Original Article

Hand Grip Strength in Relation to Anthropometric Measures of School Children: A Cross Sectional Study

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Abstract

Background and Purpose: Grip strength is a good predictor of hand functions; it is an important part of hand assessment for proper hand function and integrity of muscles. It is not clear whether a relationship exists between hand grip strength and anthropometric measures of the upper limb from childhood period to adolescence period. The aim of this study was to evaluate the correlation between hand grip strength and some upper limb anthropometric measures and to detect the difference between boys and girls for all measured parameters in different school grades. **Design:** Cross Sectional study. **Participants:** Seven hundred and fifty seven healthy children of both sexes with age range between 7 to 18 years. **Methods:** Hand grip strength was assessed by hydraulic hand held dynamometer and it was correlated to some anthropometric measures including (Height, whole arm length, upper arm length, forearm length, Hand width (cm), weight (kg), percentile body mass index (PBMI), and hand grip strength for both dominant and non-dominant hands for each child in each grade separately. **Results:** A strong positive relationship between hand grip strength and anthropometric measures in primary grades was detected with a weak positive relationship in preparatory and secondary grades. Multiple regression analysis revealed that age, sex, weight and height were predictors of grip strength in both hands. **Conclusion:** It was concluded that hand grip strength had a significant relationship with some anthropometric measures of upper limb in Egyptian school children in different grades.

Keywords: Grip strength; Children; Adolescence; Weight; Height; Anthropometric measures

Introduction

Hand grip strength is a physiological variable that is affected by several factors including age, gender, and body size. [1] The power of grip is the result of forceful flexion of all fingers joints with a maximal voluntary force that the subject is able to exert under normal biokinetic conditions, as it is directly affected by the muscular, skeletal and neural systems. [2] Measurement of the hand grip was convenient mean to evaluate forearm and hand functions. In addition, grip strength has been used as a predictor of etiological factors of mortality and disability in many patients. Hand grip assessment can be used in the evaluation of patients with a large range of pathologies that impair the upper extremities. [3-5] Grip strength also has an important role in determining treatment efficacy, such as in the evaluation of different wrist orthoses, the effect of hand exercises in rheumatoid arthritis and recovery after trauma; also, it is used in evaluation after many different surgical procedures. [6]

Hand anthropometric measurements include structural and functional components, structural anthropometry includes lengths, breadth, and circumference of the hand, palm and fingers while, functional anthropometry includes measurements taken while the hand is in motion or engaged in physical activity e.g. grip reach, elbow grip length. [7] Anthropometric data are needed to determine whether or not a device or tool can be designed to accommodate most of the population. It is also used to ensure that an item fits a specific group of people. [8] Finally; the scope of this study was to determine whether there is a relationship between some anthropometric measures of upper limb and hand grip strength in school children at different grades.

Methods

Study design and participants

The current cross section study was conducted after its approval by the local ethical committee of the Faculty of Physical Therapy, Cairo University, Following the Education Ministry official rules and after gaining the agreements of the schools managers and explaining to them the aim and procedures of the study. Seven hundred and fifty seven healthy children of both sexes with age ranged from 7-18 years were selected from different schools' grades. Based on age factor, each child was enrolled into one of three categories (Primary stage: 7 to 12 years with total number of 298 child, preparatory stage: with age range between 13 to 15 years included 225 child and secondary stage with age range from 16 to 18 years with total number of 234 child.

Based on gender; children in each stage were re-classified into boys and girls as follows; primary stage included 150 boy and 148 girl with percentage of 50.3% and 49.7 % respectively,

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while children in the preparatory stage were 109 boy and 116 girl with percentage of 48.4% and 51.6% respectively and finally children in the secondary stage were 114 boy and 120 girl with percentage of 48.7% and 51.3% respectively).

Participants were selected from different schools in Shoubra, District (Egypt) based on certain inclusion criteria including; free history of injury or fracture of upper limbs, practicing normal ADL activities. Children with clinical evidence of debilitating diseases and those practicing competitive sport, or those with any neuromuscular disorders or system pathology that affects grip strength, inability to use hand held dynamometer and children with previous hand surgery were excluded from this study.

Procedures

Anthropometric measurements

The first step after recording the age and gender of each child was detecting body weight (Kilograms) and height (Meters) which was detected by using the calibrated weight and height scale. Dividing body weight by the square of body height was then done for calculating the Percentile body mass index. Anthropometric measures (cm) including 1- upper arm length (measured from acromion process to the tip of the olecranon process) 2- forearm length (from the head of radius to the lateral styloid process), 3- whole arm length: measured from acromion process at tip of the shoulder to the tip of middle finger and 4- Hand width: measures at base of the first metacarpal bones of the thumb.

Hand grip strength measurements

Hand grip strength was measured for each hand by Hydraulic Hand Held Dynamometer by asking the child to assume sitting position with shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral position, wrist between 0 and 30° extension and between 0 and 15° ulnar deviation [9], then each Participant was asked to squeeze with maximal force on the dynamometer. Repeating each trail three times and the highest value of three trials was recorded.

Data analysis

• Mean and standard deviation (SD) were calculated for all the parameters.

• Independent T-Test was used for the comparison of hand grip strength between boys and girls in both dominant and non-dominant hands.

• Finally, linear correlation was determined in each educational stage for hand grip strength and anthropometric measures (height, weight, PBMI). Multiple regression analysis was used to evaluate all anthropometric measures factors that might affect grip strength. The least significant variables were discarded stepwise, while strongly inter-correlated variables were excluded. Significance was set at $p<0.05$ for all comparisons using SPSS 20 for Windows (IBM SPSS Inc.).

Results

Mean values of age, weight, height, percentile body mass index, whole arm length, upper arm length, forearm length, hands width and hand grip strength for both dominant and non-dominant hands for each child in primary, preparatory and secondary stages are illustrated in Table 1. Statistical analysis of mean values of weight variable in primary and secondary stage showed a statistical significant difference as their mean values were (40.87 ± 15.56,) (36.86 ± 11.69) and (70.78 ± 13.14, 63.30 ± 8.31) for boys and girls respectively in both stages, with no statistical significant difference was found in preparatory stage with mean values of (61.18 ± 13.93) for boys and (60.21 ± 14.48) for girls. Regarding height, a significant difference between boys and girls in primary stage as their mean values were (131.44 ± 16.12, 127.45 ± 13.53) respectively, for preparatory stage it was (163.62 ± 9.53) for boys and (160.00 ± 9.36) for girls, and for secondary stage mean values were (172.51 ± 7.16, 162.48 ± 4.79) for boys and girls respectively.

For percentile body mass index, results showed no statistical significant difference between boys and girls in primary and

Table 1: Characteristics of study participants.

	Primary grades			Preparatory grades			Secondary grades		
	Boys Mean ± SD	Girls Mean ± SD	P value 95% CI	Boys Mean ± SD	Girls Mean ± SD	P value 95% CI	Boys Mean ± SD	Girls Mean ± SD	P value 95% CI
Age, y	9.57 ± 1.08	9.35 ± 1.73	0.293/-0.18,0.62	14.00 ± 0.77	13.99 ± 0.82	0.935/-0.20,0.21	17.04 ± 0.82	16.95 ± 0.79	0.419/-0.12,0.29
Weight, Kg	40.87 ± 15.56	36.86 ± 11.69	0.012*/0.87,7.14	61.18 ± 13.93	60.21 ± 14.48	0.609/-2.76,4.70	70.78 ± 13.14	63.30 ± 8.31	0.001*/4.62,10.33
Height, Cm	131.44 ± 16.12	127.45 ± 13.53	0.021*/0.60,7.38	163.62 ± 9.53	160.00 ± 9.36	0.004*/1.13,6.09	172.51 ± 7.16	162.48 ± 4.79	0.001*/8.44,11.61
PBMI, Kg/cm^2	85.45 ± 20.77	82.39 ± 23.72	0.237/-2.01,8.14	73.22 ± 24.26	77.69 ± 23.56	0.163/-10.74,1.82	68.45 ± 22.51	74.19 ± 19.19	0.037*/-11.1,-0.35
DUAL, Cm	26.31 ± 2.80	25.80 ± 2.63	0.107/-0.11,1.12	32.36 ± 2.86	30.72 ± 2.53	0.001*/0.93,2.35	34.56 ± 2.02	32.50 ± 2.09	0.001*/1.53,2.59
DFL, Cm	22.32 ± 2.54	21.59 ± 2.56	0.015*/0.14,1.30	27.23 ± 2.83	25.51 ± 2.20	0.001*/1.05,2.39	28.45 ± 1.91	27.20 ± 1.72	0.001*/0.77,1.71
DWAL, cm	59.88 ± 5.99	58.82 ± 5.91	0.127/-0.30,2.41	74.04 ± 6.78	69.79 ± 4.59	0.001*/2.71,5.77	78.08 ± 5.562	73.66 ± 4.60	0.001*/3.10,5.74
DHW, Cm	17.14 ± 1.25	16.88 ± 1.58	0.115/-0.06,0.58	20.06 ± 1.54	19.10 ± 1.21	0.001*/0.59,1.32	21.41 ± 1.54	19.93 ± 1.36	0.001*/1.11,1.86
NDUAL, Cm	26.21 ± 2.87	25.72 ± 2.88	0.138/-0.16,1.15	32.38 ± 2.83	30.74 ± 2.52	0.001*/0.93,2.33	34.77 ± 2.22	32.50 ± 2.09	0.001*/1.71,2.82

NDFL, Cm	22.29 ± 2.53	1.38 ± 2.704	0.003*/0.31,1.51	27.24 ± 2.80	25.28 ± 2.20	0.001*/1.09,2.42	28.10 ± 1.53	27.20 ± 1.71	0.001*/0.47,1.31
NDWAL, Cm	59.74 ± 6.08	58.66 ± 6.02	0.125/-0.30,2.45	73.94 ± 6.83	69.82 ± 4.60	0.001*/2.58,5.66	77.96 ± 5.43	73.65 ± 4.61	0.001*/3.00,5.60
NDHW	17.09 ± 1.29	16.88 ± 1.57	0.200/-0.11,0.54	20.09 ± 1.52	19.12 ± 1.21	0.001*/0.61,1.33	21.28 ± 1.48	19.93 ± 1.35	0.001*/0.98,1.71
DGS	10.96 ± 4.67	8.82 ± 3.59	0.001*/1.19,3.09	23.97 ± 8.21	16.99 ± 5.91	0.001*/5.11,8.85	33.99 ± 9.09	23.47 ± 6.78	0.001*/8.46,12.58
NDGS	9.39 ± 4.63	7.52 ± 3.72	0.001*/0.90,2.82	22.02 ± 7.62	16.20 ± 8.48	0.001*/3.69,7.94	32.16 ± 9.29	21.71 ± 6.79	0.001*/8.35,12.53

SD.: Standard Deviation, PBMI: Percentile Body Mass Index, DUAL: Dominant Upper Arm Length, DFL: Dominant Forearm Length, DWAL: Dominant Whole Arm Length, DHW: Dominant Hand Width, NDUAL: Non-Dominant Upper Arm Length, NDFL: Non-Dominant Forearm Length, Ndwal: Non- Dominant Whole Arm Length, NDHW: Non-Dominant Hand Width, DGS: Dominant Grip Strength, NDGS: Non-Dominant Grip Strength.

preparatory stages with mean values of (85.45 ± 20.77, 82.39 ± 23.72) for the primary stage and (73.22 ± 24.26, 77.69 ± 23.56) for the preparatory stage respectively, with a significant difference was recorded in secondary stage as mean values were (68.45 ± 22.51, and 74.19 ± 19.19) respectively, (P<0.05).

Statistical insignificant differences for upper arm length, whole arm length and hand width between boys and girls in primary stage were recorded for dominant hand as the mean values were (26.31 ± 2.80,25.80 ± 2.63) for upper arm length, it was (59.88 ± 5.99,58.82 ± 5.91), for whole arm length and it was (17.14 ± 1.25,16.88 ± 1.58) for hand width. While for non-dominant hand they were (26.21 ± 2.87 ± 25.72 ± 2.88) for upper arm length, (59.74 ± 6.08, 58.66 ± 6.02) for whole arm length and it was (17.09 ± 1.29, 16.88 ± 1.57) for hand width. Statistical significant difference was found in preparatory stage (32.36 ± 2.86) for boys and (30.72 ± 2.53) for girls for upper arm length, while (74.04 ± 6.78) for boys and (69.79 ± 4.59) for girls regarding to whole arm length and (20.06 ± 1.54, 19.10 ± 1.21) for boys and girls respectively for hand width, In secondary stage; it was (34.56 ± 2.02) for boys and (32.50 ± 2.09) for girls for upper arm length, while (78.08 ± 5.562) for boys and (73.66 ± 4.60) for girls for whole arm length and (21.41 ± 1.54, 19.93 ± 1.36) for both boys and girls respectively for hand width regarding to dominant hand. For non-dominant hand statistical significant difference was recorded in preparatory stage as (32.38 ± 2.83) for boys and (30.74 ± 2.52) for girls for upper arm length, (73.94 ± 6.83) for boys and (69.82 ± 4.60) for girls for whole arm length and (20.09 ± 1.52, 19.12 ± 1.21) for boys and girls respectively for hand width, while (34.77 ± 2.22) for boys and (32.50 ± 2.09) for girls for upper arm length, (77.96 ± 5.43) for boys and (73.65 ± 4.61) for girls for whole arm length and (21.28 ± 1.48, 19.93 ± 1.35) for boys and girls respectively for hand width.

Statistical significant difference was found for forearm length between boys and girls in primary, preparatory and secondary stages as their mean values were (22.32 ± 2.547, 21.59 ± 2.566) (27.23 ± 2.83, 25.51 ± 2.20) (28.45 ± 1.91, 27.20 ± 1.72) respectively for dominant hand and (22.29 ± 2.53, 21.38 ± 2.704) (27.24 ± 2.80, 25.28 ± 2.20) (28.10 ± 1.53, 27.20 ± 1.71) respectively for non-dominant hand. In addition, statistical significant difference was recorded in hand grip strength between boys and girls in primary, preparatory and secondary stages as their mean values were (10.95 ± 4.67, 8.81 ± 3.58) (23.97 ± 8.21, 16.99 ± 5.91) (33.99 ± 9.09, 23.47 ± 6.78) respectively for dominant hand and (9.39 ± 4.63, 7.52 ± 3.72) (22.02 ± 7.62, 16.20 ± 8.48) (32.16 ± 9.29, 21.71 ± 6.79) respectively for non-dominant hand.

Tables 2, 3 and 4, show a strong positive correlation between hand grip strength for both hands and the tested anthropometric measures excepted for PBMI was weak positive in primary grades. Weak positive association for all anthropometric measures except weak negative for PBMI in preparatory and secondary grades was observed. In order to establish the association between anthropometric measures with hand grip strength. We performed multi-level analysis adding them as a fixed factor as shown in Table 5. As shown in Table 6 the model can predict that for every year increase in age, the increase in dominant and non-dominant hand grip strength in primary stage was 1.388 and 1.412 kg respectively, and 3.378 and 2.397 kg respectively in preparatory stage and 1.734 kg increase in secondary stage for dominant hand. Reduction in dominant hand grip strength in primary, preparatory and secondary stages by -1.626, -6.139 and -4.816 kg were recorded in females, respectively, while it was reduced by -1.308, -4.965 and -4.835 kg respectively in non-dominant hand grip strength. However, for every kilogram increase in weight, there was an increase in dominant and non-dominant hand grip strength in primary stage by 0.054 and 0.063 kg, respectively. While for every centimeter increase in height, there was an increase in dominant hand grip strength in preparatory and secondary stages by 0.227 and 0.231 kg, respectively, and 0.554 and 0.559 kg respectively for non-dominant hand grip strength.

Discussion

Hands are continuously used in everyday activities such as writing, eating, handling and manipulating objects, gripping and many other activities. The characteristic structure of the hand is related to its function as a grasping tool. Grasping ability is made possible by the fact that the thumb can be opposed to the fingers. The fingers and the thumb act as a versatile pair of pliers. They need the palm of the hand as a flat base, on which the object grasped can be held. [10] The results of the current study showed an increase in hand grip strength with age for both genders in both dominant and non-dominant hands which may be attributed to the increase in the concentration of both muscle fiber composition, adenosine triphosphate (ATP) and phosphocreatine muscle concentration. In addition, the observed increase in hand grip strength with age is largely dependent on the parallel increase in muscle mass. [11] Results also revealed that boys have powerful hand grip strength than girls and is returned to the lower total muscle mass in girls

Table 2: Correlation between anthropometry and grip strength in dominant and non-dominant side in primary grades.

	DHGS	Age	Sex	Wt.	Ht.	PBMI	DUAL	DFL	DWAL	DHW
DHGS	1									
Age	0.702	1								
Sex	-0.25	-0.061	1							
Wt.	0.594	0.688	-0.145	1						
Ht.	0.574	0.685	0.133	0.688	1					
PBMI	0.079	0.186	-0.069	0.074	0.034	1				
DUAL	0.52	0.75	-0.094	0.531	0.595	0.101	1			
DFL	0.501	0.701	-0.141	0.518	0.601	0.086	0.865	1		
DWAL	0.575	0.819	-0.089	0.581	0.637	0.103	0.876	0.869	1	
DHW	0.365	0.572	-0.092	0.363	0.443	0.165	0.66	0.603	0.638	1
	NDHGS	**Age**	**Sex**	**Wt.**	**Ht.**	**PBMI**	**NDUAL**	**NDFL**	**NDWAL**	**NDHW**
DHGS	1									
Age	0.73	1								
Sex	-0.217	-0.061	1							
Wt.	0.625	0.688	-0.145	1						
Ht.	0.582	0.685	-0.133	0.688	1					
PBMI	0.112	-0.186	-0.069	0.074	0.034	1				
NDUAL	0.555	0.763	-0.086	0.531	0.593	0.111	1			
NDFL	0.551	0.744	-0.172	0.534	0.623	0.11	0.868	1		
NDWAL	0.596	0.838	-0.089	0.591	0.645	0.11	0.873	0.874	1	
NDHW	0.401	0.587	-0.075	0.371	0.451	0.15	0.641	0.606	0.632	1

Table 3: Correlation between Anthropometry and Grip Strength in Dominant and non-dominant side in preparatory grades.

	DHGS	Age	Sex	Wt.	Ht.	PBMI	DUAL	DFL	DWAL	DHW
DHGS	1									
Age	0.446	1								
Sex	-0.442	-0.005	1							
Wt.	0.215	0.2	-0.034	1						
Ht.	0.478	0.385	0.189	0.432	1					
PBMI	-0.122	-0.11	-0.093	0.069	-0.049	1				
DUAL	0.312	0.243	-0.292	0.008	0.211	-0.031	1			
DFL	0.312	0.239	-0.323	0.046	0.212	-0.021	0.818	1		
DWAL	0.307	0.316	-0.347	0.003	0.202	-0.084	0.825	0.829	1	
DHW	0.245	0.149	-0.33	0.059	0.15	-0.014	0.677	0.627	0.652	1
	NDHGS	**Age**	**Sex**	**Wt.**	**Ht.**	**PBMI**	**NDUAL**	**NDFL**	**NDWAL**	**NDHW**
DHGS	1									
Age	0.323	1								
Sex	-0.34	-0.005	1							
Wt.	0.172	0.2	-0.034	1						
Ht.	0.399	0.385	-0.189	0.432	1					
PBMI	-0.102	-0.11	0.093	0.069	-0.049	1				
NDUAL	0.172	0.235	-0.293	0.008	0.206	-0.032	1			
NDFL	0.192	0.244	-0.331	0.047	0.222	-0.018	0.821	1		
NDWAL	0.19	0.321	-0.337	0.001	0.211	-0.078	0.834	0.832	1	
NDHW	0.089	0.134	-0.334	0.046	0.151	-0.021	0.677	0.629	0.659	1

Table 4: Correlation between Anthropometry and Grip Strength in Dominant and non-dominant side in secondary grades.

	DHGS	Age	Sex	Wt.	Ht.	PBMI	DUAL	DFL	DWAL	DHW
DHGS	1									
Age	0.242	1								
Sex	-0.552	-0.053	1							
Wt.	0.407	0.109	-0.325	1						
Ht.	0.644	0.183	-0.639	0.604	1					
PBMI	-0.101	-0.176	0.137	0.243	-0.149	1				
DUAL	0.312	0.203	-0.449	0.201	0.398	-0.148	1			
DFL	0.284	0.138	-0.325	0.137	0.303	-0.118	0.655	1		
DWAL	0.365	0.243	-0.399	0.189	0.395	-0.206	0.751	0.693	1	
DHW	0.286	0.162	-0.457	0.135	0.336	-0.015	0.612	0.492	0.448	1
	NDHGS	**Age**	**Sex**	**Wt.**	**Ht.**	**PBMI**	**NDUAL**	**NDFL**	**NDWAL**	**NDHW**
DHGS	1									

Age	0.179	1								
Sex	-0.543	-0.053	1							
Wt.	0.327	0.109	-0.325	1						
Ht.	0.617	0.183	-0.639	0.604	1					
PBMI	-0.142	-0.176	0.137	0.243	-0.149	1				
NDUAL	0.299	0.244	-0.467	0.201	0.421	-0.172	1			
NDFL	0.199	0.029	-0.266	0.124	0.255	-0.098	0.619	1		
NDWAL	0.321	0.234	-0.395	0.188	0.408	-0.211	0.772	0.647	1	
NDHW	0.217	0.11	-0.43	0.116	0.316	-0.023	0.557	0.492	0.404	1

Table 5: Multivariate analysis of grip strength data.

Source	Sum of Squares	df	Mean Squares	F-value	P-Value
Dominant hand grip strength					
Primary grades					
Regression	3024.82	3	1008.275	120.59	0.0001*
Residual	2458.09	294	8.361		
Total	5482.92	297			
Preparatory grades					
Regression	6374.55	3	2124.85	61.21	0.0001*
Residual	7670.82	221	34.71		
Total	14045.38	224			
Secondary grades					
Regression	9959.97	3	3319.99	67.46	0.0001*
Residual	11318.73	230	49.212		
Total	21278.70	233			
Non-Dominant hand grip strength					
Primary grades					
Regression	3201.14	3	1067.04	137.36	0.0001*
Residual	2283.79	294	7.76		
Total	5484.94	297			
Preparatory grades					
Regression	4497.83	3	1499.27	27.73	0.0001*
Residual	11945.22	221	54.05		
Total	16443.06	224			
Secondary grades					
Regression	9045.64	2	4522.82	83.008	0.0001*
Residual	12586.33	231	54.48		
Total	21631.97	233			

DF. : Degrees of freedom

Table 6: Predictor variables of grip strength in dominant and non-dominant sides in different school grades.

	Estimate	SE	t-value	p-value	95% CI	
					Lower	Upper
Dominant grip strength						
***Primary grades**						
Constant	-4.52	0.957	- 4.730	0.000	-6.41	-2.64
Age	1.38	0.131	10.59	0.000	1.13	1.64
Sex	-1.62	0.339	-4.79	0.000	-2.29	-0.95
Weight	.054	0.017	3.21	0.001	0.02	0.08
***Preparatory grades**						
Constant	-60.37	8.28	-7.28	0.000	-76.70	-44.05
Age	3.37	0.53	6.26	0.000	2.31	4.44
Sex	-6.13	0.80	-7.65	0.000	-7.72	-4.55
Height	.277	0.04	4.98	0.000	0.13	0.31
***Secondary grades**						
Constant	-91.13	15.05	-6.05	0.000	-120.79	-61.47
Age	1.73	0.58	2.96	0.003	0.58	2.88
Sex	-4.81	1.19	-4.03	0.000	-7.17	-2.45
Height	0.554	0.07	7.15	0.000	0.40	0.70
Non-dominant grip strength						
***Primary grades**						
Constant	-6.69	0.923	-7.25	0.000	-8.50	-4.87
Age	1.41	0.126	11.17	0.000	1.16	1.66
Sex	-1.30	0.327	-4.00	0.000	-1.95	-0.66
Weight	0.063	0.016	3.89	0.000	0.03	0.09

***Preparatory grades**						
Constant	-49.30	10.33	-4.77	.000	-69.67	-28.93
Age	2.39	.673	3.56	.000	1.07	3.72
Sex	-4.96	1.00	-4.95	.000	-6.93	-2.99
Height	.231	.057	4.07	.000	.119	.343
***Secondary grades**						
Constant	-64.32	13.81	-4.65	.000	-91.53	-37.10
Sex	-4.83	1.25	-3.85	.000	-7.30	-2.36
Height	.559	.080	6.99	.000	.402	.717

SE: Standard Error, T: Test Statistics, P: Significance Level, CI: Confidence Interval.
Dominant hand grip strength: Primary= -4.52+ (1.38 age)-(1.62 girl) + (0.054 weight), Preparatory= -60.37+ (3.37 age)-(6.13 girl)-(0.277 height), Secondary= -91.13+ (1.73 age)-(4.81 girl) + (0.554 Height).
Non-dominant hand grip strength: Primary= -6.69+ (1.41 age)-(1.30 girl) + (0.063 weight), Preparatory= -49.30+ (2.39 age)-(4.96 girl) + (0.231 height), Secondary= -64.32-(4.83 girl) + (0.559 height).

in relation to total body mass as boys convert more of their caloric intake into muscle and expendable circulating energy reserves, while girls tend to convert more into fat deposits, as a result, boys are generally physically stronger than girls. [12] The results also showed that boys had higher mean values for all the tested anthropometric measures than girls, except for PBMI where girls had higher mean values in both preparatory and secondary stages. This could be either due to non-involvement of girls in much physical activity as boys do or may be due to higher fat deposition in girls compared to boys, in addition to the presence of greater percentage of muscularity among boys than girls due to the regular exercising of the boys that prevent the accumulation of fat in the body. [12] There are at least three effects of gender-specific development, which all contribute to higher forearm muscle mass and strength in boys compared with girls. First, boys become taller than girls who lead to generally greater force since greater body height means greater bone length, which is an important determinant of muscle mass and force. Second, the greater difference in forearm length is more obvious than would be expected from the difference in height. [13] This is because, the forearm length to height ratio increases in boys but not in girls. Third, the difference in forearm length is considered for forearm muscle growth which is wider in boys than in girls. [14] The results of the current study also revealed a strong positive correlation between anthropometric measures of upper limb and hand grip strength in primary stage which can be the result of age dependent increase of hand grip strength which is strongly associated with changes of muscle mass during their childhood. Regarding height, a positive correlation with the hand grip strength could be the result of various factors such as with greater height that would lead to longer arms, with greater lever arm for force generation, resulting in an efficient amount of force. [15] The fact of increasing muscle length causes increase in the output tension produced by the muscle as what happens in power grip. The power grip requires strong forces from finger flexors, intrinsic muscles of the fingers and thumb and the wrist extensors that are needed to stabilize the partially extended wrist joint. It was also found that the wrist extension while closing hand helps to maintain an optimal length of the intrinsic finger flexors. [16] It was believed that having a significant correlation between hand width (at the level of Meta-carpophalengeal joint (MCP)) and hand grip strength may be attributed to the role of the MCP joint as a meeting point (or fulcrum) around which the hand grip strength is calculated. The moment arm of the finger flexors is the perpendicular distance from the muscles action line to the MCP joint axis, being the origin of the lengths of the moment arms. Balancing these moments ensures static equilibrium. [17] Also the results of our study showed weak relationship between hand grip strength and PBMI as overall muscle function was impaired in obese individuals compared to the non-obese counterparts and not only the lack of physical activity but obesity and its metabolic consequences also might be responsible for these findings. [18] At whole muscle and fascicular levels, adiposity of obesity was associated significantly with lower skeletal muscle contractile capacity. [19] On the other side, a weak positive association was found between anthropometric measures and hand grip strength in both preparatory and secondary grades and this increase in hand grip strength may be returned mainly to changes occur during the process of puberty, which are the influence of sex hormones (testosterone in boys, estrogen in girls). These two sex steroids hormones play the key role for variances in physical fitness. A rise in testosterone level in boys is closely associated with the alteration in muscle strength and the increase in estrogen levels in girls regulates the ability of muscles to contract by about 10%, with a peak in strength just before ovulation. Another explanation was the increase in grip strength per muscle cross sectional area. [20]

Conclusion

From this study it can be concluded that positive correlation was found between some anthropometric variables of the upper limb and hand grip strength which is strong in primary grades due to higher physical performance and pre-pubertal factors and weak in preparatory and secondary grades due to hormonal changes in both genders. So, this study would be helpful to search talents in sports, diagnose various musculoskeletal deformities especially related to upper extremities. In addition, the normal data gathered in this study may also needed in clinical practice, e.g. physiotherapy, hand surgery.

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Conflict of Interest

All authors disclose that there was no conflict of interest.

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