

# ARE ADULT MUSCLES INTRINSICALLY STRONGER THAN THOSE OF CHILDREN?

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## INTRODUCTION

It is known that adults are stronger than children, with the increase in strength reported to be greater than the increase in muscle size [e.g. 1]. As a result it has been assumed that the specific tension (intrinsic force-producing capacity) of skeletal muscle must be increased with maturation. This conclusion draws support from the reported increase in the proportion of type II fibres in adult muscle [2]. However, these assumptions are based on studies that have quantified muscle size as the anatomical cross-sectional area. To date, the only study to have calculated the physiological cross-sectional area surprisingly found that specific tension was greater in boys than men [3]. This study, therefore, set out to confirm whether quadriceps muscle specific tension differs between adults and children.

## METHODS

Measurements were taken of the knee extensor muscles of men and women and late pre-pubertal children of both sexes aged 8-10yrs ( $n=10$ ). The specific tension of the quadriceps femoris muscle was calculated as the ratio between the quadriceps tendon force and the sum of the physiological cross-sectional area (PCSA) of the four muscle heads, each multiplied by the cosine of the angle of pennation of that head. The maximal quadriceps tendon force was the knee extension maximum voluntary contraction (MVC) moment corrected for EMG-based estimates of antagonist co-activation, for incomplete quadriceps activation using the interpolation twitch technique and for MRI-based measurements of the patellar tendon moment arm (PTMA) with respect to the tibio-femoral contact point. PCSA was calculated as the muscle volume, measured from serial MRI sections, divided by optimum fascicle length, measured from ultrasound images during MVC at the angle of peak quadriceps muscle force. Differences between groups were tested for with multiple analysis of variance.

## RESULTS AND DISCUSSION

The MVC joint moment in the men ( $272 \pm 80\text{Nm}$ ) was significantly greater than in women ( $177 \pm 60\text{Nm}$ ), who in turn produced significantly greater MVC joint moments than boys ( $78 \pm 17\text{Nm}$ ) and girls ( $91 \pm 28\text{Nm}$ ) ( $p<0.01$ , for all). The MVC joint moment was similar between boys and girls.

The calculated maximal quadriceps tendon force and PCSA of men was significantly greater than the women ( $p<0.01$ ), while that of both adult groups was greater than that of the children ( $p<0.01$ ). There was no difference between boys and girls (Table 1). The angle of pennation did not differ between the groups in any of the quadriceps heads. The specific tension was similar ( $p> 0.05$ ) between groups (Table 1).

The antagonist co-activation moment relative to the agonist MVC moment was similar in all groups (~6-9%), consequently, it explained very little of the inter-group differences in MVC joint moment. Agonist voluntary activation level was similar between men and women, but explained 7% and 31% of the difference in MVC joint moment between boys and men, and girls and women, respectively. The larger PTMA of men compared to women explained 20% of the MVC joint moment difference. The PTMA was larger in the adults than children and explained 17 and 16% of the difference between males and females, respectively. This means that in males 75% of the increased MVC joint moment with pubertal maturation is due to the increased PCSA. In females, the larger PCSA of women compared to girls explained only 50% of the increase. Whilst, of the inter-gender MVC joint moment difference in adults, 80% could be explained by differences in PCSA. The greater growth of PCSA in males compared to females is most likely due to the increased levels of testosterone in the males.

Table 1. Mean (SD) peak quadriceps tendon force ( $F_{\text{quad}}$ ), PCSA and specific tension (ST) of the entire quadriceps muscle.

Group	$F_{\text{quad}}$ (N)	PCSA ( $\text{cm}^2$ )	ST ( $\text{N}\cdot\text{cm}^{-2}$ )
Men	11439 (1938)	231.8 (56)	55 (11)
Women	8695 (2586)	162.8 (30)	57 (13)
Boys	5235 (1248)	105 (20)	54 (14)
Girls	6117 (1852)	108 (19)	60 (15)
	M>W,B, G	M>W, B, G	–
	W>B, G	W>B, G	

Significant differences between (M) men, (W) women, (B) boys and (G) girls,  $p<0.01$ .

## CONCLUSIONS

These findings challenge the view that intrinsic muscle strength changes with maturation and show that the differences in muscle strength between children and adults is not due to differences in “muscle quality” but due to inter-group differences in moment arm length, voluntary activation level and muscle size. Muscle models in musculoskeletal simulation applications should incorporate a common value of specific tension for adults and children.

## REFERENCES

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