Effect of age and sex on absolute strength in human muscle

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Abstract

Maximum voluntary strength per unit muscle area (absolute strength) related to age was investigated in normal 131 males and 127 females, 7 to 18 years of age. A Cybex machine was used to measure the isometric muscle strength in flexion and extension at elbow and knee joints, respectively. The cross-sectional muscle area of extensor and flexor at right upper arm and thigh were determined by using ultrasonic apparatus. The muscle area increased with age from 7 to 17 years in males and to 12 years in females. The absolute strength tended to increase with age from 7 to 12 years in males and 7 to 9 years in females. Observing from the view point of relative growth the absolute strength increased with the increment of body height up to 150–160 cm in males and 140–150 cm in females. Above about these heights the absolute strength was independent of the height in both sexes. There were no differences in the absolute strength between both sexes at a given age or body height. These result indicate that under 12 years (155 cm of height) for boys and 9 years (145 cm) for girls the increment in muscle area with age is not enough accompanied with the development of muscle function.

Key words : muscle area, absolute strength, age and sex.

Introduction

The maximum voluntary strength is considered to be affected by some factors of muscular and nervous system such as muscle cross-sectional area[11,13,16], muscle fiber type[15,18], and level of ex citation of central nervous system and number of motor units recruitments in muscle contraction[6]. It is considered that these factors are developed not altogether with age. The nervous system developed mostly in babyhood up to about 10 years old, while muscular system developed rapidly in secondary sex character period.

There are several reports for the age trends of muscle strength. Maximum voluntary strength in human elbow flexor developed above 12 years old was caused by the increment of cross-section of muscle, because of no changes in strength per unit muscle area with age and sex[6]. However, in the animal experiments (mice) the tension per unit muscle area increased with age.

The purpose of the present study is to observe the effect of age on strength per unit area of muscle (absolute strength) in the ages of 7 to 18 years old.

Method

Subject were 131 of males and 127 of females, aged 7 to 18 years old. The cross-sectional area of flexor and extensor muscle of upper arm and thigh were measured by means of ultrasonic apparatus (ALOKA SSD-120 connected to circular compound system). The sites of measurements of cross-section of limbs were as follows:

upper arm; 60% distal point of humerus length,

thigh ; 50% of femur length.

The cross-sectional area were measured at the body position of full extension of both knee and elbow joints in right side limbs.

The maximum isometric voluntary strength of extension and flexion of elbow and knee joints were measured by Cybex 11 at the sitting position on specially designed apparatus. The joint angle for measuring the strength were 110 degrees for flexion and 130 degrees for the extension of elbow joint, and that of 140 degrees for flexion and 110 degrees for extension of knee joint, respectively.

Results

Figure 1 shows changes in cross-sectional area of flexor and extensor muscle at upper arm and thigh. In males both flexor and extensor muscle area increased with age. Above about 12 years old the higher increment of muscle area were observed. On the other hand, females indicated lower increment of muscle area than that of males above 13 years old. It was observed that the differences of muscle area between males and females increased above 13 years for arm muscle and 14 years for

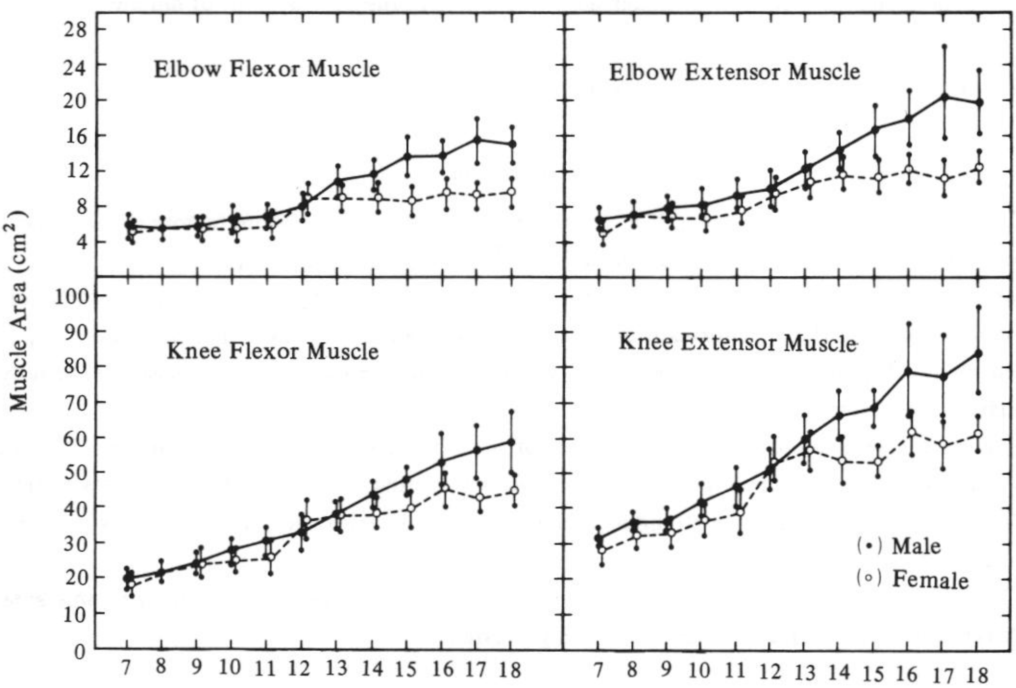

Fig. 1 Changes in cross-sectional area of muscle with age

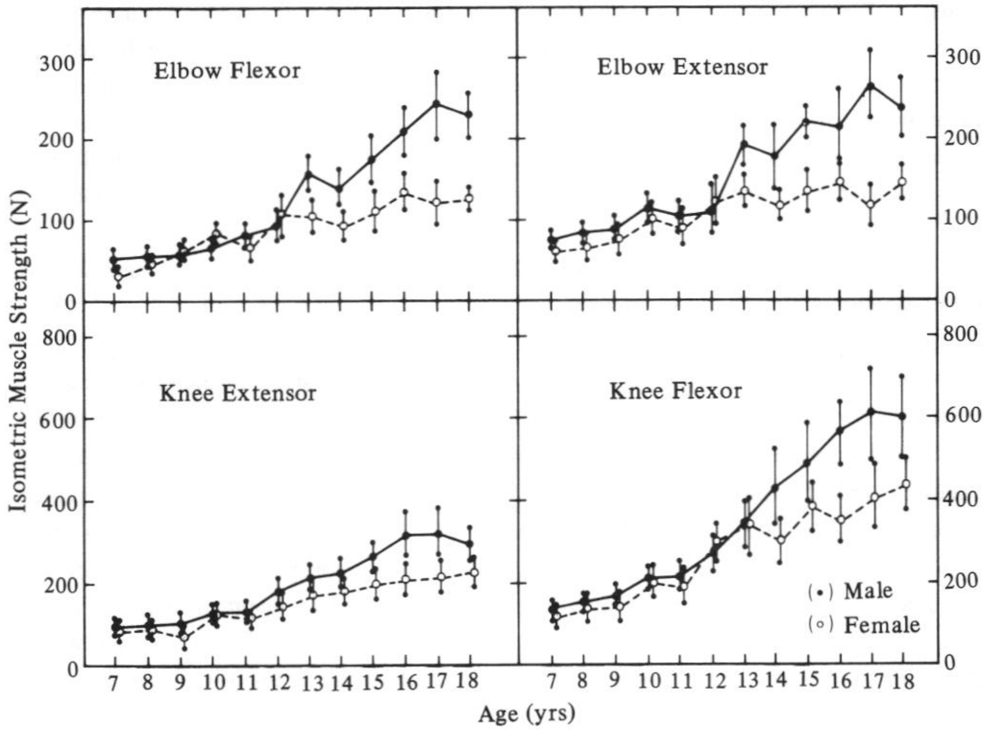

Fig. 2 Changes in cross-sectional area of muscle with age

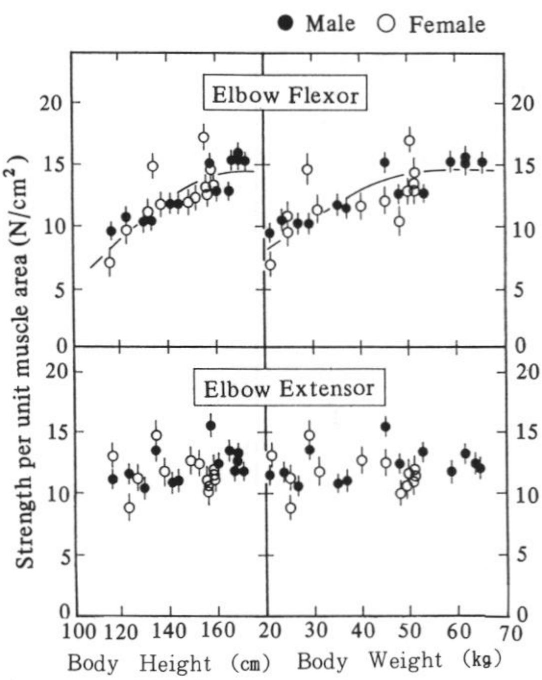

Fig. 3 The absolute strength of elbow flexor and extensor related to body height and weight.

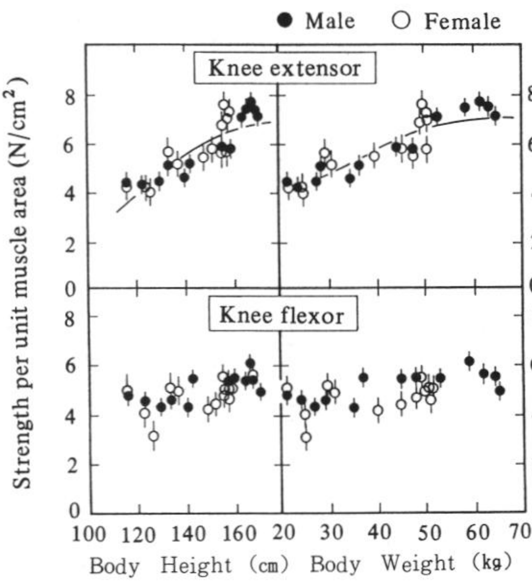

Fig. 4 The absolute strength of knee extensor and flexor related to body height and weight.

thigh muscle. Figure 2 indicates changes in muscle strength with age. The strength for males increased rapidly above about 12 years old with age. On the other hand, females indicated continuous linear slight increasing of the strength with increase of the ages, resulting clear sex differences of the strength above about 13 years old.

The absolute strength is shown in Table 1. The absolute strength indicated significantry lower values in 7–12 years in boys and 7–9 years in girls than the other ages, except for elbow extensor muscle.

The absolute strength of elbow flexor and extensor are observed as the changes with the body height and weight in Fig. 3. Plots express as means and standard errors at each age. The absolute strength in elbow flexor increased with the height and weight under about 150–160 cm and about 50 kg, respectively. However in elbow extensor muscle the absolute strength indicated almost constant values, regardless of body height and weight. In generally, there were no significant differences of absolute strength between both sexes. Figure 4 shows the changes in absolute strength of knee extensor and flexor with the height and weight. Knee extensor muscle indicated the increment of absolute strength with height and weight under about 150–160cm of height and about 50 kg of weight, respectively. However, the absolute strength of knee flexor were independent of height and weight and indicated about 4–6 N/cm^2. Between male and female no significant differences were observed in absolute strength of knee extensor and flexor at a given height and weight. The absolute strength related to cross-sectional area of muscle and bone are observed in Figures 5 and 6. The absolute

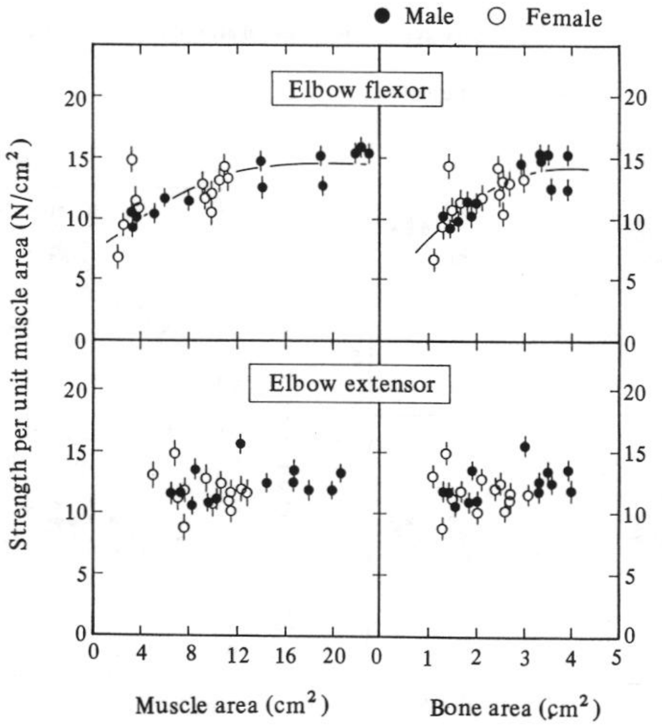

Fig. 5 The absolute strength of elbow flexor and extensor related to cross-sectional area of muscle and bone.

Age (yrs)		n	Elbow Flexor (kg/cm²)	Elbow Extensor (kg/cm²)	Knee Flexor (kg/cm²)	Knee Extensor (kg/cm²)
7	M	10	9.11±1.20	11.53±2.24	4.78±0.75	4.37±0.40
	F	10	6.75±1.42	13.07±3.72	4.96±0.92	4.41±0.70
8	M	10	10.31±2.06	11.67±1.64	4.58±0.71	4.35±0.51
	F	10	9.45±1.70	8.71±1.76	4.05±0.69	4.19±0.71
9	M	10	9.95±1.28	10.49±2.36	4.34±0.63	4.53±0.70
	F	10	10.85±1.46	11.13±1.44	3.06±0.42	4.01±0.74
10	M	10	10.13±1.40	13.49±2.94	4.61±0.71	5.10±0.65
	F	10	14.59±2.14	14.76±2.30	5.21±2.01	5.70±1.42
11	M	10	11.59±1.58	10.83±2.32	4.26±0.85	4.58±0.64
	F	10	11.25±1.21	11.73±2.24	4.93±0.70	5.21±1.01
12	M	10	11.39±2.06	10.99±3.34	5.50±1.09	5.23±0.53
	F	10	11.69±2.60	12.67±2.82	4.21±1.07	5.51±0.68
13	M	12	14.86±2.28	15.50±2.42	5.38±0.70	5.86±1.20
	F	12	11.95±1.48	12.35±1.14	4.40±0.94	5.80±1.15
14	M	12	12.47±2.08	12.27±3.18	5.51±1.19	5.83±1.47
	F	12	10.27±1.36	10.11±1.44	4.75±0.64	5.70±0.75
15	M	11	12.51±1.62	13.45±1.78	5.43±1.03	7.11±1.59
	F	13	12.85±1.90	11.59±1.96	5.03±1.22	7.58±1.34
16	M	12	15.24±1.90	11.81±2.38	6.07±1.32	7.47±1.45
	F	10	14.33±1.68	11.89±2.48	4.59±1.01	5.74±0.86
17	M	12	15.40±2.10	13.29±2.66	5.64±5.55	7.81±0.82
	F	10	12.97±2.40	10.99±2.78	5.04±0.93	7.05±1.27
18	M	12	15.26±2.20	11.93±2.74	4.92±0.76	7.21±1.42
	F	10	13.07±1.42	11.49±1.80	5.06±1.01	7.21±1.13
20	M	20	15.90±2.08	12.45±1.52	5.50±0.44	7.62±0.97
	F	20	17.80±2.98	10.59±2.12	5.51±0.71	6.93±1.62

M : Male
F : Female

mean ± SD

strength of elbow flexor and knee extensor in male subjects increased with the muscle and bone areas in elementary school ages (under about 12–16 cm^2 in elbow flexor muscle and about 40–50 cm^2 of knee extensor muscle, and under about 2–3 cm^2 of bone area of humerus and about 4–5 cm^2 of femur). However, in elbow extensor and knee flexor the absolute strength were independent of muscle and bone area in both males and females.

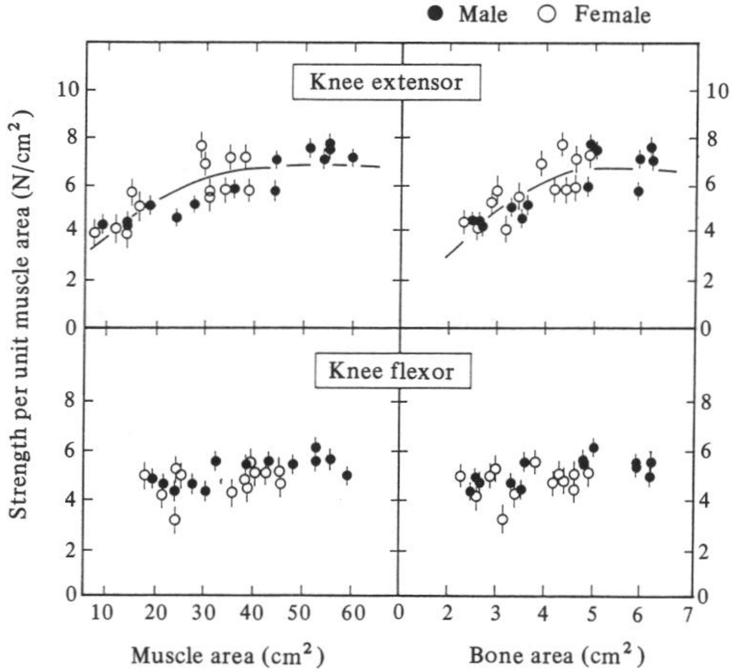

Fig. 6 The absolute strength of knee flexor and extensor related to cross-sectional area of muscle and bone.

Discussion

In the present study changing in the strength per unit area (absolute strength) with age indicated to have different growth patterns due to various muscle groups. Elbow flexion and knee extension indicated clearly low strength per unit area under 12 years compared with other age groups. These represent to have different growth pattern between cross-section and function of muscle tissues.

Interesting point in the present study was that the absolute strength increased with age in childhood under about 12 years old. In animal experiments it was reported that the strength per unit area in mouse muscle increased with age from 1 to 5 weeks. These data are agreed with the present study.

It is considered that the absolute strength is affected by the muscle fiber types(12). Fast twitch fibers exerts higher tension and power of contraction compared to slow twitch fibers. There were various reports for the effect of fiber types on the strength per unit muscle area in human and also animal muscles. Close(4) found that no significant differences of strength per unit area was observed between fast and slow twitch fibers. Woitiez et al.(20) reported, however, higher strength per unit area of fast fibers than that of slow fibers.

According to the studies for the effect of age on the fiber types the ratios of number of FT fibers in vastus lateraris were reported to be almost the same in 6 years boys as in adults. On the other hand, caliber of muscle fiber indicated same values between type I fiber and type II fiber in human baby of 1 year old(5), and the fiber area increased more in II fiber with age than that of I fiber, resulting larger cross-sectional area of II fiber than that of I fiber in adults(10). These may indicate that FT fiber increase its cross-section with growth than that of ST fiber. However, in the present study above about 12 years in males and 9 years in females there were no significant differences of strength per unit cross-sectional area of muscle, indicating no effect of fiber types on strength per unit muscle area in lower ages.

Muscle fiber is mainly consisted of myofibril and sarcoplasm. It is considered that the ratio of myofibril to sarcoplasm affect on the relation between strength and muscle area. In mouse experiments the number of myofibril increased up to about 10–15 times with age. The percent ratio of myofibril increased rapidly in 30 days after birth. Assuming for these tendency to apply to the human muscle, changes in strength per unit area with age in the present study may be caused by the changes in number of myofibril in childhood.

The factor for nervous system was reported to affect on the strength per unit muscle area. Maximum voluntary strength was due to the number of motor units in contraction which was caused by the level of excitation of cerebral cortex. The nervous system developed rapidly in lower ages, and reaches to about the same level as adults at the ages of 12–15 years old.

It was observed that two types of muscle came into existence during human growth. One type of that is the muscle groups such as elbow extensor and knee extensor which the absolute strength increased with age (or body height and weight) in elementary school period. These differences of between both muscle groups may be considered to be induced by daily physical activities; anti gravitational muscle such as elbow flexor and knee extensor are activated more in physical movement than the other muscles.

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