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Hand anthropometry: Correlation with grip strength and macronutrient intake among basketball players

Rupal Pankaj Agrawal and Prajakta Jayant Nande

Abstract
In sports, physical strength is known to increase sporting success and performance. Especially, hand grip strength (grasping strength) is the most important determinant. This study deals with the effect of macronutrients intake on handgrip strength & its relation with hand anthropometric indices of young girls and boys undergoing regular basketball training (age: 10-15 yrs, n=400). Players were selected from leading basketball training clubs of Nagpur city of Maharashtra State, India. Mid upper arm circumference (MUAC), elbow breadth, forearm circumference, wrist circumference, palm width, palm length, index finger length, ring finger length & arm length of basketballers were measured. Fat folds at biceps & triceps were measured using skinfold caliper. Upper arm muscle circumference (UAMC) and upper arm muscle area (UAMA) of players were also derived. Handgrip strength of basketballers using a grip strength dynamometer was examined. Dietary intake data was collected by 24 hour's dietary recall method for consecutive three days. Players were unable to meet the standards for MUAC, elbow breadth, forearm circumference & wrist circumference for their age & gender but possessed wider & longer palms as compared to reference standards. Mean index finger & ring finger lengths significantly increased with age in both the genders. Girls demonstrated higher mean values of biceps & triceps skinfolds than boys. Players failed to meet the age wise standards for UAMC & UAMA. Being regular in their daily meal timings, basketballers failed to meet the daily requirements of energy but consumed higher quantities of proteins. The younger & older groups of boys possessed significantly more powerful handgrip strength than the younger & older groups of girls, respectively. Age wise improvement in hand grip strength was noted among girls & boys. The results indicate that handgrip strength of basketballers is positively influenced by their hand anthropometric characteristics and nutritional status.

Keywords: Basketball players, hand anthropometry, handgrip strength, macronutrient intake

1. Introduction
Strength can be defined as the maximal force of the muscle(s) or muscle group. Muscular strength and power are important in all team sports and sports that are dominated by speed [1]. Hand grip strength shows the maximum strength which is derived from combined contraction of extrinsic and intrinsic hand muscles leading to the flexion of hand joints. Strength in basketball depends on the athlete's position to an extent, although all basketball players also need to have significant amount of muscle strength. Hand grip strength is affected by nutritional status of an individual to a greater extent [2]. The strength of a hand grip is nothing but the forceful flexion of all finger joints, thumbs, and wrists with the maximum force that the player can exert under normal conditions. Strong correlations between grip strength and various anthropometric traits were reported in different studies [3].
Handgrip strength become important in basketball as various movements like catching, holding, shooting and throwing the ball rely on the continuous use of wrist and digits flexor muscles. Hence, the assessment of handgrip strength is used in prepubertal, adolescent and adult basketball players [4]. Fingers are the smallest & lightest parts of the motor apparatus that represent the parts most easily deflected by force from the ball, but at the same time, finger control is especially important for the accuracy of different shots in basketball. Thus, it becomes necessary to measure finger length and perimeters of the hand for practical reasons [5].
Physical activity increases the requirement for energy and macronutrients, which increases the demand on athlete eating behaviors to satisfy the needs. Athletes require adequate supply of total energy for their bodies to get maximum benefit and recover from training to improve and advance in their games [6].

Measuring body composition serves a qualitative aspect of nutritional status among athletes, whereas muscle function shows a dynamic indicator of muscle mass. Measurement of muscle function as indicator of functional as well as nutritional status has therefore received considerable attention in the past few years [7]. Hand grip strength is a validated and most feasible & frequently used tool. Insufficient diet intake results in a compensatory loss of whole protein from the body which is preferably lost from the body's largest protein reserve i.e. muscle mass which apparently results in decreased muscle strength, i.e. weakness, which is also reflected in deteriorating function tests. Reduced muscle strength has been associated with loss of physical functionality putting negative impact on performance of basketball players [8].

The information regarding the effect of macronutrient intake on handgrip strength of basketballers and association of hand grip strength with various hand anthropometries in junior basketball players is scanty. So the present study dealt with the effect of macronutrient intake on handgrip strength of basketballers and its correlation with hand anthropometry of basketball players.

2. Materials and Methods

2.1 Selection of Sample: The study was conducted in Nagpur city, Maharashtra, India. Young female and male basketball players engaged in regular practice schedules and participating in competitive events/tournaments of basketball were selected purposively from leading basketball training clubs and institutes in Nagpur city. A total of 400 competitive basketball players (100 girls and 100 boys from each age group of 10 to 12 years and 13 to 15 years) were purposively selected for the present study. Table 1 shows age wise classification of subjects.

Table 1: Classification of Subjects

Sr. No.	Age Group (years)	Subjects (N = 400)	
		Girls (n = 200)	Boys (n = 200)
1	10 - 12	100	100
2	13 - 15	100	100

2.2 Anthropometric Measurements: Mid upper arm circumference (MUAC), forearm circumference, wrist circumference, elbow breadth, palm width, palm length, index finger length, ring finger length & arm length of basketballers were measured using standard equipments and procedures. Comparisons were done with reference standards for gender & age [9-18]. Skinfold measurement at biceps & triceps were measured with the help of skinfold caliper. Arm anthropometry i.e. upper arm muscle circumference (UAMC) & upper arm muscle area (UAMA) of players were derived based on the triceps skinfold measurement & MUAC using standard equations [17, 19].

2.3 Nutrient Intake: Food intake of each basketballer was recorded using 24 hour's three days dietary recall method. On the basis of this, intake of macronutrients i.e. carbohydrate, protein and fat was calculated using food composition tables [20] Energy intake of each subject was calculated based on macronutrient intake. Comparisons were done with recommended dietary allowances (RDAs) [21].

2.4 Hand Grip Strength Test: Hand grip dynamometer was used to measure grip strength of players. Maximum reading from three attempts was recorded using dominant hand & mean was considered & compared with normative data [22-24].

2.5 Statistical Analysis: Data was tabulated & grouped for statistical analysis. Mean, standard deviation, minimum, maximum & percentage values were derived. Within & between group comparisons were done using z test. Correlations were derived using Pearson's product moment coefficient of correlation. The differences were tested at both 0.01 & 0.05 levels of significance.

3. Results and Discussion

Anthropometric measurements are useful in determination of body dimensions, physical fitness & nutritional status. Table 2 shows data on anthropometric measurements of players.

Table 2: Data on Anthropometric Measurements of Basketballers

Sr. No.	Parameters	Girls			Boys		
		Age Group 10-12 Yrs (n=100)	Age Group 13-15 Yrs (n=100)	z Values ¶	Age Group 10-12 Yrs (n=100)	Age Group 13-15 Yrs (n=100)	z Values ¶
1	**Mid Upper Arm Circumference (MUAC) (cm)**						
i	M±SD	20.21±2.37	21.94±2.03	5.55*	20.32±2.97	21.47±2.65	2.90*
ii	Range	16.00-25.50	17.50-28.00		15.50-28.00	16.00-28.50	
iii	Standard	24.47	27.47		24.63	28.00	
iv	% Deficit	-17.41	-20.13		-17.50	-23.32	
v	z Values#	17.96*	27.16*		14.50*	24.60*	
2	**Forearm Circumference (cm)**						
i	M±SD	19.81±1.48	21.22±1.24	7.27*	20.13±1.93	21.71±1.69	6.17*
ii	Range	16.50-23.00	19.00-25.00		17.00-26.00	18.00-27.50	
iii	Standard	19.53	22.10		20.13	23.17	
iv	% Deficit/Excess	+1.43	-3.98		0.00	-6.30	
v	z Values#	1.92	7.14*		0.03	8.69*	
3	**Wrist Circumference (cm)**						
i	M±SD	13.77±0.80	14.46±0.77	6.19*	13.97±1.17	15.01±1.21	6.15*
ii	Range	11.50-15.50	12.50-16.50		11.00-17.00	12.50-18.50	
iii	Standard	13.73	14.80		13.73	15.37	
iv	% Deficit/Excess	+0.29	-2.30		+1.75	-2.34	
v	z Values#	0.48	4.42*		2.07	3.01	
4	**Elbow Breadth (cm)**						
i	M±SD	5.06±0.43	5.21±0.39	2.55**	5.20±0.48	5.45±0.42	3.81*
ii	Range	4.00-5.90	3.90-6.10		3.90-6.10	4.10-6.10	

iii	Standard	5.90	6.20		6.23	7.00	
iv	% Deficit	-14.23	-15.97		-16.53	-22.14	
v	z Values#	19.59*	25.60*		21.28*	36.76*	
5	**Palm Width (cm)**						
i	M±SD	7.40±0.50	7.68±0.50		7.52±0.80	8.13±0.72	
ii	Range	6.00-8.50	6.00-9.00		6.50-11.50	6.30-11.5	
iii	Standard	6.90	7.60	3.96*	7.07	7.50	5.72*
iv	% Excess	+7.25	+1.05		+6.36	+8.40	
v	z Values#	9.89*	1.55		5.53*	8.80*	
6	**Palm Length (cm)**						
i	M±SD	16.46±1.00	17.34±0.93		16.07±1.13	17.75±1.40	
ii	Range	14.00-19.00	13.50-19.70		14.00-19.50	15.50-22.00	
iii	Standard	15.20	16.80	6.41*	15.27	15.90	9.32*
iv	% Excess	+8.29	+3.21		+5.24	+11.64	
v	z Values#	12.65*	5.77*		7.14*	13.19*	
7	**Index Finger Length (cm)**						
i	M±SD	6.30±0.56	6.76±0.56		6.03±0.59	6.85±0.70	
ii	Range	3.20-7.90	5.40-8.10		5.00-8.50	5.40-9.00	
iii	Standard	6.20	6.80	5.71*	6.07	6.87	8.85*
iv	% Deficit/Excess	+1.61	-0.59		-0.66	-0.29	
v	z Values#	1.79	0.80		0.61	0.31	
8	**Ring Finger Length (cm)**						
i	M±SD	6.86±0.50	7.11±0.53	3.47*	6.63±0.55	7.36±0.70	8.14*
ii	Range	5.90-8.20	5.00-8.50		5.60-8.40	6.10-9.50	
9	**Arm Length (cm)**						
i	M±SD	56.30±5.21	61.84±5.39		54.61±5.01	64.08±7.79	
ii	Range	45.50-66.00	46.00-72.00		44.50-69.00	49.00-87.00	
iii	Standard	63.67	67.72	7.39*	60.31	68.27	10.23*
iv	% Deficit/Excess	-11.58	-8.68		-9.45	-6.14	
v	z Values#	14.16*	10.93*		11.38*	5.38*	
10	**Biceps Skinfold (mm)**						
i	M±SD	7.13±2.93	7.30±2.64		7.10±3.02	6.24±2.90	
ii	Range	2.00-15.00	3.00-14.00		3.00-15.00	2.00-13.00	
iii	Standard	7.99	8.56	0.43	6.27	5.56	2.06**
iv	% Deficit	-10.76	-14.72		+13.24	+12.23	
v	z Values#	2.94*	4.78*		2.75*	2.35**	
11	**Triceps Skinfold (mm)**						
i	M±SD	10.97±2.97	11.87±2.27		10.56±3.59	9.93±3.48	
ii	Range	3.00-18.00	6.00-17.00		4.00-21.00	3.00-18.00	
iii	Standard	15.83	18.73	2.41**	15.07	13.07	1.26
iv	% Deficit/Excess	-30.70	-36.63		-29.93	-24.02	
v	z Values#	16.35*	30.19*		12.57*	9.02*	
12	**Upper Arm Muscle Circumference (UAMC) (mm)**						
i	M±SD	167.65±18.73	182.15±17.67		170.00±23.75	183.52±21.62	
ii	Range	130.30 - 217.30	144.16 - 232.88		127.30 - 232.43	128.58 - 234.73	
iii	Standard	180.67	199.67	5.63*	186.00	223.67	4.21*
iv	% Deficit/Excess	-7.21	-8.77		-8.60	-17.95	
v	z Values#	6.95*	9.91*		6.73*	18.57*	
13	**Upper Arm Muscle Area (UAMA) (mm^2)**						
i	M±SD	2264.19 ± 514.56	2664.85 ± 523.98		2344.36 ± 671.54	2717.07 ± 641.06	
ii	Range	1351.09 - 3757.61	1653.77 - 4315.57		1289.59 - 4299.19	1315.72 - 4384.73	
iii	Standard	2604.00	3199.33	5.46*	2755.67	3999	4.01*
iv	% Deficit	-13.05	-16.71		-14.93	-32.06	
v	z Values#	6.60*	10.20*		6.12*	20.00*	

¶ - z values are for between group comparison (i.e. comparison between age groups 10-12 yrs & 13-15 yrs); # - z values are for comparison between data of subjects & standards; * - Significant at both 5 % & 1% levels ($p<0.01$); ** - Significant at 5 % level but insignificant at 1 % level ($0.01<p<0.05$); Values without any mark indicate insignificant difference at both 5% & 1% levels ($p>0.05$).

Mid upper arm circumference (MUAC) is a useful tool for a fast assessment of the nutritional status which helps in the estimation of the muscle protein amount in the body. As clearly depicted in Table 2, the mean values for MUAC were recorded as 20.21±2.37 cm, 21.94±2.03 cm, 20.32±2.97 cm & 21.47±2.65 cm for girls aged 10-12yrs, girls aged 13-15yrs, boys aged 10-12yrs & boys aged 13-15yrs, respectively; with significantly greater MUAC among older girls and older boys (z=5.55 & 2.90, respectively, $p<0.01$). Similar to MUAC, effect of age was seen clearly on forearm & wrist circumferences (z=6.15 to 7.27, $p<0.01$), elbow breadth, palm width & lengths like palm, ring finger, index finger & arm [z=2.55 ($0.01<p<0.05$) to 10.23 ($p<0.01$)].

Circumferences like MUAC & forearm are used to check for athletic fitness and weight gain. They are also used in anthropometric measures of skeletal muscle mass and to calculate the amount of muscle protein in the region. The girls & boys from both the age groups i.e. 10-12 yrs & 13-15 yrs had significantly lower mean MUAC measurements than the standards (z=14.50 to 27.16, $p<0.01$). Also, older groups of girls & boys showed less round forearms (z=7.14 & 8.69, respectively, $p<0.01$). Less intake of energy &/or high energy

expenditure among basketballers might be the reason of lower girths at mid upper arm & forearm regions.

There are number of muscles involved in movement of the forearm and wrist, with many of these involved in gripping activities. Control and accuracy of basketballer's shot depend solely on the strength of their forearm, wrists and fingertips. Mean values of wrist circumference were recorded as 13.77±0.80 cm, 14.46±0.77 cm, 13.97±1.17 cm and 15.01±1.21 cm for 10-12 yrs and 13-15 yrs aged girls, 10-12 yrs and 13-15 yrs aged boys, respectively (Table 2). Mean wrist circumference was greater than standards among girls & boys aged 10-12 yrs [z=0.48 (p>0.05) & 2.07 (0.01<p<0.05), respectively] whereas it was significantly lower than standards among girls & boys aged 13-15 yrs (z=4.42 & 3.01, respectively, p<0.01).

One of the best ways to determine the body frame size is measuring the elbow breadth, the distance between the two epicondyles of the elbow. Irrespective of age & gender, basketballers under this research were not able to meet the standards for elbow breadth; girls & boys from age groups 10-12 yrs & 13-15 yrs showed % deficits of 14.23, 15.97, 16.53 & 22.14, respectively (z=19.59, 25.60, 21.28 & 36.76, respectively, p<0.01) (Table 2).

Bigger hand surfaces helps to easily palm the ball and make the basket. Players with small hands might find it difficult to control the ball while dribbling or passing. Hence, upper extremity muscle and grip strength are the primary physical factors affecting passing accuracy. Girls & boys aged 10-12 yrs & possessed wider & longer palms as compared to reference standards [z=9.89 & 12.65 for girls aged 10-12 yrs (p<0.01); z=1.55 (p>0.05) & 5.77 (p<0.01) for girls aged 13-15 yrs; z=5.53 & 7.14 for boys aged 10-12 yrs (p<0.01) and z=8.80 & 13.19 for boys aged 13-15 yrs (p<0.01), respectively for palm width & palm length]. However, greater individual differences were noted in both the width & length readings of palm as also seen from the minimum & maximum values which were 6.00-8.50 cm, 6.00-9.00 cm, 6.50-11.50 cm and 6.30-11.5 cm for palm width and 14.00-19.00 cm, 13.50-19.70 cm, 14.00-19.50 cm and 15.50-22.00 cm for palm length for girls aged 10-12 yrs, girls aged 13-15 yrs, boys aged 10-12 yrs & boys aged 13-15 yrs, respectively (Table 2).

Nag *et al*. (2003) [25] studied hand anthropometry of Indian women and concluded that handgrip strength is important for catching and throwing the ball in ball games and when the fingers are longer, hand surface variables are greater for grasping the ball & hence, fingers are less widely spread, and grasping the ball is more efficient and less fatiguing. Girls from age group 10-12 yrs had longer mean index finger & ring finger lengths than boys from same age group. In contrast to this, boys from age group 13-15 yrs had longer mean index finger & ring finger lengths than girls from same age group. Longer fingers increase the surface of the hand and increase the accuracy of the different shots required in basketball. With the exception of younger girl's group, the players from other groups failed to match the standards for index finger length having % deficit values calculated as 0.59, 0.66 and 0.29 for girls from age group 13-15 yrs and boys from age groups 10-12 yrs, 13-15 yrs, respectively.

Minimum and maximum data of the players for arm length showed greater differences which were 45.50-66.00 cm, 46.00-72.00 cm, 4.50-69.00 cm and 49.00-87.00 cm, respectively for girls aged 10-12 yrs, girls aged 13-15 yrs, boys aged 10-12 yrs and boys aged 13-15 yrs. It is postulated that that tall people tend to have longer arms. In Italian female national basketball teams (under 14 to senior), Pizzigalli *et al*. (2017) [26] found that seniors showed higher values than younger groups (under-14 and under-15) for arm length (p<0.05). Similar results were obtained for the present research (Table 2) but in comparison with standards, players possessed significantly shorter mean arm length (z=5.38 to 14.16, p<0.01).

Athlete's body composition and body fat percentage can also be measured by taking the skinfolds at biceps and triceps. The average values for the skinfolds were found as 7.13±2.93 mm, 7.30±2.64 mm, 7.10±3.02 mm and 6.24±2.90 mm for biceps and 10.97±2.97 mm, 11.87±2.27 mm, 10.56±3.59 mm and 9.93±3.48 mm for triceps skinfolds in girls aged 10-12 yrs, girls aged 13-15 yrs, boys aged 10-12 yrs and boys aged 13-15 yrs, respectively (Table 2). Lower mean values of both the skinfolds in players in comparison with standards might be linked with positive influence of sports training at the expense of body fat content. The effect was more pronounced among older group of boys for whom mean biceps & triceps skinfolds were found to be less than younger group of boys [z=2.06 (0.01<p<0.05) & 1.26 (p>0.05), respectively].

Upper arm anthropometry has a potential role to provide useful estimations of body composition and nutritional status of players. The upper arm muscle area is derived to assess the nutritional status related to reserve body protein. The mean values for UAMC were recorded as 167.65±18.73 mm, 182.15±17.67 mm, 170.00±23.75 mm & 183.52±21.62 mm whereas the mean values of UAMA were recorded as 2264.19±514.56, 2664.85±523.98, 2344.36±671.54, 2717.07±641.06 mm^2, respectively in girls aged 10-12 yrs & 13-15 yrs and boys aged 10-12 yrs & 13-15 yrs. Age and sex specific mean values of UAMC and UAMA increased as the players approached higher ages (z=5.65 & 5.46 for girls aged 10-12 yrs vs. girls aged 13-15 yrs and z=4.21 & 4.01 for boys aged 10-12 yrs vs. boys aged 13-15 yrs, respectively, p<0.01). The age-specific mean values of these measurements were observed to be higher among boys than girls. However, both the age groups of girls & boys were unable to meet the standards of UAMC & UAMA for age (p<0.01, Table 2).

Basketball is a high-intensity game which requires both physical agility and mental sharpness. Energy demands during the basketball competition are strongly high and may be even higher during off-season training. Hence selection of foods that provide the energy to support competition and training becomes essential, which may also be quite challenging. Although total energy intake is important to reduce the chances of weight loss during the season, the source of the calories plays an important role to provide the muscle with the right type of fuel. Table 3 presents data on daily intake of energy, carbohydrate, protein and fat by basketballers.

Table 3: Data on Daily Intake of Energy, Carbohydrate, Protein and Fat by Basketballers

Sr. No.	Parameters	Girls			Boys		
		Age Group 10-12 Yrs (n=100)	Age Group 13-15 Yrs (n=100)	z Values ¶	Age Group 10-12 Yrs (n=100)	Age Group 13-15 Yrs (n=100)	z Values ¶
1	**Energy (kcal)**						
i	M±SD	1865±282	2242±204	10.88*	2181±159	2479±183	12.27*
ii	Range	1280-2359	1521-2714		1792-2557	2000-2806	
iii	RDA	2010	2330		2190	2750	
iv	% Deficit	-7.24	-3.76		-0.41	-9.87	
v	z Values#	5.17*	4.31*		0.57	14.80*	
2	**Carbohydrate (g)**						
i	M±SD	314.91±55.05	380.37±33.90	10.12*	372.79±26.05	411.08±35.04	8.77*
ii	Range	188.26-404.89	242.80-455.55		**311.63-430.82**	311.74-471.41	
3	**Protein (g)**						
i	M±SD	48.41±7.57	58.84±7.22	9.97*	56.90±5.90	64.02±5.00	9.21*
ii	Range	29.99-64.24	37.31-72.54		41.52-68.51	52.93-72.64	
iii	RDA	40.40	51.90		39.90	54.30	
iv	%Excess	+19.83	+13.37		+42.61	+17.90	
v	z Values#	10.58*	9.62*		28.82*	19.44*	
4	**Fat (g)**						
i	M±SD	45.69±6.49	53.94±7.97	8.03*	51.35±6.30	64.26±5.79	15.09*
ii	Range	35.07-60.63	37.79-72.41		37.67-66.29	51.41-78.21	

¶- z values are for between group comparison (i.e. comparison between age groups 10-12 yrs & 13-15 yrs); # - z values are for comparison between data of subjects & RDAs; * - Significant at both 5 % & 1% levels (p<0.01); ** - Significant at 5 % level but insignificant at 1 % level (0.01<p<0.05); Values without any mark indicate insignificant difference at both 5% & 1% levels (p>0.05).

From Table 3, it is noted that irrespective of the age and gender, all the groups of players had lower mean daily intake of energy than RDAs (1865±282 kcal, 2242±204 kcal, 2181±159 kcal & 2479±183 kcal in girls from 10-12yrs, 13-15yrs age groups and boys from 10-12yrs, 13-15yrs age groups, respectively). Mean daily carbohydrate intake by girls aged 10-12yrs, girls aged 13-15yrs, boys aged 10-12yrs & boys aged 13-15yrs was 314.91±55.05 g, 380.37±33.90 g, 372.79±26.05 g & 411.08±35.04 g, respectively which was found to be increased with age in both the genders which may be attributed to increased energy demands for growing age & for the sport. Mean daily protein intake for all four groups of basketballers was found to be significantly higher than RDAs (z=10.58, 9.62, 28.82 & 19.44, respectively for girls aged 10-12yrs, girls aged 13-15yrs, boys aged 10-12yrs & boys aged 13-14yrs, p< 0.01). Older age groups of female & male basketballers consumed significantly higher mean daily fat than younger groups of female & male basketballers (z=8.03 for girls aged 10-12yrs vs. girls aged 13-15yrs and z=15.09 for boys aged 10-12yrs vs. boys aged 13-15yrs).

Handgrip strength is important in sport like basketball in which the hands are used for catching, throwing or lifting. Also, as a general rule people with strong hands tend to be strong elsewhere, so hand grip strength test is often used as a general test of strength. Table 4 shows data on hand grip strength test of basketballers.

Table 4: Data on Hand Grip Strength Test of Basketballers

Sr. No.	Subjects	Parameters	Hand Grip (kg)		z Values ¶
			Age Group 10-12 Yrs (n=100)	Age Group 13-15 Yrs (n=100)	
1	Girls	Mean±SD	24.99±6.04	29.08±5.78	4.89*
		Range	14.00-36.00	15.00-41.00	
		Performance Assessment Based on Mean	Good	Good	
2	Boys	Mean±SD	27.16±6.64	31.26±6.07	4.56*
		Range	15.00-65.00	16.00-43.00	
		Performance Assessment Based on Mean	Fair	Poor	
z Values■			2.42**	2.60*	-

¶ - z values are for between group comparison (i.e. comparison between age groups 10-12 yrs & 13-15 yrs); ■ - z values are for between gender comparison (i.e. comparison between girls & boys from age group 10-12 yrs & between girls & boys from age group 13-15 yrs); * - Significant at both 5 % & 1% levels (p<0.01); ** - Significant at 5 % level but insignificant at 1 % level (0.01<p<0.05); Values without any mark indicate insignificant difference at both 5% & 1% levels (p>0.05).

Mean values for grip strength test were found to be higher in male players from age groups 10-12 & 13-15 yrs (27.16±6.64 kg & 31.26±6.07 kg, respectively) as compared to female players from age groups 10-12 & 13-15 yrs (24.99±6.04 kg & 29.08±5.78 kg, respectively) showing more strength in the hands among boys (z=2.42 for girls aged 10-12 yrs vs. boys aged 10-12 yrs and z=2.60 for girls aged 13-15 yrs vs. boys aged 13-15 yrs). Older females possessed significantly stronger hand grip strength than younger females (z=4.89, (p<0.01). Similar results were obtained for male players (z=4.56, (p<0.01, Table 4).

Based on the mean results, female players from both the age groups of 10-12 & 13-15 yrs were rated "good" for their hand grip performance whereas it was "fair" for boys aged 10-12 yrs and "poor" for boys aged 13-15 yrs.

Figure 1 demonstrates the percentage wise distribution of basketballers based on performance assessment for hand grip for grip strength test.

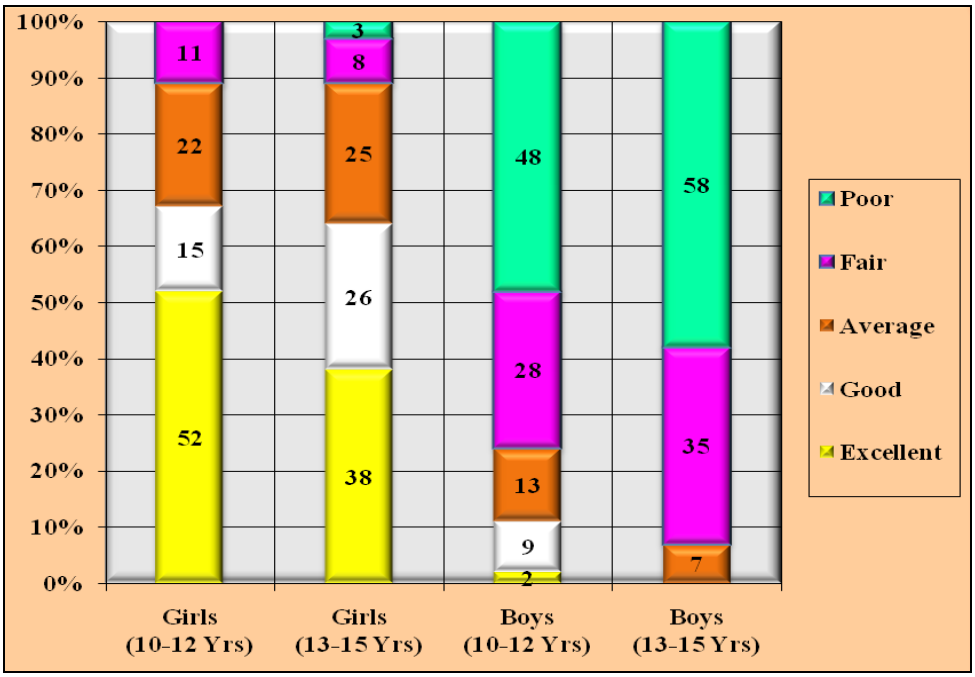

Fig 1: Percentage Wise Distribution of Basket Ballers Based on Performance Assessment for Hand Grip Strength Test

Majority of female players from 10-12 yrs age group (52%) & 13-15 yrs age group (38%) showed excellent hand grip strength whereas only 2% of boys from 10-12 yrs age group reflected excellent handgrip muscle strength. Nearly half of the male players from 10-12 yrs age group (48%) & 13-15 yrs age group (58%) performed poorly which indicated poor hand muscle strength among these subjects.

Table 5 presents data on correlates of grip strength test performance.

Table 5: Correlates of Grip Strength Test Performance

Sr. No.	Parameters	Correlation Coefficient Values (r)			
		Girls		Boys	
		Age Group 10-12 Yrs	Age Group 13-15 Yrs	Age Group 10-12 Yrs	Age Group 13-15 Yrs
1	Grip Strength Test Performance vs. MUAC	0.2565*	0.0911	0.0223	0.0958
2	Grip Strength Test Performance vs. Forearm Circumference	0.3135*	0.0804	0.0646	0.2182**
3	Grip Strength Test Performance vs. Wrist Circumference	0.2559*	0.1553	0.0674	0.2846*
4	Grip Strength Test Performance vs. Elbow Breadth	0.2138**	0.0543	0.0254	0.1713
5	Grip Strength Test Performance vs. Palm Width	0.3200*	-0.0032	0.0525	0.3094*
6	Grip Strength Test Performance vs. Palm Length	0.3158*	-0.0259	0.0821	0.3283*
7	Grip Strength Test Performance vs. Index Finger Length	0.0874	-0.0499	0.0157	0.1844
8	Grip Strength Test Performance vs. Ring Finger Length	0.2889*	0.2285**	0.0870	0.2682*
9	Grip Strength Test Performance vs. Biceps Skinfolds	0.2211**	-0.0234	-0.0270	0.0378
10	Grip Strength Test Performance vs. Triceps Skinfolds	0.1518	0.2184**	-0.0348	-0.0001
11	Grip Strength Test Performance vs. UAMC	0.2491**	0.0167	0.0444	0.1176
12	Grip Strength Test Performance vs. UAMA	0.2463**	0.0165	0.0491	0.1226
13	Grip Strength Test Performance vs. Energy Intake	0.2052**	0.1667	0.0107	0.1235
14	Grip Strength Test Performance vs. Carbohydrate Intake	0.2081**	0.1236	0.0493	0.1400
15	Grip Strength Test Performance vs. Protein Intake	0.1561	0.0622	0.0168	0.1634
16	Grip Strength Test Performance vs. Fat Intake	0.1237	0.2143**	0.1136	0.0048

Grip strength test performance among all four groups of basketballers was found to be correlated positively with MUAC [r=0.0223 (p>0.05) to 0.2565 (p<0.01)], forearm circumference (r=0.0646 to 0.3135, p>0.05) & wrist circumference [r=0.0674 (p>0.05) to 0.2846 (p<0.01)] which can be attributed to the muscular development of upper arm & lower arm which give general strength. Grip strength test performance depicted positive correlation with elbow breadth in girls of 10-12 yrs age group, girls of 13-15 yrs age group, boys of 10-12 yrs age group & boys of 13-15 yrs age group (r=0.2138, 0.0543, 0.0254 & 0.1713, respectively, p>0.05). Broader are the elbows, powerful is the hand grip. Subjects had broader and longer palms and the results suggest that larger hand surfaces lead to stronger grip power. Grip strength test performance depicted positive correlation with palm width and palm length in girls aged 10-12 yrs, boys aged 10-12 yrs & boys aged 13-15 yrs [r=0.3200 (p<0.01); r=0.0525 (p>0.05) & r=0.3094 (p<0.01) for palm width and r=0.3158 (p<0.01); r=0.0821 (p>0.05) & 0.3283 (p<0.01) for palm length, respectively].

In grip sport like basketball, the accuracy of the shots or throw is better with the longer fingers [27]. In girls of 10-12 yrs age group, girls of 13-15 yrs age group, boys of 10-12 yrs age group & boys of 13-15 yrs age group, grip strength was found to have positive correlation with index finger length & ring finger length [r=0.0874, 0.0499, 0.0157 & 0.1844, respectively, p>0.05 for index finger length and r=0.2889 (p<0.01), 0.2285 (0.01<p<0.05), 0.0870 (p>0.05) & 0.2682

(p<0.01), respectively for ring finger length].
Hurbob and Jurimaea (2009) [28] found that biceps and triceps skinfolds were not related to handgrip strength among prepubertal children aged between 8 and 11 years (n=64, 27 boys, 37 girls). But for this study, grip strength test performance showed negative correlation with biceps skinfold in older girls & younger boys (r=-0.0234 & -0.0270, respectively, p>0.05) but significantly positive in younger girls (r=0.2211, 0.01<p<0.05). Grip strength test performance also found to have negative correlation with triceps skinfold in male players aged 10-12 yrs & male players aged 13-15 yrs (r= -0.0348 & -0.0001, p>0.05) but positive in case of female players aged 10-12 yrs & female players aged 13-15 yrs [r=0.1518 (p>0.05) & 0.2184 (0.01<p<0.05), respectively]. The results indicate that as the subcutaneous fat decreased in male players, their handgrip strength improved showing positive effect of exercise. Grip strength test of basketballers was found to have direct correlation with UAMC [r=0.0167 (p>0.05) to 0.2491 (0.01<p<0.05)] & UAMA [r=0.0165 (p>0.05) to 0.2463 (0.01<p<0.05)] indicating that arm muscle mass contributes to hand strength in basketballers.
As shown in Table 5, grip strength test performance also reflected positive correlation with energy intake [r=0.0107 (p>0.05) to 0.2052 (0.01<p<0.05)], carbohydrate intake [r=0.0493 (p>0.05) to 0.2081 (0.01<p<0.05)], protein intake (r=0.0168 to 0.1634, p>0.05) & fat intake [r=0.0048 (p>0.05) to 0.2143 (0.01<p<0.05)] in all four age groups of basketballers indicating the importance of sufficient intake of energy along with three major nutrients to sustain hand related physical activities in sport.

4. Conclusion
In the current study, the effect of macronutrient intake on handgrip strength & its association with hand anthropometric indices of young girls and boys undergoing basketball training was assessed. The basketballers, especially older players were unable to meet the standards for MUAC & forearm circumference. Fast growing at this age and less intake of energy &/or high energy expenditure among basketballers might be the reason of lower girth measurements. Older girls & boys had significantly greater mean wrist circumference and wider elbows than their younger counterparts which definitely showed impact of age & longer involvement in sports training. Girls & boys from age groups of 10-12 yrs & 13-15 yrs significantly possessed wider & longer palms as compared to reference standards. Girls aged 10-12 yrs had longer mean index finger & ring finger lengths than boys from same age group but boys from aged 13-15 yrs had longer mean index finger & ring finger lengths than girls from same age group. Female players demonstrated higher mean biceps & triceps skinfolds than their male counterparts. Biceps & triceps skinfolds increased with age in girls whereas it decreased in boys. Increase in the skinfolds in girls may be attributed to the fact that women deposit fat primarily to a greater extent as essential as well as stored fat than men. Decrease in skinfold thickness for boys may be explained by male type body characteristics as well as effect of sports training. Mean values of UAMC & UAMA were observed to be higher among boys than girls, although all four age groups of players significantly failed to meet the age wise standards for these measurements. The mean daily energy intake by younger & older groups of boys was found to be significantly greater than that of younger & older groups of girls, respectively. Mean values of daily protein intake for all the groups of basketballers were found to be significantly higher than RDAs. Even though boys possessed higher mean readings for hand grip strength than girls, on the basis of the age & gender wise norms, their ratings were inferior to girls. MUAC, forearm and wrist are thoroughly involved in gripping activities and are important in determining the grip strength in players, hence, showed positive correlation with grip strength test performance. Hand grip strength also correlated positively with palm length, palm width, ring & index finger lengths among players with the exception of older girls. It may be concluded that palm width and finger lengths may be more significant in handgrip strength and may prove to be good predictors of handgrip strength. Also it is invaluable for athletes to have adequate macronutrient intake for their strength and performance. Athletes should be made aware that low-energy intake will not sustain athletic training and performance.

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