Original article:

The influence of gender on force per square unit area in young Indian adults and its correlation with endurance and aerobic capacity

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Abstract:

Background: Gender, a social construct, cannot realistically affect muscular strength. But sex, a biological state, most certainly has an impact on a person's strength. Adult men, on average, tend to be 10 to 20 percent larger than women both in height, weight and muscle mass. Thus males are definitely having more muscular strength as compared to females. Does this mean that women's muscles are weaker or just that they are having less mass? To address this issue we started our study with the objective to compare maximum handgrip strength (F_{max}), handgrip endurance (HGE) and force per unit area in males and females. Also to find out its correlation with aerobic capacity (VO_2 max).

Method:90 male and 110 female subjects within age group of 19 to 21 were selected in the study. Those involved with regular exercises and with skeleton-muscular or other disorders were excluded. Forearm circumference and forearm skin-fold thickness was measured. Bone and fat free forearm muscle area (FAMA) was calculated. F_{max} and HGE was measured using handgrip dynamometer. F_{max} per unit muscle area was calculated. VO2 max was estimated using bicycle ergometry. Data was then compared and correlated using student's t-test and Pearson's correlation test.

Results: Males had significantly higher FAMA, F_{max}, HGE and F_{max} per unit muscle area($P<0.05$) as compared to females. Statistically non significant correlation was found between VO_2 max and HGE, $F_{max}$and FAMA in both genders. ($P>0.05$)

Discussion & conclusion: In the present study there is clear gender difference in skeletal muscle strength and endurance which is more in males. These differences are ascribed not only to the different body composition, but also to the different hormonal profile and some other factors like psychology and type of muscle fibres. Also our study indicates grip strength, endurance are unrelated to VO_2 max so Ergonomists should consider most important and appropriate design.

Keywords: Maximum handgrip strength (F_{max}), Handgrip endurance (HGE), force per unit area, Bone and fat free forearm muscle area (FAMA), Aerobic Capacity VO_2 max.

Introduction

In today's world we always consider male and female to be equal in performing various tasks and strength to do various jobs. But biologically there is vast difference in strength simply looking at their different body structure. Adult men, on an average; tends to be 10-20%, larger than adult women. [1] This size difference is apparent in height, weight and muscle

mass. Thus males are definitely having more strength as compared to females. Does this mean women's muscle are weaker or just that they are having less mass? To address this issue, we reviewed the literature. According to textbook of medical physiology by Guyton and Hall – most of the difference in total muscle performance lies in the extra percentage of male muscle, caused by endocrine difference. When measured in terms of strength per square cm of cross sectional area, the female muscle can achieve almost exactly the same maximal force of contraction as that of male.[2] This means that women muscle are structurally similar to men's muscle.

Muscle grow through biological processes involving protein synthesis. Although male and female both are capable of synthesizing protein, only men have naturally high amounts of testosterone. This extra amount of testosterone allows men to grow their muscle faster, leading to more muscle mass. [5] Also there are studies which suggest testosterone also affect the type of muscle fibre. Males have more of type 1 muscle fibre which are capable of producing more strength and endurance. [6] This seems contradictory to the statement of Guyton and Hall. This leads us to study the issue of influence of gender on muscle strength, endurance and force per square unit area and its co relation to aerobic capacity. Not only the difference in muscle strength but also aerobic capacity i.e.VO_2max is significantly more in males.

Material and Methods

The present study was conducted from October 2014 to December 2014 in the department of physiology B.J.Govt.MedicalCollege,Pune. A total of 200 students' of1st M.B.B.S in the age group of19-21 years were included.All the volunteers were briefed in detail about the objective as well as the protocol of the study. Then the written informed consent was obtained from all the participants. To avoid the confounder of dominance of handedness only right handed students were included. [7] Exclusion criteria were left handed students' diagnosed cases of skeletal muscle disorder, acute or chronic illness, diabetes mellitus and those involved with regular exercises or sports activity.Height was measured using the scale encrypted on the wall with the person asked to stand with feet touching the wall to the nearest cm.Weight was measured using Krupp's weighing machine to nearest kg.BMI was calculated using formula BMI=wt in kg/(ht in mt)^2

Then forearm circumference was measured using measuring tape 4 inches below the olecranon process.Forearm skin fold thickness was measured using skin calliper at same sight.Then the forearm muscle area (FAMA) was calculated using Heymsfield's formula. [8]

FAMA $= [\mathbf{FAC} - (\pi \times \boldsymbol{SFT})]^2/4\pi - 10$ **FOR MEN**

FAMA $= [\mathbf{FAC} - (\pi \times \boldsymbol{SFT})]^2/4\pi - 6.5$**FOR WOMEN**.

Then aerobic capacity(VO_2max)was measured using bicycle ergometer. Maximum handgrip strength measured using maximum handgrip dynamometer manufactured by INCO Ambala. First it was demonstrated to the participants then they were asked to hold the dynamometer in right hand in standing position arm close to the body. Then they asked to pull the handle as forcefully as possible. Three such attempts were made. Best of 3 was taken as final reading to nearest kg. This reading was labelled as Fmax. Then handgrip endurance was measured. For this 50% of Fmax was calculated. Volunteers were asked to hold the 50% of Fmax as

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long as possible. Three such trials were made. And best of 3 was chosen as handgrip endurance in seconds. Then force per square unit area was calculated using Fmax/FAMA.

All the data obtained from above methods was tabulated .Then mean andstandard deviation were calculated. Comparison was done with using student t test and co relation withVO_2 max was done using Pearson's correlation test.

Results

Table-1: showing comparison of various parameters in males and females.

s.no	Parameter	Male (n=)	Female (n=)	t value	Significance
1	Height in mt.	1.69±0.06	1.57±0.04	8.98	p<0.05 (s)
2	Weight in kg	56.63±10.04	48.70±6.50	3.72	p<0.05 (s)
3	BMI in kg/m^2	19.62±2.60	19.81±2.20	0.30	p>0.05(ns)
4	Forearm circumference in cm	25.11±2.36	22.94±1.57	4.45	p<0.05 (s)
5	Skin fold thickness in cm	0.44±0.11	0.54±0.16	2.87	p<0.05 (s)
6	Forearm muscle areain cm^2	35.45±8.30	29.62±5.67	3.26	p<0.05 (s)
7	F_{max} in kg	68.13±12.15	39.26±9.67	10.52	p<0.05 (s)
8	Force/square unit area in kg/cm^2	1.99±0.45	1.35±0.34	6.39	p<0.05 (s)
9	Endurance(50% of Fmax) in sec.	14.98±7.76	6.22±3.05	5.80	p<0.05 (s)
10	Vo_2 max (ml/kg/min)	41.9+ 1.6	35.8+ 1.2	2.33	p<0.05 (s)

TABLE 1 depicts male has significantly higher height and weight as compared to female, but BMI was found to be statistically non significant.Forearm circumference,forearm muscle area were significantly higher in male as compared to female. While skin fold thickness was significantly higher in females.Fmax –maximum strength in male was 68.13±12.15 and female it was 39.26±9.67 and differencewas found to be statisticallyhigher in male. Force/square unit area was 1.99±0.45 and 1.35±0.34in male and female respectively and differencewas found to be statistically higher in male as compared to female. Endurance(50% of vmax) was 14.98±7.76 and 6.22±3.0534 in male and female respectively and differencewas found to be statistically higher in male as compared to female.VO2 max in males was 41.9± 1.6while in females it was 35.8± 1.2.this difference was found to be significantly higher in males as compared to the female.

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Table no.2correlation of VO_2 max with F max ,Endurance, Force per square unit area

Parameter	Male	Female
Fmax	r =0.2337(NS)	r =0.2718(NS)
Endurance	r =0.2663(NS)	r =0.2047(NS)
Force /square unit area	r =0.2950(NS)	r =0.2821(NS)

As depicted in Table no.2 correlation of VO_2 max with F max , force per square unit area was found to be statistically nonsignificant.

Discussion

In the present study, we found that height, weight was significantly higher in male while BMI was statistically non-significant. This suggest in the present study, male and female body composition is approximately similar. This makes our study comparable.Forearm circumference was significantly higher in males, while skin fold thickness was significantly higher in females. This indicates that males have more muscle mass while females have more fat mass. Calculated fat and bone –free muscle area using Heymsfield's formula was significantly higher in males as compared to females. Similar findings were depicted by the studies done by Geer EB et al 2009 [9], Wirth A et al 1998 [10] and Blaak E 2001 [11]. The probable reason for this finding is the different hormonal profile. More testosterone in males leads to more lean body mass [3] while estrogen has effect on more fat deposition n females [4].

Fmax was significantly higher in males. Similar studies which depicts this finding are studies of Padmavathi R et al in 1999 and Barbat-Artigas S et al in 2013.The probable reason for this finding is more muscle mass in males as compared to females. This in turn is due to effect of testosterone.

Force per square unit area calculated was also significantly higher in males as compared to females. The findings depicted by guyton and hall [2] and Gonzales JU et al in 2005 [14] is in contradiction with the present result. The probable reason for this finding is that not only the more muscle mass in case of males is but there must be some other factors involved. These probablefactors are different hormonal profile, type of muscle fiber, different lifestyle,genetic and psychological factor.There are several studies which suggests that testosterone apart from increasing the muscle mass also affects the type of muscle fibers.Ricardo NoboroIsayama et al 2006 showed testosterone administration improved the type II muscle fibers in rats. [15] similar results were also obtained by Sinha-Hikim I et al 2002 [16] and Sinha-Hikim I et al 2006 [17].Thus it seems the difference in the muscle strength is not only due to muscle mass as believed earlier. But it is also due to other factors such asdifferent hormonal profile, type of muscle fiber.

Present study also showed forearm muscle endurance is more in males.Endurance is ability to resist fatigue. The study of Novak CM et al in 2009 and Baumgart C et al in 2014 depits the similar findings while study of Hick AL and Kent-Braun et al in 2001 suggested that females have greater resistance to fatigue than males. [18]The probable reason of gher endurance in males in the present study is more muscle mass as well as the type of muscle fiber in case of males.

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Summary & Conclusion

In the present study there is clear gender difference in skeletal muscle strength and endurance which is more in males. These differences are ascribed not only to the different body composition, but also to the different hormonal profile and some other factors like type of muscle fibres andpsychology.Further research is required to delineate these probable causes. Also our study indicates grip strength, endurance are unrelated to VO_2 max so Ergonomists should consider most important and appropriate design.

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