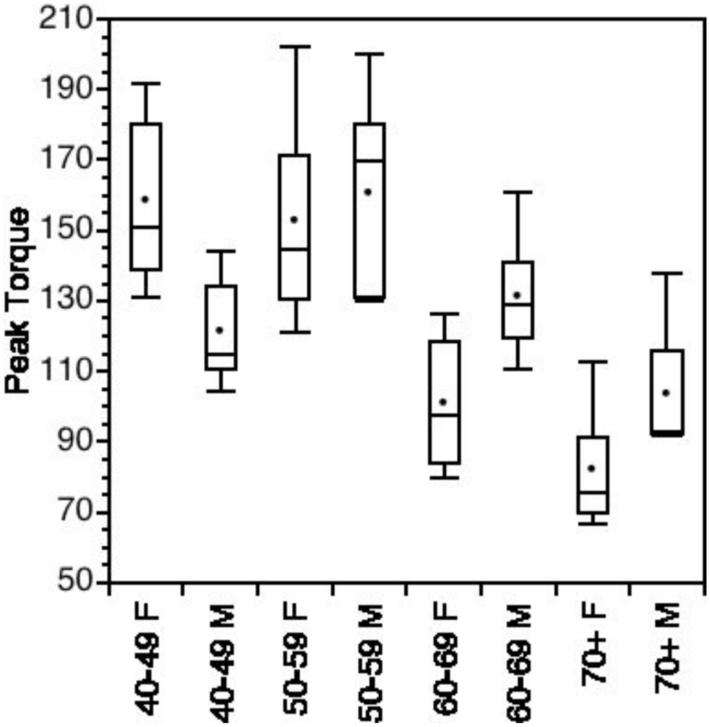


Figure 6: Specific Peak Torque by age group and sex. Specific Peak Torque changed significantly after age 60. There was no significant difference between athletes older than 60. Group mean represented by the dot, median as a line inside the box which corresponds to 50% of the distribution.