

Original Research Article

## Normative Data for Trunk and Lower Extremity Muscle Strength by Hand Held Dynamometer for Indian Children Aged 5-14 Years: A Cross Sectional Study

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### ABSTRACT

**Purpose:** The purpose of the study was to establish isometric muscle strength reference values for healthy 5 to 14 year old children for 2 trunk and 8 lower extremity muscles and to determine the effect of age, weight and height upon muscle strength.

**Method:** Baseline hand held dynamometer was used to obtain muscle strength values for 400 (200 boys and 200 girls) children.

**Results:** Age-referenced muscle strength values are provided for each muscle group. Muscle strength was constant till 8 years after that it increased up to 14 years with fluctuations between 11 to 13 years. Boys are found to be stronger than girls no significant differences were noted between both sides. Regression analysis shows age and weight have good effect on muscle strength than height.

**Conclusion:** This study provides hand held dynamometer strength reference values. These values can be employed in a clinical setting to document whether any child is impaired relative to healthy subjects of same gender and age.

**Keywords:** Child, Muscle strength, Hand held dynamometer, Normative data, Reference values, Factors affecting muscle strength.

### INTRODUCTION

Strength is defined as the ability to exert maximal voluntary force <sup>[1]</sup> and weakness is any impairment of this ability.

<sup>[2]</sup> Decrease in muscle strength can lead to

functional limitations in children.

<sup>[3]</sup> Assessment of muscle strength is important for Physiotherapist to understand the condition and to plan the management if there is any decrease in muscle strength.

Muscle strength can be evaluated and estimated using various methods, ranging from observation without equipment to laboratory examination with isokinetic instruments. [4, 5] In routine clinical practice, the most common method is Manual Muscle Testing (MMT). [6] However assigning MMT grades relies largely upon the examiners judgment of the amount of force generated by the subject and, therefore is subjective and prone to examiner bias [7, 8] and the sensitivity to detect changes in muscle strength with MMT is poor, especially in grades 3+ to 5. [9, 10]

In recent decade another instrument is more popularizing to compensate disadvantages of MMT and to give more accurate values for strength is Hand-held dynamometer (HHD). It is a portable, standardized, reliable, sensitive, valid yet practical method to obtain quantitative measurement of muscle strength for children. [11, 12, 13, 14] HHD provides a measurement of isometric contraction, two types of measurement techniques are described i.e. the make test and break test. [15]

The make test is characterized by the examiner holding the dynamometer in a stationary positing with the subject pushing against the dynamometer. During the break test, the examiner pushes the dynamometer against subject's limb until the subjects maximal effort is over come and the joint gives away. [16] The make test has been shown to have higher reliability than the break test. [17] Although an isokinetic dynamometer has the advantage of being able to accurately measure muscle force continuously throughout the range of motion, the length of time needed to perform the testing procedures, and the high cost and decreased portability of the unit usually preclude its use in pediatric settings. [18] To identify if muscle weakness is present in a child, reference values in typically

developing children are needed. Several studies have given isometric muscle strength reference values with HHD for normal children age 3.5 years to 16 years. [3, 16, 19, 20]

Even though they have done on large sample size the number of children however, in each age group was relatively small (9 to 23 children) except in study. But which has take only 3 age groups that is 6, 7, 8 years. Although trunk muscle strength is very important for function, in all these studies upper and lower limb muscles only tested and all the studies are done on western population. In children strength has association with age, gender, height and weight but it is unclear that which of these factors has greatest effect on muscle strength. [19, 20, 21, 22, 23]

Only a few studies have provided reference values for children's muscle strength obtained by hand-held dynamometry. Such values are essential for establishing the degree to which an individual strength is impaired. The aim of the current study was to establish normative data for isometric muscle strength in trunk flexors, trunk extensors, hip flexors, hip extensors, hip adductors, hip abductors, knee flexors, knee extensors, ankle plantar flexors and ankle dorsiflexors of both right and left sides for Indian children age 5 to 14 years and to study the effect of age, height, weight on strength.

## **METHODOLOGY**

### **Subjects**

Subjects included are 400 children (boys 200 girls 200) who were healthy and developing typically aged 5 to 14 years, recruited from public and private schools. Children were divided into 10 groups according to their age. The division was 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 years. 40 children were included in each group (boys 20 girls 20). Number of males and females in each group with their mean weight and

height  $\pm$ SD are presented in table-1. In this cross sectional study children were selected by using multi stage sampling. Duration of the study was 1 year 6 months and tester was qualified Physiotherapist who has 5-6 years of experience using HHD.

### Inclusion and Exclusion criteria

Children with 5-14 years of age with unrestricted ranges of motions in all joints were included. Children with H/O any Neurological, Musculoskeletal, Cardiovascular and/or systemic problems, H/O recent injury to spine and limbs, recent

H/O surgery and medication which affect muscle strength were excluded.

### Instrumentation

A Baseline Hydraulic Digital Push Pull Hand Held Dynamometer (Fig-1) was used to record force in pounds (Lbs). The dynamometer can measure both traction and compression with maximum force of about 250lb and a precision of 1lb. the dynamometer was calibrated with known weights before and after the study. Other equipments like weighting machine, measuring tape, couch, stabilization straps and sponge pad were used.



Fig 1: Baseline push-pull digital hand-held dynamometer



Fig 2: Trunk flexors testing

### PROCEDURE

Permission from block education officer was taken and list of schools were collected. From the list of schools 6 schools were selected by random sampling using random number table. Permission was taken from the school authorities to carry out the study. The classes where the target population is located were identified. Children were selected by random sampling using lottery method and initial screening for the inclusion and the exclusion criteria were done. Health questionnaire along with consent and assent form was given to the children for the approval of their parents the selected children were explained in brief

regarding the study. After the children given assent and parents consent the whole test procedure and the purpose of the study was elaborately explained to the children.

The documentation of age was done from school records, the weight in kilograms by weighing machine, height in centimeters by calibrated height scale. Strength measurements were taken by Hand Held dynamometer for trunk flexors and extensors, lower limb hip flexors, extensors, abductions, adductors, knee flexors, knee extensors, ankle dorsiflexors and ankle plantar flexors. Detailed explanations of muscles to be tested, subject's position, examiners position with stabilization and

placement of dynamometer which are taken from previous literature [3, 16, 24, 25, 26, 27] with some minor modifications are given in table-2.

Test started in sitting position and child was familiarized with the procedure and practice. This was followed by testing in supine and prone position. Make test technique was used where resistance is gradually built up for about 5 seconds. 3 attempts were made for each muscle group best response out of 3 was taken in to consideration. Time for rest was given between trials and we varied between measurements of right leg and left leg to avoid fatigue. Encouragement to maximum effort was given. HHD was placed distally at the segment tested at a place where a strong pressure on the skin did not hurt and prevent a maximal contraction and which was comfortable for the subject. Only for knee extensors we used extra sponge pad.

### Data analysis

Muscle strength normative data for ten muscle groups of all ages both boys and girls was calculated by using descriptive statistics and effect of height, weight and age on muscle strength and was calculated by using regression analysis. P Value <0.05 was taken as significant and SPSS.13 was used for analysis.

### RESULTS

Height, weight of 10 groups of children was described in table -1. The height, weight data of these children is comparable with normative data of Indian children. [28]

It shows that as the age is increasing height and weight are increasing up to 14 years except between 6-7 years. Where weight was constant and shows no much difference.

Trunk flexors and extensors muscle strength values were described for 10 groups of children in Table-3. It shows as the age

increasing trunk flexors and extensors muscle strength was fluctuating and more or less same till 8 years but after that it was increasing up to 14 years.

Hip, knee and ankle muscle strength for both right side and left side were described in table - 4, 5, 6 and graphs 1 to 8. As the age increasing all the muscle group strength values of both right side and left side was fluctuating and more or less remain constant up to 8 years but after that there is increase up to 14 years except ages between 11, 12, 13 where values were fluctuating and more or less same or sometimes decreasing.

In all the muscle groups there is no significant difference between right side and left side values (Graph 1-8). In all most all the muscle groups males are more stronger than females in all the age groups (Graph 1-8).

Regression analysis was done to establish the best predictors of muscle strength among the age, height and weight. Results of regression analysis in the form of unstandardized coefficient, standardized coefficient, t value, p value, r value,  $r^2$  values for all the muscle groups were shown in table-7 and 8. Regression analysis shows over all age and weight as the best set of independent predictors of the muscle strength not the height.

### DISCUSSION

This study provides normative data for maximal isometric muscle strength measured by HHD in trunk and lower extremity muscle groups of normal children age 5 to 14 years. The normative data in table - 3, 4, 5 and 6 are not only ones available to the therapist who is seeking normative value against which to compare a patient performance. [3, 16, 19, 20, 23] But the values in this article, however, are derived from a larger sample and of different varieties of muscle groups than previous studies.

None of the previous researcher's data on children's muscle strength could be matched with the other researcher's data exactly. Even our study values could not be exactly matched with any of the previous ones but it is similar to Nystrom Eek M data. [16]

As it is proven that muscle strength is correlated to age, gender, height, weight and physical activity [3, 20, 29] etc, this variability in strength values from researchers to researcher may be due to variations in the population tested and the variations in their anthropometric measures and environmental factors, and it is proven that Indian children anthropometry is entirely different compared to western population. [30, 31, 32]

In our study we saw that muscle strength was not increased significantly up to 8 years but after wards there is a significant increments up to 14 years except between 11, 12 and 13. This may be due to retarded growth patterns in younger children of our population up to 8 years compared to westerners. [33] As the age of puberty in our population is 10 to 12 years, [33] puberty related hormonal changes attributed directly to anthropometric fluctuations and indirectly to muscle strength differences between 11 to 14 years of age.

Boys are stronger than girls this may be attributed to their anatomical structural built and growth patterns which are better than girls. There is no significant differences in strengths between both the sides because dominance may have more effect on upper extremity than the lower extremity. The major functions of lower extremity like walking, running, jumping, climbing and transfers etc are almost symmetrical compared to upper extremity functions. This may be the explanations for symmetry in the strength values. Like other researchers in our study also we found that age and weight

are the best set of independent predictors of the muscle strengths. [16, 19, 34]

One crucial requirement when testing the torque with an HHD is that the tester has to be stronger than the patient. [35] Otherwise one is not measuring the maximum force of the patient but of the examiner. In our study it was not a problem because the maximum force the child could exert in any muscle group was not beyond 40lbs which is well tolerable by our examiners strength.

Even though physical activity of child and torque measurements is important considerations for muscle strength because of unexpected errors during information collection we could not pool the data for these parameters.

Muscle strength can vary between the positions. Although we had followed standard positions future researchers can think of proposing muscle strength measurements in different positions of limbs and at different ranges of joint movement. They can also compare these isometric HHD data to isokinetic data and see which can be more accurate to follow.

## CONCLUSION

This study provides muscle strength values for trunk flexors, extensors and 8 lower extremity muscle groups measured by hand held dynamometer for children who are healthy and typically developing aged 5 to 14 years to enable the clinicians to judge whether clients of same age, height and weight produce muscle strength values that fall within the provided reference ranges. These values can be used to identify muscle weakness that may contribute to functional limitations in children and to monitor changes in strength in this population. Age and weight are the best predictors of strength than height.

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**TABLES**

**Table – 1; Demographic characteristics of 10 groups of children**

	G	No	5yrs	6yrs	7yrs	8yrs	9yrs	10yrs	11yrs	12yrs	13yrs	14yrs
			M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD
H E I G H T	M	20	108.10± 4.34	112.45± 6.93	115.35 ± 5.63	119.25 ± 5.27	126.45 ± 5.19	129.35 ± 6.17	137.00 ± 5.39	138.30 ± 6.55	152.25 ± 10.23	147.15 ± 3.61
	F	20	106.05 ± 3.62	112.55 ± 5.10	114.60 ± 6.58	121.10 ± 6.98	123.95 ± 4.41	128.25 ± 7.92	137.30 ± 5.06	142.45 ± 4.21	145.50 ± 6.61	146.95 ± 6.36
	C	40	107.10 ± 4.08	112.50 ± 6.01	114.98 ± 6.05	120.18 ± 6.17	125.20 ± 4.92	128.80 ± 7.03	137.15 ± 5.16	140.38 ± 5.83	148.88 ± 9.16	147.05 ± 5.10
W E I G H T	M	20	16.95± 2.25	18.30± 2.77	19.55± 2.68	20.40 ± 2.89	24.15 ± 3.63	27.70 ± 3.43	30.55 ± 5.68	30.20 ± 5.13	40.60 ± 7.45	41.75± 5.88
	F	20	15.35± 2.92	20.85± 3.89	19.20 ± 2.68	21.80 ± 4.52	21.70 ± 2.40	27.20 ± 6.12	30.85 ± 5.57	35.90 ± 5.31	38.80 ± 5.87	45.50± 4.61
	C	40	16.15± 2.70	19.58± 3.58	19.38 ± 2.65	21.10 ± 3.81	22.93 ± 3.28	27.45 ± 4.90	30.70 ± 5.56	33.05 ± 5.90	39.70 ± 6.68	43.63± 5.55

Note:- G-Gender; No- Number; M-Mean; SD- Standard Deviation; MA-Male; F- Female; C-Combined



**Table – 2; Subject position, examiners position with stabilization and resistance placement for 10 groups of muscles**

<b>Muscle Group</b>	<b>Subject Position</b>	<b>Examiner's position and stabilization</b>	<b>Resistance</b>
<b>Hip Flexors</b>	Sitting, hips and knees flexed at 90°	Front of the subject	Anterior thigh just proximal to femoral condyles and knee
<b>Hip Extensor</b>	Prone, knee flexed to 45°	To the side of the subject; stabilizes the pelvis	Posterior thigh just proximal to femoral condyles
<b>Hip Abductors</b>	Supine Hip and knee extended	To the side of the subject; stabilizes the pelvis	Lateral femoral condyle
<b>Hip Adductors</b>	Supine Hip and knee extended Non tested knee flexed	To the side of the subject; stabilizes the pelvis	Medial femoral condyle
<b>Knee Flexors</b>	Sitting Hip and knee flexed 90°	Front of the subject stabilizes the thigh	Posterior surface of leg just proximal to malleoli
<b>Knee Extensor</b>	Sitting Hip and knee flexed to 90°	Front of the subject stabilizes the thigh	Anterior surface of leg just proximal to malleoli
<b>Ankle Dorsi Flexors</b>	Hip and knee extended and ankle neutral	To the side of the subject; stabilizes the leg	Dorsum of the foot
<b>Ankle Plantar Flexors</b>	Sitting knee extended	Front of the subject stabilizes the leg	Metatarsal head
<b>Trunk Flexors (Fig-2)</b>	Supine lying with hands placed behind head and neck	To the side of the subject; hip and knee joints stabilized with straps	Just below the sternomanubrialsymp hysis.
<b>Trunk extensors</b>	Prone lying position with hands placed behind head and neck	To the side of the subject; hip and knee joints stabilized with straps	Posteriorly at the T4 spinous process level.

**Table – 3; Trunk Flexors (TF) and Trunk Extensors (TE) muscle strength values for 10 groups of children**

Muscle groups	G	N	5yrs	6yrs	7yrs	8yrs	9yrs	10yrs	11yrs	12yrs	13yrs	14yrs	
			M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	
TF	M	20	10.25 ± 1.74	10.30 ± 2.36	10.20 ± 2.39	11.35 ± 2.54	15.60 ± 3.93	16.90 ± 3.38	17.85 ± 6.06	18.50 ± 4.32	22.70 ± 4.36	23.20 ± 4.52	
			F	20	8.85 ± 1.95	10.10 ± 2.78	9.30 ± 2.95	9.50 ± 2.56	12.65 ± 2.18	15.15 ± 2.15	17.30 ± 6.39	18.65 ± 3.96	20.45 ± 2.68
	C	40			9.55 ± 1.96	10.20 ± 2.55	9.75 ± 2.69	10.43 ± 2.68	14.13 ± 3.48	16.03 ± 2.93	17.58 ± 6.15	18.58 ± 4.09	21.58 ± 3.75
			TE	M	20	10.60 ± 1.66	10.95 ± 2.01	10.40 ± 3.13	12.35 ± 1.63	16.30 ± 3.37	18.70 ± 2.63	18.74 ± 4.54	22.30 ± 4.02
	F	20				9.35 ± 1.92	11.55 ± 2.03	10.50 ± 2.16	9.90 ± 2.17	13.65 ± 2.43	16.05 ± 2.54	18.75 ± 4.38	19.80 ± 5.01
				C	40	9.98 ± 1.88	11.25 ± 2.02	10.45 ± 2.66	11.13 ± 2.26	14.98 ± 3.19	17.38 ± 2.88	18.74 ± 4.40	21.05 ± 4.66

Note:- G-Gender; No- Number; M-Mean; SD- Standard Deviation; MA-Male; F- Female; C-Combined

**Table – 4; Hip muscle strength values for 10 groups of children**

Muscle Groups	G	No	5yrs	6yrs	7yrs	8yrs	9yrs	10yrs	11yrs	12yrs	13yrs	14yrs
			M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD	M±SD
Hip Flexors Right	M	20	13.30± 2.05	12.00± 1.68	13.20± 3.36	12.70± 3.08	17.25± 3.74	20.00± 3.65	22.00± 3.65	22.35± 3.08	21.85± 2.85	26.15± 3.40
	F		9.25± 2.63	11.55± 2.30	12.05± 2.74	11.65± 3.28	15.75± 2.97	19.50± 3.84	21.60± 3.45	23.25± 5.23	19.75± 2.14	24.85± 3.28
	C		11.28± 3.10	11.78± 2.00	12.63± 3.08	12.18± 3.18	16.50± 3.41	19.75± 3.71	21.80± 3.51	22.80± 4.26	20.80± 2.71	25.50± 3.36
Hip Flexors Left	M	20	12.30± 1.65	12.00± 2.07	13.35± 3.26	13.05± 3.13	16.75± 3.89	19.05± 3.13	21.50± 3.34	20.90± 3.49	23.80± 5.04	25.50± 3.59
	F		9.10± 2.22	11.60± 2.47	11.65± 3.32	11.70± 3.19	14.75± 2.42	19.15± 3.84	21.70± 3.23	24.30± 5.63	20.75± 1.91	24.55± 3.50
	C		10.70± 2.52	11.80± 2.26	12.50± 3.36	12.38± 3.20	15.75± 3.35	19.10± 3.46	21.60± 3.24	22.60± 4.94	22.28± 4.07	25.03± 3.53
Hip Extensors Right	M	20	10.10± 1.55	10.70± 2.34	12.85± 3.15	12.40± 2.56	16.10± 3.33	18.05± 2.80	21.50± 3.81	21.20± 4.02	20.70± 2.36	29.70± 4.95
	F		8.50± 2.37	10.50± 2.74	11.15± 3.32	10.55± 3.34	13.90± 3.79	17.15± 2.83	21.35± 3.28	20.60± 5.52	19.35± 1.92	24.60± 4.00
	C		9.30± 2.13	10.60± 2.52	12.00± 3.31	11.48± 3.08	15.00± 3.70	17.60± 2.81	21.43± 3.51	20.90± 4.78	20.03± 2.23	27.15± 5.14
Hip Extensors Left	M	20	9.20± 1.93	10.20± 2.60	12.60± 3.45	12.50± 2.64	16.85± 4.01	18.35± 3.82	21.45± 4.48	22.20± 4.03	19.75± 1.99	26.90± 4.11
	F		8.50± 2.28	9.65± 2.72	11.25± 3.72	10.80± 3.98	13.15± 3.68	16.75± 3.11	20.80± 3.45	19.70± 3.92	20.40± 1.60	24.45± 3.80
	C		8.85± 2.11	9.93± 2.64	11.93± 3.61	11.65± 3.44	15.00± 4.24	17.55± 3.53	21.13± 3.96	20.95± 4.12	20.08± 1.81	25.68± 4.10
Hip Abductor s Right	M	20	12.40± 1.93	11.85± 2.23	12.85± 3.01	12.80± 2.19	17.00± 4.11	19.50± 2.72	22.40± 4.18	21.35± 5.00	22.40± 4.38	23.85± 3.45
	F		10.75± 1.74	11.45± 2.58	12.15± 3.21	11.60± 1.87	13.90± 3.14	18.05± 3.76	22.20± 3.94	23.15± 5.62	21.70± 5.94	24.00± 3.90
	C		11.58± 1.99	11.65± 2.39	12.50± 3.09	12.20± 2.10	15.45± 3.94	18.78± 3.32	22.30± 4.01	22.25± 5.33	22.05± 5.16	23.93± 3.64
Hip Abductor s Left	M	20	13.35± 2.25	12.05± 1.98	12.65± 2.43	12.90± 2.26	17.00± 4.16	19.00± 2.12	23.10± 4.02	19.70± 5.39	20.65± 2.96	25.60± 3.66
	F		9.85± 1.87	12.10± 2.51	12.30± 3.40	11.00± 2.15	14.30± 3.21	17.80± 2.84	21.85± 3.96	24.10± 6.72	21.25± 3.86	24.30± 4.45
	C		11.60± 2.70	12.08± 2.23	12.48± 2.92	11.95± 2.38	15.65± 3.91	18.40± 2.55	22.48± 3.99	21.90± 6.41	20.95± 3.41	24.95± 4.07
Hip Adductor s Right	M	20	12.40± 1.63	11.75± 2.71	12.50± 2.83	13.15± 2.60	17.20± 6.73	20.30± 4.30	22.75± 6.28	22.05± 6.27	21.65± 2.56	23.10± 3.74
	F		9.15± 2.56	11.40± 2.28	11.90± 3.59	11.50± 2.98	14.05± 2.52	18.60± 5.09	21.95± 4.07	22.05± 3.42	20.80± 1.64	25.10± 4.40
	C		10.78± 2.68	11.58± 2.48	12.20± 3.21	12.33± 2.88	15.63± 5.26	19.45± 4.73	22.35± 5.24	22.05± 4.99	21.23± 2.16	24.10± 4.15
Hip Adductor s Left	M	20	11.85± 1.49	11.70± 2.67	12.85± 3.06	12.85± 2.13	18.25± 5.63	20.80± 4.17	24.05± 6.05	22.55± 5.89	19.75± 2.95	23.40± 5.06
	F		9.50± 2.09	10.85± 2.83	11.80± 3.77	11.30± 2.71	14.80± 3.87	20.15± 5.97	22.70± 3.89	22.65± 4.25	23.65± 3.89	25.05± 4.07
	C		10.68± 2.15	11.28± 2.75	12.33± 3.43	12.08± 2.53	16.53± 5.08	20.48± 5.09	23.38± 5.07	22.60± 5.07	21.70± 3.94	24.23± 4.61

Note:- G-Gender; No- Number; M-Mean; SD- Standard Deviation; MA-Male; F- Female; C-Combined

**Table – 5; Knee muscle strength values for 10 groups of children**

	G	No	5yrs	6yrs	7yrs	8yrs	9yrs	10yrs	11yrs	12yrs	13yrs	14yrs
			M± SD	M± SD	M± SD	M± SD	M± SD	M± SD	M± SD	M± SD	M± SD	M± SD
Knee Flexors Right	M	20	14.2	12.3	13.3	12.8	16.6	18.3	23.7	22.0	22.0	26.8
	A		5± 3.76	0± 2.29	0± 2.83	0± 2.28	5± 2.92	0± 3.93	0± 5.35	5± 4.21	5± 2.85	5± 6.46
	F		9.25 ± 2.35	11.5 0± 2.18	10.8 5± 3.39	10.1 5± 3.01	14.4 5± 3.60	18.0 0± 3.35	21.1 5± 3.24	20.6 0± 4.18	20.4 0± 2.06	24.7 0± 5.31
C	40	11.7 5± 4.00	11.9 0± 2.25	12.0 8± 3.32	11.4 8± 2.96	15.5 5± 3.42	18.1 5± 3.61	22.4 3± 4.55	21.3 3± 4.20	21.2 3± 2.59	25.7 8± 5.94	
Knee Flexors Left	M	20	13.4	12.8	13.3	12.7	17.4	18.8	23.9	20.8	21.7	26.8
	A		0± 3.23	0± 2.39	0± 3.43	5± 2.44	0± 2.66	0± 3.51	0± 5.00	5± 4.54	5± 3.16	0± 4.91
	F		9.65 ± 1.75	10.9 0± 2.24	10.5 0± 3.38	10.0 5± 3.42	14.5 0± 2.16	17.8 5± 3.43	22.2 0± 2.85	20.2 5± 2.24	20.9 0± 1.94	24.1 5± 4.88
C	40	11.5 3± 3.19	11.8 5± 2.48	11.9 0± 3.65	11.4 0± 3.24	15.9 5± 2.81	18.3 3± 3.46	23.0 5± 4.11	20.5 5± 3.55	21.3 3± 2.62	25.4 8± 5.01	
Knee Extensors Right	M	20	14.3	13.7	13.9	13.9	19.5	22.2	26.9	28.8	28.8	31.8
	A		5± 2.79	0± 2.45	0± 2.97	5± 1.87	0± 5.94	0± 6.57	0± 7.19	5± 7.23	5± 6.27	0± 2.76
	F		9.70 ± 2.34	12.0 5± 2.80	12.3 0± 2.97	10.6 5± 2.68	17.7 0± 4.83	23.1 5± 5.95	28.5 5± 4.71	24.7 0± 5.42	27.5 5± 3.39	29.2 0± 5.04
C	40	12.0 3± 3.46	12.8 8± 2.72	13.1 0± 3.04	12.3 0± 2.83	18.6 0± 5.42	22.6 8± 6.20	27.7 3± 6.06	26.7 8± 6.65	28.2 0± 5.02	30.5 0± 4.22	
Knee Extensors Left	M	20	13.8	13.4	13.7	13.3	19.2	21.5	27.7	28.5	28.7	29.5
	A		5± 2.72	0± 2.25	5± 2.91	0± 2.53	5± 5.75	5± 6.91	0± 6.39	5± 6.88	5± 6.71	5± 3.22
	F		9.60 ± 2.58	12.2 0± 3.33	12.5 0± 3.30	10.6 0± 2.39	17.0 5± 4.19	22.5 0± 6.00	28.2 0± 4.85	25.7 0± 6.75	27.3 0± 3.98	28.0 0± 4.36
C	40	11.7 3± 3.38	12.8 0± 2.87	13.1 3± 3.13	11.9 5± 2.79	18.1 5± 5.09	22.0 3± 6.41	27.9 5± 5.60	27.1 3± 6.88	28.0 3± 5.50	28.7 8± 3.86	

Note:- G-Gender; No- Number; M-Mean; SD- Standard Deviation; MA-Male; F- Female; C-Combined

**Table – 6; Ankle muscle strength values for 10 groups of children**

	G	No	5yrs	6yrs	7yrs	8yrs	9yrs	10yrs	11yrs	12yrs	13yrs	14yrs
			M± SD	M± SD	M± SD	M± SD	M± SD	M± SD	M± SD	M± SD	M± SD	M± SD
Plantar Flexors Right	M	20	11.7	10.9	11.6	11.5	14.4	19.3	22.9	21.9	18.0	23.9
	A		0±	0±	0±	5±	5±	0±	0±	5±	0±	0±
			2.34	3.00	2.83	2.48	5.33	5.10	5.99	5.53	2.05	2.88
Plantar Flexors Left	F	20	9.85	10.5	10.0	9.10	15.4	18.6	21.5	23.6	22.7	21.7
			±	0±	0±	±	0±	5±	0±	5±	0±	5±
			1.81	1.90	2.65	2.24	4.91	5.25	3.05	5.10	3.64	2.38
Plantar Flexors Right	C	40	10.7	10.7	10.8	10.3	14.9	18.9	22.2	22.8	20.3	22.8
			8±	0±	0±	3±	3±	8±	0±	0±	5±	3±
			2.27	2.49	2.83	2.64	5.08	5.12	4.74	5.32	3.76	2.82
Plantar Flexors Left	M	20	11.4	10.1	11.5	11.0	14.2	18.8	23.2	21.4	18.8	23.2
	A		0±	0±	0±	5±	5±	0±	5±	5±	0±	0±
			2.18	2.53	3.41	2.83	5.41	4.92	6.63	5.77	2.09	2.28
Plantar Flexors Left	F	20	9.05	10.3	10.0	8.85	14.3	18.3	22.1	23.0	22.6	22.0
			±	0±	5±	±	5±	0±	0±	5±	0±	0±
			2.01	2.61	3.06	2.30	4.72	5.52	3.21	5.72	3.99	2.29
Plantar Flexors Left	C	40	10.2	10.2	10.7	9.95	14.3	18.5	22.6	22.2	20.7	22.6
			3±	0±	8±	±	0±	5±	8±	5±	0±	0±
			2.39	2.54	3.28	2.78	5.01	5.17	5.17	5.73	3.68	2.34
Dorsi Flexors Right	M	20	10.2	9.70	10.2	10.8	12.6	16.9	18.2	17.8	16.1	20.6
	A		0±	±	0±	0±	0±	0±	5±	5±	0±	0±
			1.88	2.47	2.62	2.64	4.79	3.24	3.66	3.48	2.61	2.90
Dorsi Flexors Right	F	20	8.95	9.65	9.15	8.85	12.4	15.1	18.9	16.5	18.7	19.6
			±	±	±	±	5±	5±	0±	0±	0±	5±
			1.87	1.92	3.16	2.45	3.70	2.94	2.40	4.53	3.68	2.36
Dorsi Flexors Right	C	40	9.58	9.68	9.68	9.83	12.5	16.0	18.5	17.1	17.4	20.1
			±	±	±	±	3±	3±	8±	8±	0±	3±
			1.96	2.18	2.92	2.70	4.23	3.18	3.07	4.05	3.41	2.66
Dorsi Flexors Left	M	20	9.75	9.35	10.4	10.7	12.5	17.7	18.4	17.5	16.2	20.4
	A		±	±	5±	5±	5±	5±	0±	5±	5±	5±
			1.80	2.83	2.48	2.46	5.41	4.20	3.57	3.44	1.88	2.72
Dorsi Flexors Left	F	20	8.75	9.60	9.15	8.45	12.7	15.5	18.7	17.8	18.1	19.7
			±	±	±	±	0±	0±	0±	0±	5±	5±
			2.09	2.18	3.03	2.21	4.11	2.74	2.36	5.98	2.88	2.07
Dorsi Flexors Left	C	40	9.25	9.48	9.80	9.60	12.6	16.6	18.5	17.6	17.2	20.1
			±	±	±	±	3±	3±	5±	8±	0±	0±
			1.99	2.50	2.81	2.59	4.74	3.68	2.99	4.82	2.59	2.41

Note:- G-Gender; No- Number; M-Mean; SD- Standard Deviation; MA-Male; F- Female; C- Combined



**Table –7; Regression analysis of Trunk, Hip muscle strength by age, height,weight by age-by-height-by-weight interaction.**

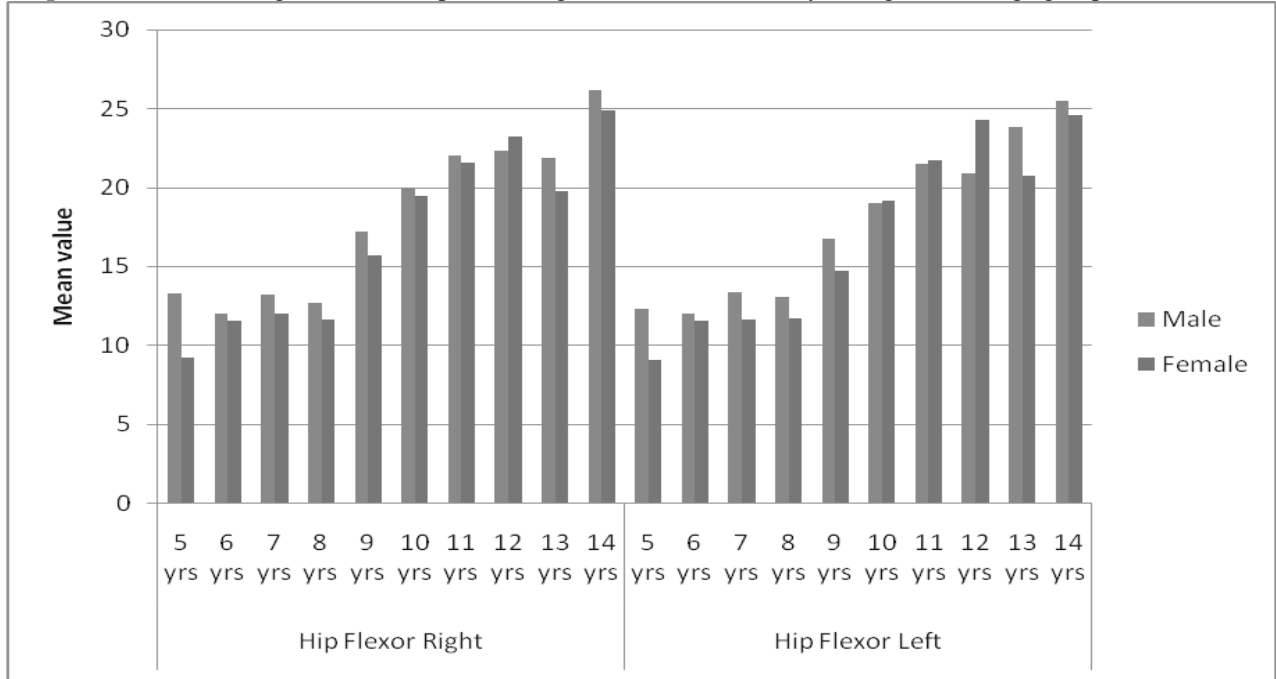
Muscle group	Model	Un standardized Coefficients		Standardized Coefficients	t value	p value	R value	R Square value
		B	Std. Error	Beta				
Trunk Flexor	(Constant)	.099	2.820		-.035	.972	.799	.693
	Age(months)	.095	.014	.531	6.859	<0.001**		
	Height (cm)	-.012	.034	-.031	-.365	.715		
	Weight(kg)	.200	.042	.324	4.717	<0.001**		
Trunk Extensors	(Constant)	-8.402	2.699		-3.113	.002**	.817	.667
	Age(months)	.078	.013	.436	5.850	<0.001**		
	Height (cm)	.097	.032	.243	3.020	.003**		
	Weight(kg)	.102	.041	.166	2.513	.012*		
Hip Flexors Right	(Constant)	-4.021	2.662		-1.510	.132	.814	.662
	Age(months)	.092	.013	.524	7.002	<0.001**		
	Height (cm)	.063	.032	.159	1.968	.050		
	Weight(kg)	.094	.040	.155	2.344	.020*		
Hip Flexors Left	(Constant)	-5.656	2.647		-2.137	.033*	.826	.683
	Age(months)	.084	.013	.466	6.421	<0.001**		
	Height (cm)	.075	.032	.187	2.376	.018*		
	Weight(kg)	.125	.040	.203	3.156	.002*		
Hip Extensors Right	(Constant)	-3.350	2.826		-1.185	.237	.824	.678
	Age(months)	.129	.014	.680	9.308	<0.001**		
	Height (cm)	.019	.034	.043	.550	.583		
	Weight(kg)	.076	.042	.116	1.796	.073		
Hip Extensors Left	(Constant)	-4.547	2.770		-1.641	.102	.823	.677
	Age(months)	.136	.014	.732	9.992	<0.001**		
	Height (cm)	.033	.033	.078	.988	.324		
	Weight(kg)	.014	.042	.022	.343	.731		
Hip Abductors Right	(Constant)	-.543	2.912		-.187	.852	.779	.607
	Age(months)	.097	.014	.544	6.740	<0.001**		
	Height (cm)	.023	.035	.057	.658	.511		
	Weight(kg)	.123	.044	.201	2.813	.005**		
Hip Abductors Left	(Constant)	.336	2.915		.115	.908	.778	.606
	Age(months)	.087	.014	.491	6.070	<0.001**		
	Height (cm)	.015	.035	.038	.431	.666		
	Weight(kg)	.168	.044	.276	3.845	<0.001**		
Hip Adductors Right	(Constant)	-5.071	3.093		-1.640	.102	.768	.590
	Age(months)	.075	.015	.406	4.916	<0.001**		
	Height (cm)	.076	.037	.184	2.056	.040*		
	Weight(kg)	.131	.046	.206	2.821	.005**		
Hip Adductors Left	(Constant)	-6.268	3.340		-1.876	.061	.755	.571
	Age(months)	.095	.016	.489	5.789	<0.001**		
	Height (cm)	.083	.040	.190	2.085	.038*		
	Weight(kg)	.065	.050	.098	1.304	.193		

**Table – 8; Regression analysis of Knee, Ankle muscle strength by age, height, weight by age-by-height-by-weight interaction.**

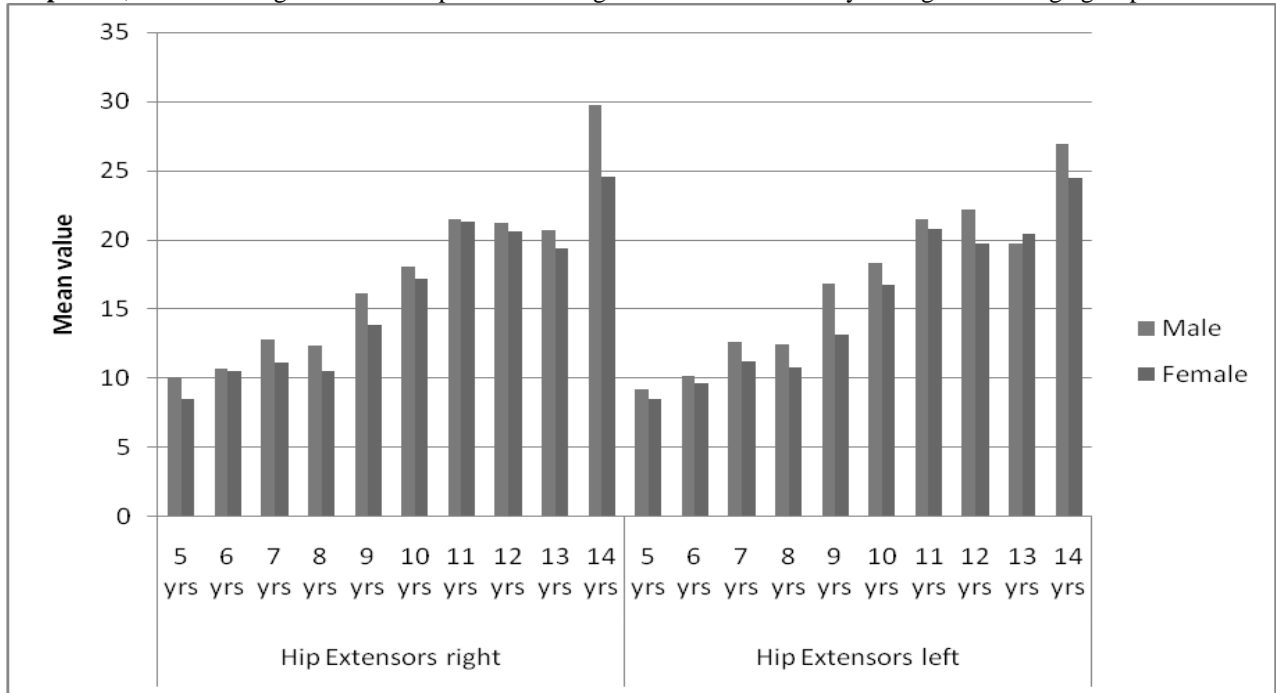
Muscle group	Model	Un standardized Coefficients		Standardized Coefficients	t value	p value	R value	R Square value
		B	Std. Error	Beta				
Knee Flexors Right	(Constant)	-3.935	3.058		-1.287	.199	.775	.600
	Age(months)	.087	.015	.471	5.779	<0.001**		
	Height (cm)	.058	.037	.140	1.586	.114		
	Weight(kg)	.121	.190	.190	2.632	.009**		
Knee Flexors Left	(Constant)	-4.101	2.865		-1.431	.153	.793	.628
	Age(months)	.089	.014	.497	6.326	<0.001**		
	Height (cm)	.060	.034	.149	1.753	.080		
	Weight(kg)	.106	.043	.172	2.476	.014*		
Knee Extensors Right	(Constant)	-21.748	3.745		-5.808	<0.001**	.822	.676
	Age(months)	.089	.018	.354	4.827	<0.001**		
	Height (cm)	.232	.045	.411	5.183	<0.001**		
	Weight(kg)	.070	.056	.081	1.240	.216		
Knee Extensors Left	(Constant)	-23.868	3.773		-6.326	<0.001**	.814	.663
	Age(months)	.073	.019	.296	3.960	<0.001**		
	Height (cm)	.262	.045	.471	5.823	<0.001**		
	Weight(kg)	.060	.057	.070	1.055	.292		
Plantar Flexors Right	(Constant)	-7.419	3.292..		-2.254	.025*	.750	.562
	Age(months)	.091	.016	.479	5.619	<0.001**		
	Height (cm)	.091	.039	.213	2.307	.022*		
	Weight(kg)	.051	.049	.079	1.042	.298		
Plantar Flexors Left	(Constant)	-8.751	3.376		-2.592	.010**	.753	.567
	Age(months)	.090	.017	.460	5.424	<0.001**		
	Height (cm)	.098	.040	.223	2.425	.016*		
	Weight(kg)	.062	.051	.092	1.223	.222		
Dorsi Flexors Right	(Constant)	.300	2.566		.117	.907	.750	.563
	Age(months)	.090	.013	.6057	7.096	<0.001**		
	Height (cm)	.010	.031	.029	.310	.757		
	Weight(kg)	.068	.039	.133	1.765	.078		
Dorsi Flexors Left	(Constant)	-2.921	2.680		-1.098	.273	.749	.561
	Age(months)	.075	.013	.488	5.706	<0.001**		
	Height (cm)	.046	.032	.135	1.459	.145		
	Weight(kg)	.079	.040	.150	1.980	.048*		

## GRAPHS

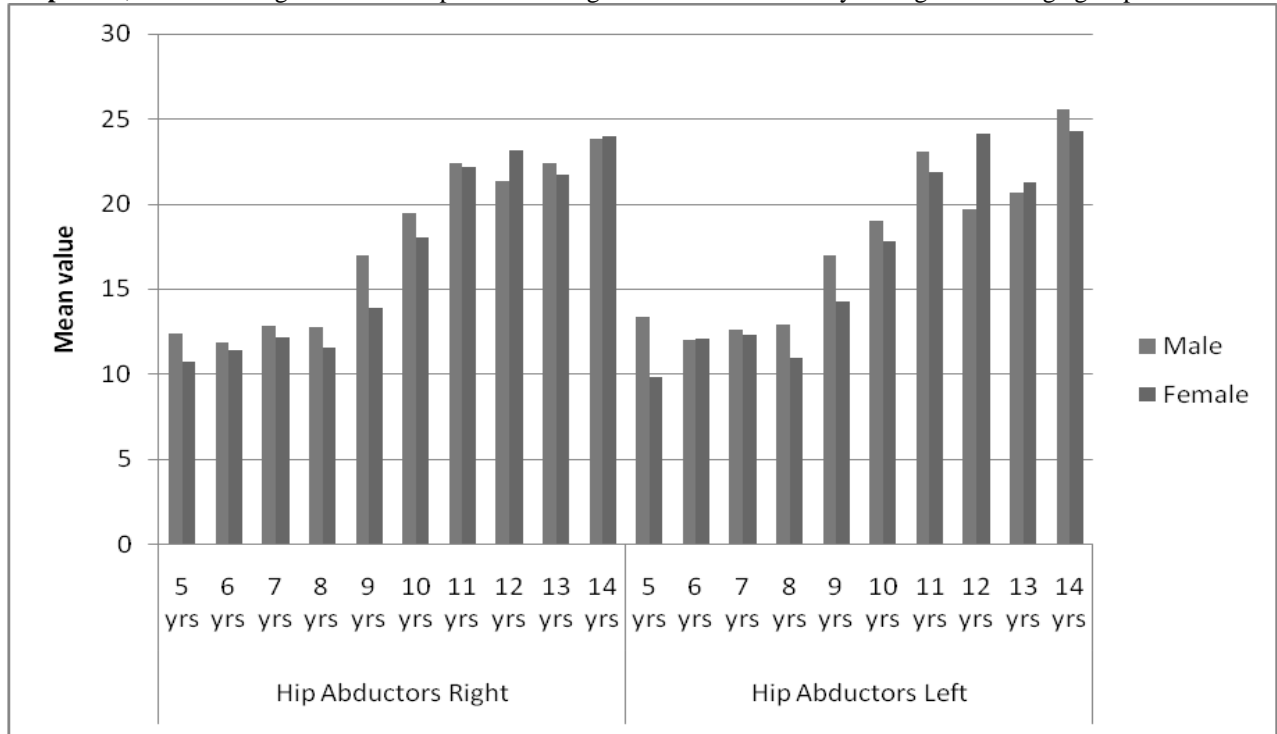
**Graph – 1 ;** Muscle strength values of hip flexors right and left sides for boys and girls of 10 age groups



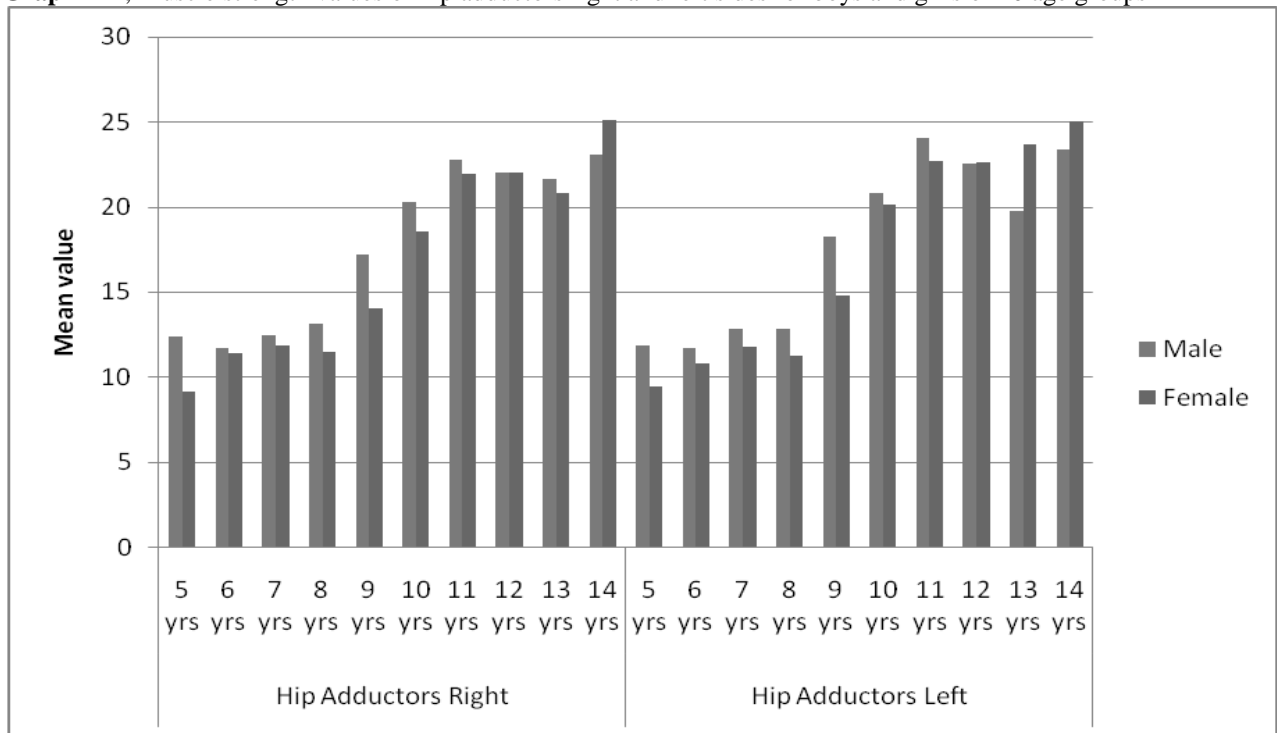
**Graph – 2 ;** Muscle strength values of hip extensors right and left sides for boys and girls of 10 age groups



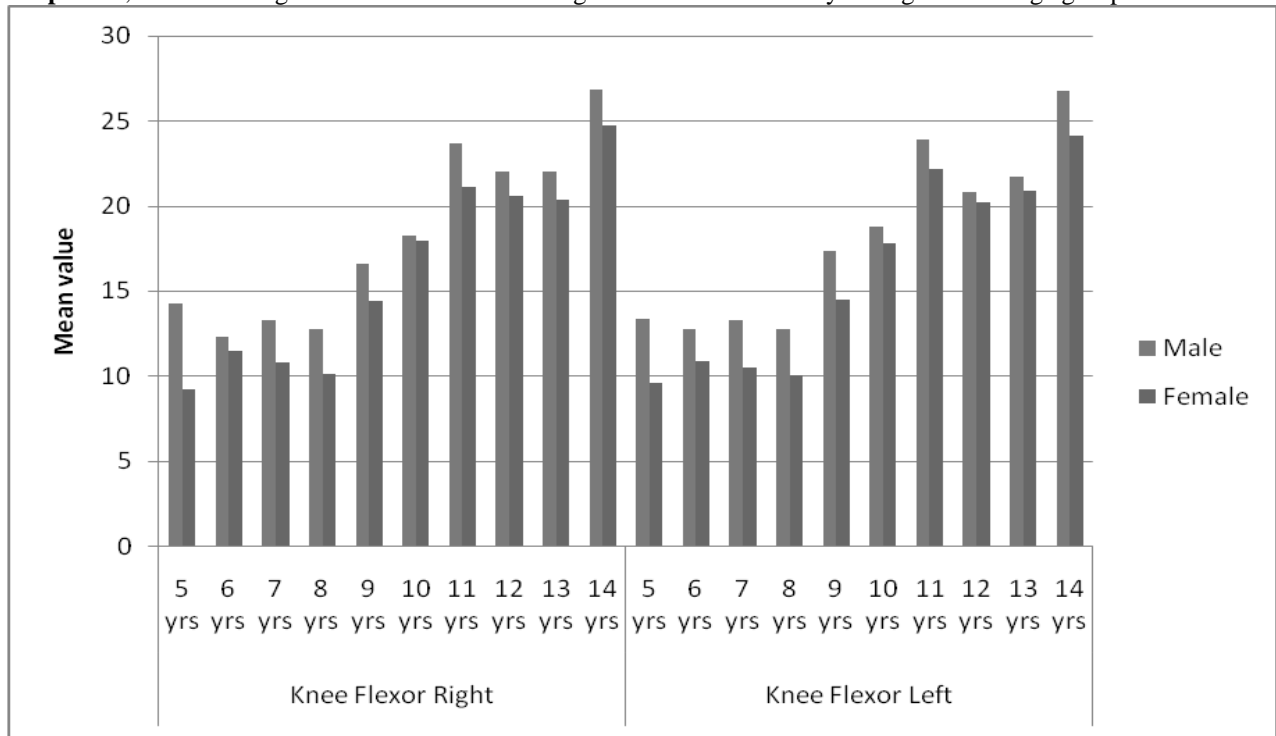
**Graph – 3 ;** Muscle strength values of hip abductors right and left sides for boys and girls of 10 age groups



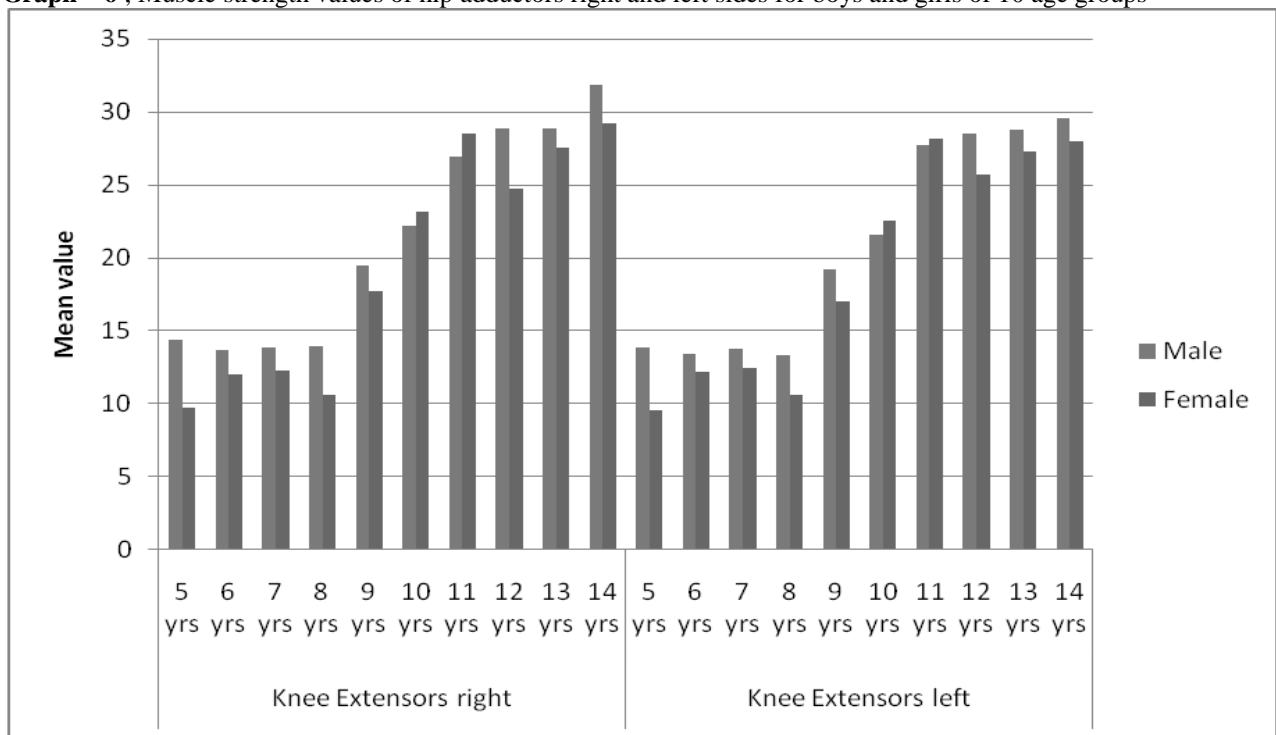
**Graph – 4 ;** Muscle strength values of hip adductors right and left sides for boys and girls of 10 age groups



**Graph – 5 ;** Muscle strength values of knee flexors right and left sides for boys and girls of 10 age groups

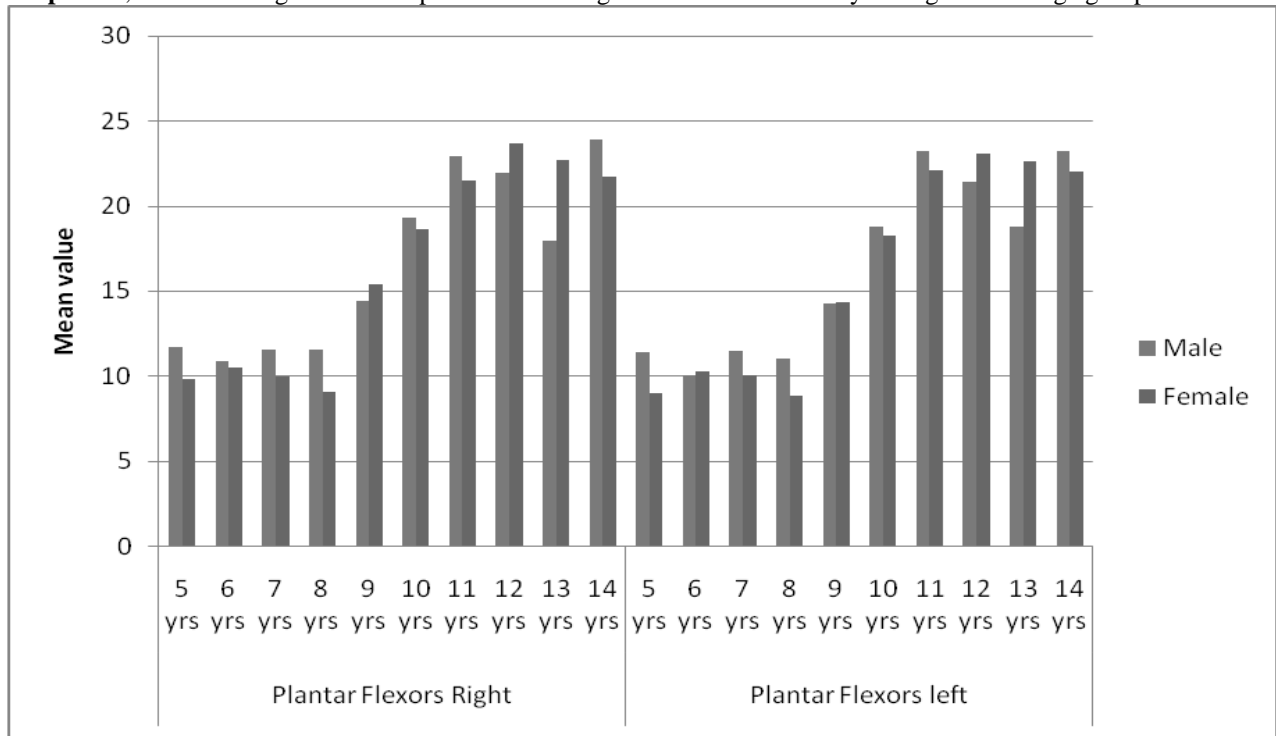


**Graph – 6 ;** Muscle strength values of hip adductors right and left sides for boys and girls of 10 age groups

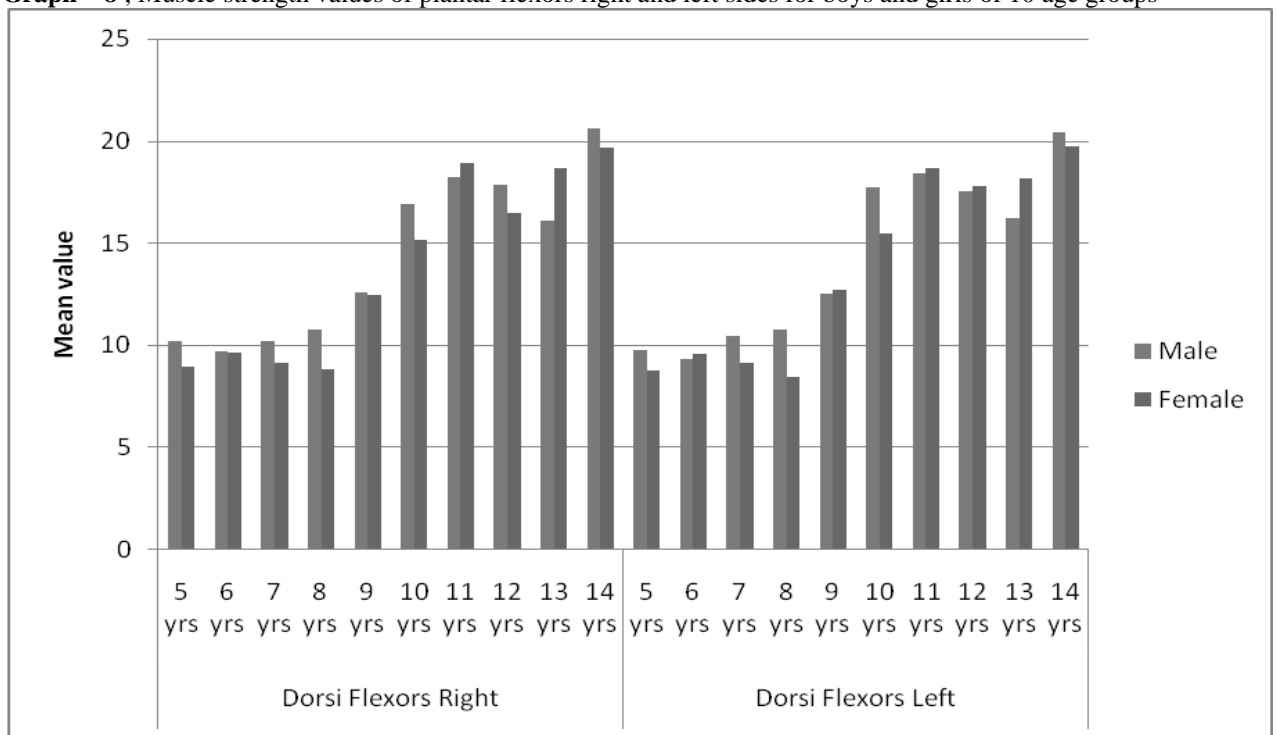




**Graph – 7 ; Muscle strength values of plantar flexors right and left sides for boys and girls of 10 age groups**



**Graph – 8 ; Muscle strength values of plantar flexors right and left sides for boys and girls of 10 age groups**



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