

# Strength and muscle mass loss with aging process. Age and strength loss

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## Summary

**Background:** aging process is associated with changes in muscle mass and strength with decline of muscle strength after the 30<sup>th</sup> life year.

The aim of this study was to investigate these changes in muscle mass and strength.

**Patients & Methods:** for this analysis 26 participants were subdivided in two groups. Group 1 comprises participants aged <40 years (n=14), group 2 those >40 years (n=12).

We assessed anthropometrics, range of motions, leg circumferences and isometric strength values of the knee joints.

**Results:** besides comparable anthropometrics, circumferences and strength were higher in group 1 than in group 2. Circumference of upper leg (20 cm above knee articular space) showed for right leg a trend to a significant (median: 54.45 cm (1<sup>st</sup> quartile: 49.35/ 3<sup>rd</sup> quartile: 57.78) vs 49.80 cm (49.50/50.75), p=0.0526) and for left leg a significant 54.30 cm (49.28/58.13) vs 49.50 cm (48.00/52.53), p=0.0356) larger circumference in group 1. Isometric strength was in 60° knee flexion significantly higher in group 1 than in group 2 for right (729.88N (561.47/862.13) vs 456.92N (304.67/560.12), p=0.00448) and left leg (702.49N (581.36/983.87) vs 528.49N (332.95/648.58), p=0.0234).

**Conclusions:** aging process leads to distinct muscle mass and strength loss. Muscle strength declines from people aged <40 years to those >40 years between 16.6% and 40.9%.

**KEY WORDS:** muscle, strength, sarcopenia, isometric, age, aging.

## Background

Aging process is connected with widespread and typical changes in human body<sup>1-9</sup>. With increasing age body composition is changing<sup>3, 5, 10-12</sup> with a loss of muscle mass and bone mass<sup>1-3, 5, 9-11, 13-15</sup> and a reduction of physical capacity over years<sup>2, 8, 11, 16, 17</sup>.

Maximum of physical capacity is between 20<sup>th</sup> and 30<sup>th</sup> life years<sup>11</sup>. Pronounced changes with aging process take place after 50<sup>th</sup> life year<sup>2, 4, 11, 13, 15, 16</sup>. Profound changes with a leg lean body mass loss of 1-2%/year<sup>18-20</sup> and a strength loss of 1.5-5%/year<sup>11, 18-21</sup> are reported for individuals older than 50 years (Tab. 1).

For those aged between 30 and 50 life-years published changes in muscle mass, power and strength are small<sup>4, 11, 16</sup>.

The aim of our study was to investigate changes in muscle mass and strength with the aging process and especially the comparison between people before and after 40<sup>th</sup> life year. We hypothesised that accelerated decline of strength and muscle mass loss starts already around 40<sup>th</sup> life-year.

## Methods and patients

The study was designed to investigate the effects of aging on muscle mass and strength. 26 leg-healthy participants were examined at the orthopaedic University medical center of Frankfurt (Germany).

Patients were eligible for participation if they were at least 18 years old, not pregnant, did not had a congestive heart failure or an aortic valve stenosis, a neurological or rheumatological diseases, acute injuries of the knee joints, muscle diseases or muscle injuries of the legs. All participants gave informed consent.

For this analysis the participants were subdivided in two groups. Group 1 comprises the younger participants with age <40 years (n=14). Group 2 consists of the older participants with an age of 40 and older (40 + years) (n=12).

The participants were questioned about their medical history and we assessed anthropometric data of age,

**Table 1. Strength loss with aging in literature.**

Study	Leg lean muscle mass loss	Strength loss	Comments
Goodpaster et al. <sup>18</sup> Frontera et al. <sup>19</sup>	Approximately 1%/year 1.3%/year	2.6-4.1%/year 1.7-2.5%/year	Ethnic and sexspecific differences Longitudinal study over 12 years, starting age was in mean 65 life-years
von Haehling et al. <sup>20</sup>	1-2%/year after 50 <sup>th</sup> Life-year	1.5% between ages 50 and 60 and by 3% thereafter	
Zatsiorsky et al. <sup>11</sup>		1.5%/year between 50 <sup>th</sup> and 70 <sup>th</sup> lifeyear, 3%/year thereafter	
Doherty <sup>30</sup>		20-40% between 20 <sup>th</sup> and 80 <sup>th</sup> lifeyear	
Marcell et al. <sup>21</sup>		3.6-5%/year	Longitudinal study over approximately 5 years, starting age was 58.6±7.3 years
Proctor et al. <sup>16</sup>	35-40% between 20 and 80 years of age		

height and weight. The range of motion of the knee joints and the circumferences of the legs were measured.

We assessed the circumferences of both legs at the upper leg in 20 cm and 10 cm above the articular space of the knee joint and at the lower leg in 10 cm beyond the articular space of the knee joint and the largest circumference of the lower leg.

Moreover we measured the maximum isometric strength of extension movements in the knee joints of the participants in a sitting position with a strength measuring system (Dynamometer BIODEX® System 3) in 30° and 60° flexion of the knee joint. The torque was measured and assessed by the software Myoresearch 98 (Version 1, Noraxon, Phoenix Arizona). The length of the lever arm was used to calculate the isometric strength values of both legs. We assessed an average 3 sec maximum strength value of a maximum isometric muscle contraction of an extension movement of the leg over 5 sec.

The two groups were compared for anthropometric characteristics, circumference parameters of the legs, range of motion values and strength parameters.

### Statistic tests

The computerized analysis of the data was done with the statistic software system BIAS® Version 9.12. We used the Wilcoxon-Mann-Whitney-test to detect differences between the groups. In the text values are presented as median with 1<sup>st</sup> and 3<sup>rd</sup> quartile. The threshold for significance was set to a p-value of 0.05.

### Results

We examined 26 leg-healthy participants at the orthopaedic University medical center of Frankfurt (Germany).

The participants of group 1 were 31 years (1<sup>st</sup> quartile: 27.75/ 3<sup>rd</sup> quartile: 36.50) old in median. The median age of group 2 was 54 years (43.50/61.00). The groups were similar in the anthropometric data. Also

the parameters of range of motion were comparable between the groups. The characteristics of the groups are shown in Table 2.

The median circumference values were in all measurements larger in group 1 than in group 2 (Tab. 3). The circumference values of the upper leg in 20 cm above the articular space of the knee joint showed for the right leg a trend to a significant 54.45 cm (49.35/57.78) vs 49.80 cm (49.50/50.75), p=0.0526) and for the left leg a significant 54.30 cm (49.28/58.13) vs 49.50 cm (48.00/52.53), p=0.0356) larger circumference in the younger participants (group 1).

Also the circumference of the upper leg in 10 cm above and of the lower leg 10 cm beyond the articular space of the knee joint showed for both legs a trend to a significant larger circumference in the younger participants (group 1).

The isometric strength was in 60° knee flexion significantly higher in group 1 than in group 2 for the right leg (729.88N (561.47/862.13) vs 456.92N (304.67/560.12), p=0.00448) (Tab. 3) (Fig. 1) as well as for the left leg (702.49N (581.36/983.87) vs 528.49N (332.95/648.58), p=0.0234) (Tab. 3) (Fig. 2). In 30° flexion the mean strength values of group 1 were higher than these of group 2, but the difference between the groups was not significant (Tab. 3).

### Discussion

The muscular system accounts approximately 40% of the total body mass and human body's cell mass consists in 75% of muscle cells<sup>22</sup>. Approximately a quarter of the total body protein synthesis takes place in the muscular system<sup>22</sup>. Skeletal muscle is an important tissue of the human body<sup>23</sup>, which is especially responsible for voluntary movement control<sup>24</sup>. Aging process leads to a decrease in muscle mass and strength<sup>9, 16, 22, 25</sup>. Loss of strength is directly connected with reduction of muscle mass<sup>2, 11</sup>.

The maximum of physical capacity comprises the decade between 20<sup>th</sup> and 30<sup>th</sup> life year<sup>11</sup>. Between 30<sup>th</sup> to 50<sup>th</sup> life

**Table 2. Characteristics with regards to anthropometric values and range of motion of the knee joints of the two groups. Data were presented as mean values with standard deviation and p-values for difference.**

	Group 1 (<40 years)	Group 2 (40+ years)	P value
Number	14	12	
Age	31.43±5.37 years	52.42±8.41 years	
Height	173.64±11.03 cm	170.00±7.85 cm	p = 0.527
Weight	73.36±13.49 kg	72.67±9.42 kg	p = 1.000
Body mass index	24.26±3.51 kg/m <sup>2</sup>	25.05±1.68 kg/m <sup>2</sup>	p = 0.322
Range of motion			
Straightening right knee	-0.71±1.64 °	-0.17±0.58 °	p = 0.595
Straightening left knee	-0.86±1.99 °	-0.17±0.58 °	p = 0.595
Flexion right knee	139.36±5.81 °	135.92±4.10 °	p = 0.131
Flexion left knee	140.60±6.58 °	137.70±3.87 °	p = 0.252

**Table 3. Circumferences of the legs and isometric strength values of the two groups. Data were presented as mean values with standard deviation and p-values for difference.**

Circumference		Group <40 years	Group 40+ years	P value
Upper leg in 20cm above the articular space of the knee joint	Right leg	54.03±4.55 cm	49.98±2.50 cm	p=0.0526
	Left leg	53.87±4.69 cm	49.98±2.70 cm	p=0.0356
Upper leg in 10cm above the articular space of the knee joint	Right leg	45.39±3.41 cm	43.36±1.90 cm	p=0.0757
	Left leg	45.24±3.79 cm	42.54±2.32 cm	p=0.0673
Lower leg in 10cm beyond the articular space of the knee joint	Right leg	37.32±3.16 cm	35.08±2.56 cm	p=0.0673
	Left leg	36.73±3.19 cm	35.18±1.96 cm	p=0.0950
Largest circumference of the lower leg	Right leg	38.61±3.27 cm	36.70±2.76 cm	p=0.106
	Left leg	38.30±3.27 cm	36.71±2.67 cm	p=0.212
Isometric maximum strength in 60° knee flexion	Right leg	716.96±291.88 N	423.84±179.45 N	p=0.00448
	Left leg	757.55±291.08 N	520.97±220.25 N	p=0.0234
Isometric maximum strength in 30° knee flexion	Right leg	389.37±110.50 N	324.91±117.22 N	p=0.252
	Left leg	423.91±137.26 N	309.03±135.79 N	p=0.0596

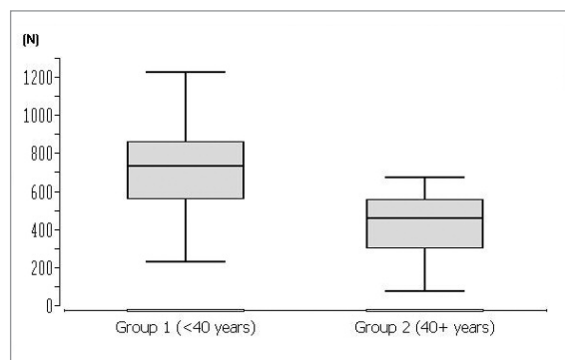


Figure 1. Maximum isometric strength of the right leg in 60° flexion of both groups.

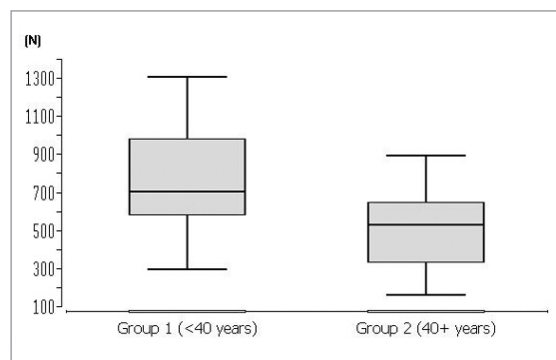


Figure 2. Maximum isometric strength of the left leg in 60° flexion of both groups.

year the reported changes in muscle mass, power and strength are small<sup>4, 11, 16</sup>. Pronounced changes with aging process occur after 50<sup>th</sup> life year with more than 15% strength loss per decade<sup>2, 4, 11, 13, 15, 16, 20, 26</sup>.

In accordance with literature the results of our study confirm that aging leads to a distinct muscle mass and strength loss. But in contrast to literature the results of our study show a larger strength decline as described in literature for the middle aged persons between 40<sup>th</sup> and 60<sup>th</sup> life years. The difference between the median age of group 1 and 2 was more than 20 years (31 years vs 54 years). The decreases

of the mean strength in these 2 decades were between 16.6% and 27.1% in 30° knee flexion and between 31.2% and 40.9% in 60° knee flexion. Therefore was the mean strength loss in these 2 decades in contrast to literature larger than estimated. These results support the hypothesis that the accelerated process of muscle mass and strength loss starts earlier nearby the 40<sup>th</sup> life year.

The pathophysiology of strength and muscle mass loss with aging process is complex<sup>27</sup>. Muscle mass loss is caused by reduced numbers of muscle fibers and motor units and decline of muscle fiber size<sup>2, 11</sup>.

<sup>27-30</sup>. If muscle fibers deceed a critical minimal size, apoptosis begins<sup>11</sup>. Other causes of apoptosis with aging process are denervation and loss of neurons<sup>4, 11, 31</sup>. Moreover strength capacities per motor unit decrease<sup>22</sup>. Loss of muscle fibers reduces strength capacities, decreases muscle metabolism and increase risk of muscle damage<sup>11</sup>. Synthesis rate of muscle protein decreases with aging process<sup>6, 14, 16, 17, 22, 28, 30, 32</sup>. Moreover muscle repair capacities are reduced with increased age<sup>33</sup>.

Atrophy of muscle fibers is disproportionally distributed with higher atrophy rate of type IIa fast twitch (FT) muscle fibers and their motor units<sup>17, 22, 30</sup>. FT muscle fibers seem to be more prone to a function failure or a function loss over time and therefore are primarily affected bei muscle fiber loss related to aging process<sup>4, 11, 28, 32</sup>. In the timeframe between 20<sup>th</sup> and 75<sup>th</sup> life year more than 50% of FT muscle fibers get lost<sup>11</sup>.

One major cause of strength and muscle mass loss with aging process is the decline of anabolic hormones, which results in a katabolic effect on muscles and bones<sup>4, 11, 15-17, 22, 25, 30</sup>. The reduced hormone levels of testosterone, dehydroepiandrosterone, growth hormone, and insulin-like growth factor-I play a main role in this process<sup>4, 15-17, 22</sup>. About the 50<sup>th</sup> life year hormonal status of human body is changing<sup>11, 25</sup>. In men andropause takes place in this time period<sup>11</sup>. The menopause of women begins between 45<sup>th</sup> and 55<sup>th</sup> life year<sup>11</sup>. The decline of hormonal synthesis leads to distinct changes in human body with decreasing muscle mass and strength<sup>11, 25, 30</sup>.

Besides the loss of anabolic factors such as neural growth factors, growth hormone, androgens and estrogens, and physical inactivity an increase of catabolic factors such as inflammatory cytokines could contribute to muscle mass and strength loss<sup>4, 22, 30</sup>. Especially interleukin-1 $\beta$ , tumor necrosis factor (TNF)- $\alpha$ , and interleukin-6 support a decrease the muscle mass<sup>4, 22, 27, 30</sup>.

Co-morbidities like malignancy, chronic obstructive pulmonary disease, congestive heart failure, inflammatory bowel disease and rheumatoid arthritis also contribute to muscle mass und strength loss with aging process<sup>34-38</sup>. Other diseases with a period of disability like deep vein thrombosis, pulmonary embolism, myocardial infarction, pneumonia or surgeries keep also the risk for strength and muscle mass loss in elderly<sup>39, 40</sup>.

The decrease in physical activity with aging process is the key factor in development of strength and muscle mass loss<sup>17, 22, 30, 41</sup>. Physical inactivity leads to muscle atrophy<sup>30</sup>. Loss of appetite is an additive problem in older adults as insufficient nutrient intake that can also contribute to muscle loss<sup>17</sup>. Therefore one of the great challenges of aging process is to decline muscle mass loss and loss of strength<sup>11, 22</sup>. Strength training is one important tool to counteract this problem<sup>2, 11, 22</sup>.

Besides the physiological loss of strength and muscle mass, sarcopenia is a syndrome characterised by progressive and generalised loss of skeletal muscle strength and mass in elderly<sup>4-8, 22, 27, 28, 30, 32, 34</sup>. Sar-

copenia is connected with physical disability, poor quality of life and death<sup>34</sup>. The criteria of the European consensus on the definition of sarcopenia comprise low muscle mass, low muscle strength and low physical performance<sup>34</sup>. The diagnosis of sarcopenia could be made if a low muscle mass consists and at least one of the two other criteria are also existing<sup>34</sup>.

## Limitations

There were some limitations of this study. At first only a small number of leg-healthy participants was included in this study. It would be of further interest to have a large number of participants of every decade of life to compare the individuals of the several decades about the muscle mass and strength loss. Moreover further studies should investigate the influence of diseases on the skeletal muscle system with its typical changes with aging process.

## Conclusions

Aging process leads to a distinct muscle mass and strength loss. The decline of the muscle strength of people, who were younger than 40 years, in comparison to those, who were older than 40 years was ranged between 16.6% and 40.9%.

## Conflicts of interest

Karsten Keller declares that he has no conflict of interest. Martin Engelhardt declares that he has no conflict of interest.

The Study was done at the Department of Orthopedics, University Hospital Frankfurt, Germany

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