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Influence of Hand Anthropometry and Nutrient Intake on Hand Grip Strength: A Correlational Study Among Young Indian Badminton Players

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ABSTRACT

Badminton is a fast shuttle-racquet game, which requires adequate endurance and agility for hitting shots. For consistent and superior performances, players need to develop decent nutritional status and tremendous physical fitness. The present study concerns with the effect of anthropometric indices and nutritional profiles on arm strength for racquet gripping. Adolescent male (N=100) and female (N=100) badminton players aged 10 to 15 years were selected from Nagpur, India, and arm anthropometric indices and skeletal muscles of the players were determined by tape and bioelectrical impedance analyzer respectively. Muscle growing macronutrient (protein) and skeletal developing micronutrients (calcium and phosphorus) were calculated from dietary data for consecutive 3 days by the 24-hour dietary recall method. Arm strength was appraised from the hand grip strength test. Statistically, the assessed data were tested at 1% and 5% significance levels. Pearson correlation coefficients were derived. All the age groups possessed substantially shorter arm lengths (2.41-15.43%) than reference standards. Older groups appeared to have greater arm circumferences (1.00-3.92 cm) than younger groups. Overall, boys showed elevated skeletal muscles (6.69% and 8.29%) than girls. Dietary protein and phosphorus ingestion were significantly higher (45.42-90.88% and 16.18-40.62%) than recommended dietary allowances (RDAs). Calcium intake (23.26-28.48%) was below the RDA. Older male players performed under excellent grade (38%) in the hand grip strength test, depicting masculine supremacy. Positive correlations (r= 0.0710 to 0.5947) between arm anthropometry and nutrient intake with grip strength proved their affirmative effects on delivering various explosive shots, which can enhance the performance level of emerging young players.

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1 Introduction

Badminton is an indoor fast-paced sporting exertion, having extensive, high-intensity activities interspersed with rest intervals (Guven et al. 2017). Players require immense physical capability especially dexterity, aerobic capacity, and explosive power, as it involves a great amount of running, jumping, and swinging, which actively utilizes all the major muscle groups (Dogra 2021). The role of anthropometry in badminton is the most crucial factor for optimum performance as "the physique, body composition, physical growth, and one's motor development are of fundamental importance in developing the criteria of talent selection and development in sports" (Mishra 2016). "Early adolescence is characterized by rapid changes in physical growth and motor skills, as well as the emergence of special skills and talents" (Brown et al. 2017). It is the most significant period in human growth and maturation; wherein, unique changes and many adult patterns are established (Patil et al. 2015).

"Nutrition is an important part of sports performance for young athletes, in addition to allowing for optimal growth and development" (Purcell 2013). A composed diet comprising suitable quantities of macronutrients and micronutrients are essential to deliver enough fuel for growth and activities (Purcell 2013). It helps to improve athletic performance by dwindling fatigue as well as disease and injury threats. Besides, it also empowers the athletes to enhance practice and speedy recovery (Hoch et al. 2008). Further, poor nutritional status can lead to growth failure or poor body dimensions in young players, which can also lead to dismal performance.

Muscle endurance is one of the most decisive factors for successful performance in individual and team sports (Newton and Kraemer 1994). The relation between active muscle strength and some specific movement performance are frequently interpreted as external validity of muscle strength tests (Wagh et al. 2017). The grip can be explained as a "forceful act resulting in flexion at all the joints of the fingers along with thumb when used as a stabilizer to the object being held between the finger and the palm" (Bohannon 1997). Grip strength is stated as a reliable and effective factor to assess the functional integrity of the hand, considering the crucial part of the musculoskeletal structure (Jones 1989). It has an imperative role in delivering effectiveness and efficiency throughout routine work and sports activities (Joseph et al. 2021). Badminton, being a racket sport, immensely requires a resilient hand grasping strength as it reflects comprehensive strength and overall health status of players (Massy-Westropp et al. 2004), hand and forearm muscles activities (Nwuga 1975), and somatic performance (Samson et al. 2000). Being a physiological parameter, it is influenced by several factors such as age, gender, and arm anthropometries (Massy-Westropp et al. 2004; Koley and Singh 2010; Kubota and Demura 2011). Significant correlation of total arm, upper arm, forearm lengths, palm length-width, hand span, and mid-upper arm, forearm, and wrist circumferences (Hager-Ross and Rosblad 2002; Koley and Srikanth 2016; Alahmari et al. 2019; Aydogmus and Ozcan 2020) with the grip strength were reported earlier. Furthermore, it is also considered to be a functional index of nutritional status (Casanova and Grunert 1989; Koley and Srikanth 2016; Nakandala et al. 2019).

Nowadays badminton emerges as the second-most played sport in India as 51% of respondents favored badminton as the sport they played most regularly (Sukumar 2021). But in comparison with South-East Asian and European countries, very few Indian players appear recurrently in international competitions. Unfortunately, due to limited sports science literatures, there is a lack of descriptive data on the physical and nutritional profiles of young Indian badminton players. So, considering the significance of the adolescent period for developing sports skills and for the aforementioned factors, it is an indispensable concern to assess the dietary intake as well as anthropometric indices and to understand their effect on the physical fitness of early adolescent badminton players of 10-15 years age for the enhanced performance level. Therefore, the present study appraises selected anthropometric indices; especially hand measures, body composition through bioelectrical impedance analysis, and particular macro and micronutrient intake, essential for musculo-skeletal build-up. Additionally, the paper concerns delineating the impact of all these parameters on arm strength, which is essential for engendering explosive power for performing shots in badminton.

Hypothesis testing was done by z test with formulating null hypothesis (H_0) and non-directional alternate hypothesis (H_1). The differences between recorded data and standards as well as recorded data between two age groups were assessed at 5% and 1% levels of significance for acceptance of H_0 or H_1.

2 Materials and Methods

2.1 Selection of subjects

For the present research, a total of 200 healthy and injury-free female and male players from 10-12 (N=100, Males: 50 and Females: 50) and 13-15 (N=100, Males: 50 and Females: 50) years age groups, involved in regular badminton game were purposively selected as sample population. The sample size determination was based on the availability of professional players enrolled in leading badminton training academies, clubs, and institutes from Nagpur city, Maharashtra, India. Only those players having at least 1.5 years of playing experience, regularly participating in various club, school, city, district, and national level competitions, and willing for assessment were considered for the present study. Players having major or minor injuries in the last three months, any serious health issues viz. diabetes, asthma, arthritis, etc., having irregular practice schedules, or furthermore not willing to take part in the assessment were kept out from the present study.

2.2 Ethical clearance

The research work was duly approved by the Central Drugs Standard Control Organization (Govt. of India) registered Institutional Ethics Committee, Arneja Heart and Multispecialty Hospital, Nagpur, and also was sanctioned by the Research and Recognition Committee of Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur, Maharashtra, India. Prior consent was taken from the coaches, players, and their guardians to perform assessments. All the assessments were done keeping in the view of COVID-19 safety measure protocols by strictly using mask, face shield, gloves, and sanitized instruments.

2.3 Anthropometric measurements

Anthropometry in sports science is perhaps one of the most decisive factors for finest performance. So considering its importance, measurements of selected arm related anthropometric variables like total arm length (TAL), upper arm length (UAL), lower arm length (LAL), hand span (HS), palm length (PL), palm width (PW) and arm circumferences, like mid-upper arm circumference (MUAC), Forearm circumference (FAC) and Wrist circumference (WC) of badminton players were recorded in centimeters. The measurements were taken by using a steel anthropometer and non-stretchable plastic tape. All the measurements were done at the closest 0.1 cm error margin due to minimal clothing thickness.

2.4 Body composition analysis

Body composition is an essential kinematics for the fitness of athletes. So, in this research study, under body composition analysis, arm skeletal muscle (SMA) percentage was measured through a digital bioelectrical impedance analyzer. Bioelectrical impedance analysis is a useful tool for estimating body composition. It is based on the subcutaneous fat (fat mass) and skeletal muscle (fat-free mass) which are related to two component (2C) body composition model (Lee and Gallagher 2008). It uses equations that can explain the statistical associations based on biological relations for a certain population. Also, the equations are convenient for only those subjects that have a proximate matching of physical outline with the reference population (Duren et al. 2008).

2.5 Nutrient intake assessment

Proper nutrition is indispensable for refining the performance of athletes (Fink et al. 2011). So, the implementation of proper dietary principles is very important in daily life. To determine players' nutrient intake, '24 hour dietary recalls method' for successive three days was followed (Hausswirth and Mujika 2013). Separate sheets of tables were provided to the players for recording each and every diet in their daily meals. Protein, calcium, and phosphorous content of diets consumed by the players were estimated by using a standard Indian food composition table (Gopalan et al. 2012; Longvah et al. 2017).

2.6 Physical strength test

As a racket sport, grip strength is very important in the game of badminton as players use several grips such as continental (handshake grip), eastern, and western (usually for forehand grips) grips for delivering shots during the game. The majority of players prefer to change grips for different shots selection in the match (Koley and Srikanth 2016). The hand grip strength (HGS) in kgs of the dominant hand of every player was measured through Camry electronic hand dynamometer. The equipment was held in the dominant hand with the extended and flexed forearm and elbow positioned at right angles. The players were directed to grip the dynamometer in such a way that the second phalanx is against the inner stirrup (Wagh et al. 2017). The subjects were instructed to give utmost force to the dynamometer for consecutive three times with a recovery interval of 30 seconds (Koley and Srikanth 2016). The average of three readings was recorded. Camry electronic hand dynamometer has excellent reliability to test grip strength among all age groups (Mani et al. 2019).

2.7 Statistical analysis

The acquired data was compiled, synthesized, and classified according to gender and age groups. The mean, standard deviation, range, and percentage of excess/deficit compared with corresponding references were calculated. The data were compared with age and gender-related reference values and RDAs using two-tailed z test (Nande and Vali 2010; Koley and Srikanth 2016; NCHS 2016; Aydogmus and Ozcan 2020; ICMR 2020). The conclusion was derived at 5% (α=0.05) and 1% (α=0.01) level of significance ($z < 1.960$; H_0 accepted at α=0.05 and 0.01, $1.960<z<2.576$; H_1 accepted at α=0.05 and H_0 accepted at α=0.01; $z>2.576$; H_1 accepted at α=0.05 and 0.01). The correlation of physical fitness with anthropometric profile as well as nutritional intake was derived by using Pearson's product-moment coefficient of correlation.

3 Results

The study represents a compiled data set of various assessed parameters of 200 badminton players. The descriptive statistics of the dataset suggested that it is well-modeled by a normal distribution.

3.1 Baseline characteristics

Sports specialization can be described as intense training of a single sport, barring all other sports round the year (Malina 2010; Jayanthi et al. 2011). So, the players of 10-12 years (Girls: 11.10 ± 0.86 years, Boys: 11.03 ± 0.84 years) and 13-15 years (Girls: 14.02 ± 0.83 years, Boys: 13.90 ± 0.86 years) who were meticulously engaged in the game of badminton for at least 1.5 years were considered as professionals in badminton and were of the main choice of the present study. The sports information of the subjects (Figure 1) specified that with the increasing age their involvement in the game practice was also increased. Elder groups showed >3 years of badminton practice (60% and 64%, for girls and boys, respectively).

3.2 Hand anthropometry

Badminton, being a racket sport needs a strong hand anthropometric profile for hitting effective shots. For assessing the arm musculoskeletal trait, selected anthropometric variables were measured and displayed in Table 1.

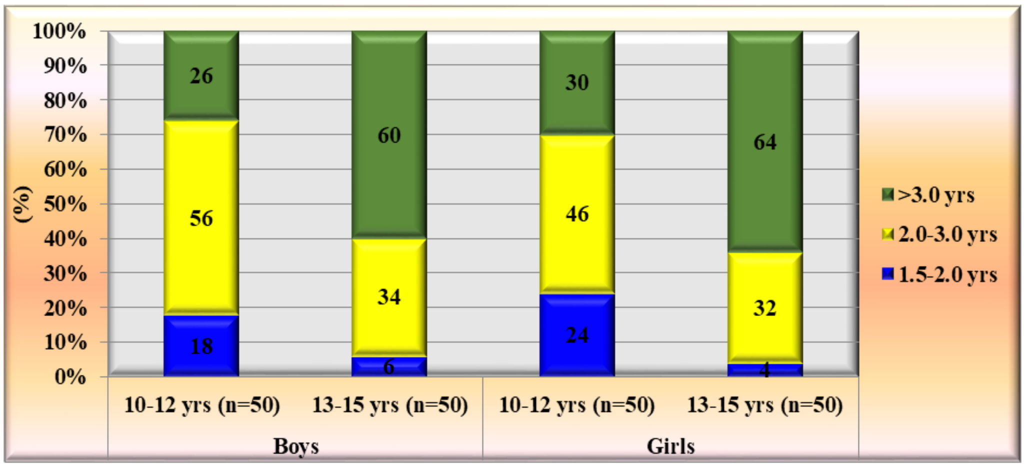

Figure 1 Percentage Distribution of Players from Different Age Groups based on Years of Game Practice

Table 1 Data on Hand Anthropometry of Badminton Players

	Parameters	Girls (N=100)			Boys (N=100)		
		10-12 years (n=50)	13-15 years (n=50)	z Values#	10-12 years (n=50)	13-15 years (n=50)	z Values#
1.	Total Arm Length (TAL) (cm)						
i.	Mean±SD	61.42±4.36	66.58±3.48		60.75±4.53	70.10±4.65	
ii.	Range	53.70-71.70	58.30-74.70		53.00-70.00	59.50-80.00	
iii.	Standard	68.36		6.54*	71.83		10.18*
iv.	z values§	11.26*	3.62*		17.30*	2.63**	
v	% Deficit	-10.15	-2.60		-15.43	-2.41	
2.	Upper Arm Length (UAL) (cm)						
i.	Mean±SD	22.89±2.00	25.31±1.62		22.52±2.02	26.18±2.04	
ii.	Range	19.00-28.00	20.60-28.50		19.20-27.00	21.40-31.00	
iii.	Standard	25.48		6.65*	26.12		9.01*
iv.	z values§	9.16*	0.74		12.60*	0.21	
v	% Deficit/Excess	-10.16	-0.67		-13.78	+0.23	
3.	Lower Arm Length (LAL) (cm)						
i.	Mean±SD	22.58±1.77	24.00±1.69		22.51±2.09	25.72±1.91	
ii.	Range	19.00-25.70	20.90-28.40		18.80-27.40	22.50-29.90	
iii.	Standard	21.36		4.10*	22.79		8.02*
iv.	z Values§	4.87*	11.05*		0.95	10.85*	
v	% Excess/Deficit	+5.71	+12.36		-1.23	+12.86	

	Parameters	Girls (N=100) 10-12 years (n=50)	Girls (N=100) 13-15 years (n=50)	z Values#	Boys (N=100) 10-12 years (n=50)	Boys (N=100) 13-15 years (n=50)	z Values#
4.	Hand Span (HS) (cm)						
i.	Mean±SD	18.80±1.44	20.27±1.18		18.11±1.75	21.22±1.43	
ii.	Range	15.50-22.00	17.70-23.50		15.20-21.40	17.00-23.80	
iii.	Standard	18.7		5.58*	21.0		9.73*
iv.	z Values§	0.49	9.41*		11.68*	1.09	
v	% Excess/Deficit	+0.53	+8.40		-13.76	+1.05	
5.	Palm Length (PL) (cm)						
i.	Mean±SD	15.96±1.07	17.27±0.87		15.66±1.15	18.41±1.30	
ii.	Range	13.70-18.50	15.70-19.20		13.80-18.00	15.20-20.50	
iii.	Standard	16.53		6.72*	17.61		11.20*
iv.	z Values§	3.77*	6.01*		11.99*	4.35*	
v	% Deficit/Excess	-3.45	+4.48		-11.07	+4.54	
6.	Palm Width (PW) (cm)						
i.	Mean±SD	6.89±0.42	7.20±0.38		6.75±0.57	7.72±0.59	
ii.	Range	6.00-8.00	6.30-7.90		5.60-8.00	6.20-9.00	
iii.	Standard	6.56		3.87*	6.58		8.36*
iv.	z values§	5.56*	11.91*		2.11**	13.66*	
v	% Excess	+5.03	+9.76		+2.58	+17.33	
7.	Mid Upper Arm Circumference (MUAC) (cm)						
i.	Mean±SD	20.69±3.28	23.32±2.27		20.23±2.87	24.15±4.13	
ii.	Range	15.00-29.00	18.00-32.00		15.50-27.00	15.50-33.00	
iii.	Standard	24.8	27.2	4.66*	24.4	28.5	5.51*
iv.	z Values§	8.86*	12.09*		10.27*	7.45*	
v	% Deficit	-16.57	-14.26		-17.09	-15.26	
8.	Forearm Circumference (FAC) (cm)						
i.	Mean±SD	19.67±2.08	21.73±1.65		19.59±1.92	22.94±3.20	
ii.	Range	15.00-25.00	19.00-30.00		15.50-24.00	16.50-35.00	
iii.	Standard	19.10	20.47	5.49*	19.10	20.47	6.35*
iv.	z Values§	1.94	5.40*		1.80	5.46*	
v	% Excess	+2.98	+6.16		+2.57	+12.07	
9.	Wrist Circumference (WC) (cm)						
i.	Mean±SD	13.49±1.18	14.49±1.24		13.59±1.08	15.32±1.32	
ii.	Range	11.00-16.00	12.70-20.50		11.00-15.50	12.00-18.00	
iii.	Standard	14.40	15.30	4.13*	14.60	16.00	7.17*
iv.	z Values§	5.45*	4.62*		6.61*	3.64*	
v	% Deficit	-6.32	-5.29		-6.92	-4.25	

z values# comparisons between younger and older groups; z values§ comparison between data of subjects and standards; Values with * indicate significant difference at both 5% and 1% levels (p<0.01), ** for the significant difference at 5% level but insignificant difference at 1% level (0.01<p<0.05) and with no mark indicate insignificant difference at both 5% and 1% levels (p>0.05).

3.2.1 Arm lengths

It was observed that younger boys had shorter total arm length (0.67 cm) than girls; whereas, elder boys had longer arms (3.52 cm) as compared with girl players. Both younger (Girls: 10.15%; z=11.26, p<0.01 and Boys: 15.43%; z= 17.30, p<0.01) and elder (Girls: 2.60%; z=3.62, p<0.01 and Boys: 2.41%; z= 2.63, p<0.01) players were unable to meet the standard arm lengths of Indian badminton players as per Koley and Srikanth (2016). In the present study, with an increment of age, the arm length development of boys (9.35 cm; z=10.18, p<0.01) was predominant over girls (5.16 cm; z=6.54, p<0.01). Mean UAL for younger groups depicted a significant deficit (Girls: 10.16%; z=9.16, p<0.01 and Boys: 13.78%; z=12.60, p<0.01) as compared to standard values (Koley and Srikanth 2016). On the contrary, older girls and boys exhibited trivial deficit of 0.67% (z=0.74, p>0.05) and surplus of 0.23% (z=0.21, p>0.05) than standards (Koley and Srikanth 2016). Like TAL, higher increments in UAL were also recorded throughout the ages in boys (3.66 cm; z=9.01, p<0.01) over girls (2.42 cm; z=6.65, p<0.01). Differences in LAL between elder and younger players were computed as 1.42 cm (z=4.10, p<0.01) for girls and 3.21 cm (z=8.02, p<0.01) for boys respectively. Except younger boys with a deficit of 1.23% (z=0.95, p>0.05) for all other players exceeded the corresponding reference standard values of badminton players [10-12 years girls: 5.71% (z=4.87, p<0.01), 13-15 years girls: 12.36% (z=11.05, p<0.01) and 13-15 years boys: 12.86% (z=10.85, p<0.01)] (Koley and Srikanth 2016).

3.2.2 Hand measures

The HS measures demonstrate that younger and older girls, as well as older boys had mean HS above (0.53%; z=0.49, p>0.05, 8.40%; z=9.41, p<0.01 and 1.05%; z=1.09, p>0.05) the standard values (Ruiz et al. 2006) whereas younger boys expressed considerable deficient mean value of 13.76% (z=11.68, p<0.01). Conspicuous differences of 1.47 cm (z=5.58, p<0.01) and 3.11 cm (z=9.73, p<0.01) were perceived between both the age groups for female and male players. The percentage excess for mean PL of older girls and boys was of 4.48% (z=6.01, p<0.01) and 4.54% (z=4.35, p<0.01), and younger girls and boys had shorter mean palms by 3.45% (z=3.77, p<0.01) and 11.07% (z=11.99, p<0.01) as compared with standards (Koley and Srikanth 2016). For PW, younger and elder gender had mean values far exceeded than standards (Koley and Srikanth 2016) with % excess of 5.03 (z=5.56, p<0.01), 2.58 (z=2.11, 0.05>p>0.01) and 9.76 (z=11.91, p<0.01) and 17.33 (z=13.66, p<0.01), for girls and boys respectively.

3.2.3 Arm circumferences

Assessing the parameters for arm circumference variables, it was noticed that the mean MUAC values for the elder girls and boys were larger than for younger groups (2.63 cm; z=4.66 and 3.92 cm; z=5.51, p<0.01). However, none of them were able to meet the corresponding age group standards for MUAC (NCHS 2016) by the deficit of 16.57% and 14.26% (z=8.86 and 12.09, p<0.01) for girls and 17.09% and 15.26% (z=10.27 and 7.45, p<0.01) for boys, respectively. Older badminton players (females and males) showed significantly higher mean FAC than standards (6.16%; z=5.40 and 12.07%; z=5.46, respectively, p<0.01) (Paswan 2020). Girls and boys aged between 10 and 12 years were marginally able to meet the standards for FAC (2.98%; z=1.94 and 2.57%; z=1.80, respectively, p>0.05) (Aydogmus and Ozcan 2020). Older players from both genders had significantly greater mean FAC than younger players (2.06 cm; z=5.49 and 3.35 cm; z=6.35, for older vs. younger girls and for older vs. younger boys, respectively). WC signified considerable deficits in girls (10-12 years: 6.32%; z=5.45, p<0.01 and 13-15 years: 5.29%; z=4.62, p<0.01) and boys (10-12 years: 6.92%; z=6.61, p<0.01 and 13-15 years: 4.25%; z=3.64, p<0.01) as compared to age and gender-specific standard values (Ozturk et al. 2017). Differences among WC of younger and older girls and boys were found to be 1.00cm (z=4.13, p<0.01) and 1.73 cm (z=7.17, p<0.01), respectively.

3.3 Body composition

Underbody composition variables arm skeletal muscle (SMA) was analyzed by bio- electrical impedance technique using arm–to-foot body composition analyzer.

3.3.1 Arm skeletal muscle

The SMA in Table 2 reflects that older girls possessed lesser skeletal muscle arms. However, trivial difference was recorded (0.70%; z=0.85, p>0.05). With increasing age, boys showed a gain in skeletal arm muscles (0.90%; z=1.21, p>0.05). Large individual variations were noted in SMA for girls and boys.

Table 2 Data on Skeletal Muscle-Arm of Badminton Players

	Parameters	Girls (N=100)			Boys (N=100)		
		10-12 years (n=50)	13-15 years (n=50)	z Values#	10-12 years (n=50)	13-15 years (n=50)	z Values#
1.	Skeletal Muscle-Arm (SMA) (%)						
i.	Mean±SD	34.49±4.18	33.79±4.04	0.85	41.18±4.59	42.08±2.60	1.21
ii.	Range	24.70-43.80	24.40-42.80		30.70-48.90	36.40-46.90	

z values# comparisons between younger and older groups

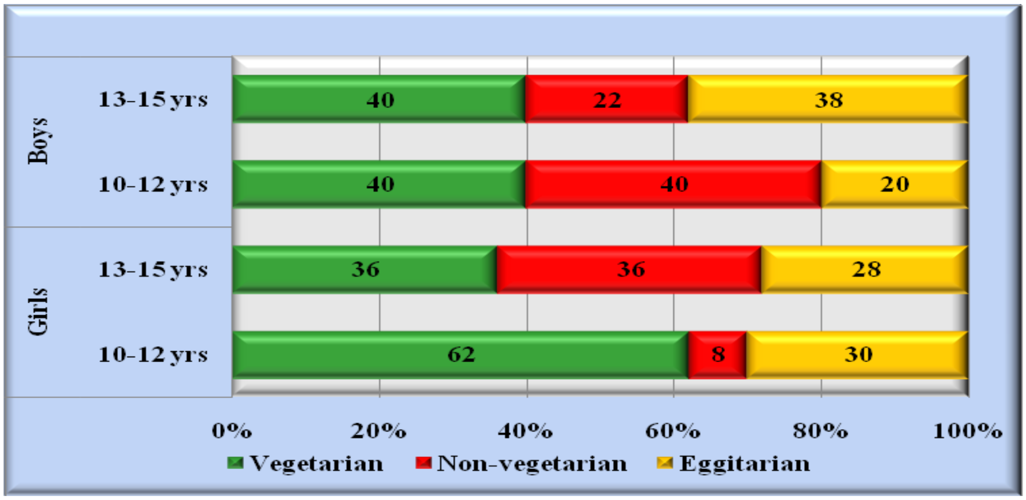

Figure 2 Food Habits of Subjects

Table 3 Data on Daily Intake of Protein, Calcium, and Phosphorus Intake by Players

	Parameters	Girls (N=100) 10-12 years (n=50)	Girls (N=100) 13-15 years (n=50)	z Values #	Boys (N=100) 10-12 years (n=50)	Boys (N=100) 13-15 years (n=50)	z Values #
1.	Protein (g/day)						
i.	Mean±SD	55.01±6.34	62.82±5.32		60.70±4.54	66.56±5.51	
ii.	Range	43.06-75.01	49.98-75.88		51.05-77.09	57.00-75.92	
iii.	RDAs	32.8	43.2	6.67*	31.8	44.9	5.80*
iv.	z Values§	24.77*	26.08*		45.01*	27.80*	
v	% Excess	+67.71	+45.42		+90.88	+48.24	
2.	Calcium (mg/day)						
i.	Mean±SD	622.06±172.59	715.19±176.58		652.29±128.98	764.09±185.71	
ii.	Range	307.04-1154.88	313.73-1260.19		416.19-906.78	436.55-1250.55	
iii.	RDAs	850	1000	2.67*	850	1000	3.50*
iv.	z Values§	9.34*	11.40*		10.84*	8.98*	
v	% Deficit	-26.82	-28.48		-23.26	-23.59	
3.	Phosphorous (mg/day)						
i.	Mean±SD	1161.79±178.44	1344.94±152.46		1305.83±130.40	1406.18±172.15	
ii.	Range	606.10-1623.13	1090.55-1616.52		889.77-1530.59	834.15-1726.75	
iii.	RDAs	1000		5.52*	1000		3.29*
iv.	z Values§	6.41*	16.00*		16.58*	16.68*	
v	% Excess	+16.18	+34.49		+30.58	+40.62	

z values# comparisons between younger and older groups; z values§ comparison between data of subjects and standards; Values with * indicate significant difference at both 5% and 1% levels ($p<0.01$), ** for significant difference at 5% level but insignificant difference at 1% level ($0.01<p<0.05$) and with no mark indicate insignificant difference at both 5% and 1% levels ($p>0.05$).

3.4 Nutrient intake

Figure 2 and Table 3 demonstrate the data on food habits and nutrient intake of players. From the nutritional assessment, it was observed that subjects had a wide variety of food choices from vegetarian, non-vegetarian, and eggetarian (Figure 2). A majority (62%) of younger female badminton players were found to be vegetarians. An equal number (40% and 36%, respectively) of boys aged between 10 to 12 years and girls aged between 13 to 15 years were found to have vegetarian and non-vegetarian food habits.

3.4.1 Protein

The mean protein intake of younger (Girls: 67.71%; z=24.77, p<0.01 and Boys: 90.88%; z=45.01, p<0.01) and older players (Girls: 45.42%; z=26.08%, p<0.01 and Boys: 48.24%; z=27.80, p<0.01) was found to be significantly higher than recommended dietary allowances (RDAs) (ICMR 2020). Overall girls (7.81 g/day; z=6.67, p<0.01) depicted a higher increment in protein intake than boys (5.86 g/day; z=5.80, p<0.01) through the ages.

3.4.2 Calcium

Calcium intake of players (Table 3) exposed significantly lesser means values for younger girls and boys as well as older girls and boys with a deficit of 26.82% (z=9.34, p<0.01), 23.26% (z=10.84, p<0.01), 28.48% (z=11.40, p<0.01) and 23.59% (z=8.98, p<0.01) as compared to RDAs, respectively. Although increment in dietary calcium intake among girls (93.13 mg/day, z=2.67, p<0.01) and boys (111.80 mg/day; z=3.50, p<0.01) with progressive ages attributed to the growth of skeletal traits during the puberty period.

3.4.3 Phosphorous

Phosphorous intake of players is displayed in Table 2. The mean intake of phosphorus by girls (10-12 years, 16.18%; z=6.41, p<0.01 and 13-15 years, 34.49%; z=16.00, p<0.01) and boys (10-12 years, 30.58%; z=16.58, p<0.01 and 13-15 years, 40.62%; z=16.68, p<0.01) from both age groups exceeded over the RDAs. Older groups of girls and boys consumed considerably higher quantities of phosphorus as compared to younger ones (183.15 mg/day; z=5.52 and 100.35 mg/day; z=3.29, respectively, p<0.01).

3.5 Physical fitness

Physical fitness is the major mantra today and players around the world are conscious of their fitness.

3.5.1 Hand grip strength

The hand grip strength (Table 4) of younger and older girls and boys demonstrates that both older girls and boys had significantly higher HGS (4.33 kg; z=5.83, p<0.01 and 7.48 kg; z=6.41, p<0.01)

Table 4 Data of Hand Grip Strength (HGS) for Players

	Parameters	Girls (N=100) 10-12 years (n=50)	Girls (N=100) 13-15 years (n=50)	z Values #	Boys (N=100) 10-12 years (n=50)	Boys (N=100) 13-15 years (n=50)	z Values #
1.	Hand Grip Strength (HGS) (kg)						
i.	Mean±SD	24.01±4.47	28.34±2.75		25.86±5.68	33.34±5.99	
ii.	Range	15.20-35.00	23.50-36.00		16.20-36.20	21.80-44.30	
iii.	Standard	20.72		5.83*	26.43		6.41*
iv.	z Values§	5.20*	19.59*		0.71	8.16*	
v	% Excess/Deficit	+15.88	+36.78		-2.16	+26.14	

z values# comparisons between younger and older groups; z values§ comparison between data of subjects and standards; Values with * indicate significant difference at both 5% and 1% levels (p<0.01), ** for significant difference at 5% level but insignificant difference at 1% level (0.01<p<0.05) and with no mark indicate insignificant difference at both 5% and 1% levels (p>0.05).

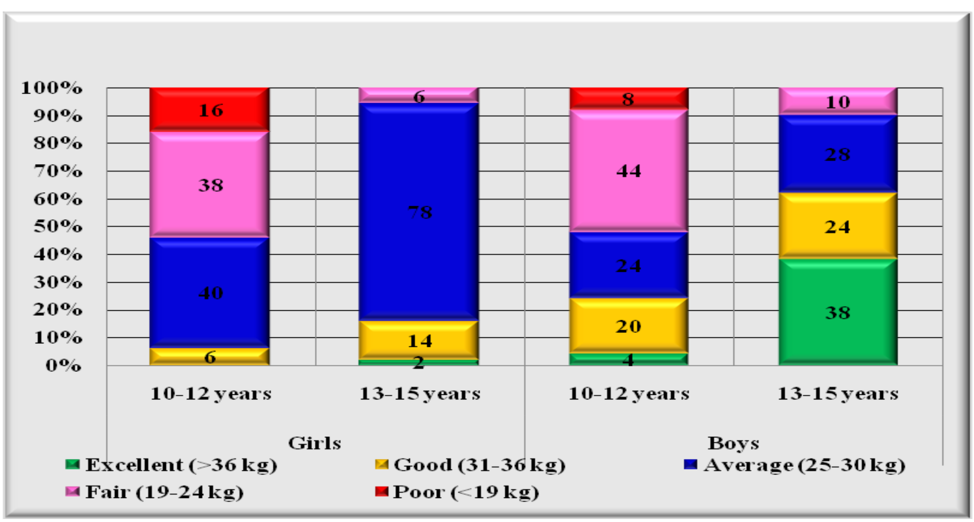

Figure 3 Distribution of Subjects based on Performance of Hand Grip Strength

than younger ones. Other than younger boys with a 2.16% (z=0.71, p>0.05) deficit in HGS, younger girls along with older girls and boys showed 15.88% (z=5.20, p<0.01), 36.78% (z=19.59, p<0.01) and 26.14% (z=8.16, p<0.01) excess of HGS.

HGS test involves the grip strength which can influence the angle of the racquet face at the time of hitting shots (Koley and Srikanth 2016). Figure 3 shows that 38% of boys aged between 13 and 15 years had excellent hand grip power. The majority (78%) of older female badminton players showed average hand grip power. Long duration of practicing, regular sports/fitness training, and upholding musculoskeletal feasibility over the years, the older players, especially the males had substantial explosive power with strong arm muscle endurance and resilient hand grip.

3.6 Coefficient of correlation between various parameters

Table 5 depicts the data on the coefficient of correlation of hand grip strength of players with anthropometric indices, body composition, and nutrient intake for players from all four age groups. From the correlation study, it was revealed that total, upper, and lower arm lengths among younger badminton players (girls and boys) reflected significant positive correlations with hand grip strength (r=0.3022, 0.05>p>0.01 to 0.5744, p<0.01). However, even though direct, these correlations were low among girls and boys of older age (r=0.1189 p>0.05 to 0.3575, 0.05>p>0.01). The larger the span of the hand, the longer and wider the palms, powerful was the hand grip among girls and boys from both age groups (r=0.1426, p>0.05 to 0.5221, p<0.01).

The hand grip strength of players was found to be directly related to arm skeletal muscle [r=0.4029, 0.5947, 0.2139, and 0.2068, respectively for girls aged 10-12 years (p<0.01), girls aged 13-15 years (p<0.01), boys aged 10-12 years (p>0.05) and boys aged 13-15 years (p>0.05)] (Table 5 and Figure 4).

Nutrition profile expressed enhanced positive correlations of protein (r= 0.1346, p>0.05 to r =0.3047, 0.05>p>0.01), calcium (r=0.1202, p>0.05 to 0.3329, 0.05>p>0.01) and phosphorus intake (r=0.0710 to 0.2211, p>0.05) with hand grip strength among all age groups of players. However, these correlations were low to moderate (Table 5 and Figures 5 - 7).

Table 5 Coefficient of Correlation of Hand Grip Strength (HGS) of Players with Different Variables

	Variables		r Values			
			Girls (N=1000)		Boys (N=100)	
			10-12 years (n=50)	13-15 years (n=50)	10-12 years (n=50)	13-15 years (n=50)
1	Hand Grip Strength vs. Anthropometric Indices	Total Arm Length	0.4556*	0.2371	0.5744*	0.2526
2		Upper Arm Length	0.4735*	0.1189	0.4731*	0.3575**
3		Lower Arm Length	0.3022**	0.1623	0.4768*	0.1325
4		Hand Span	0.4637*	0.2325	0.5099*	0.2497
5		Palm Length	0.4718*	0.4139*	0.5221*	0.2169
6		Palm Width	0.3552**	0.2267	0.4213*	0.1426
7		MUAC	0.1148	0.2044	0.4209*	0.2081
8		Fore Arm Circumference	0.1271	0.2011	0.4301*	0.1715
9		Wrist Circumference	0.2789	0.1247	0.4348*	0.1103
10	Hand Grip Strength vs. Body Composition	Arm Skeletal Muscle	0.4029*	0.5947*	0.2139	0.2068
11	Hand Grip Strength vs. Dietary Nutrient Intake	Protein Intake	0.1761	0.1378	0.3047**	0.1346
12		Calcium Intake	0.1202	0.3329**	0.1920	0.1517
13		Phosphorous Intake	0.0710	0.1823	0.2211	0.1290

Values with * indicate significant difference at both 5% and 1% levels (p<0.01), ** for significant difference at 5% level but insignificant difference at 1% level (0.01<p<0.05) and with no mark indicate insignificant difference at both 5% and 1% levels (p>0.05).

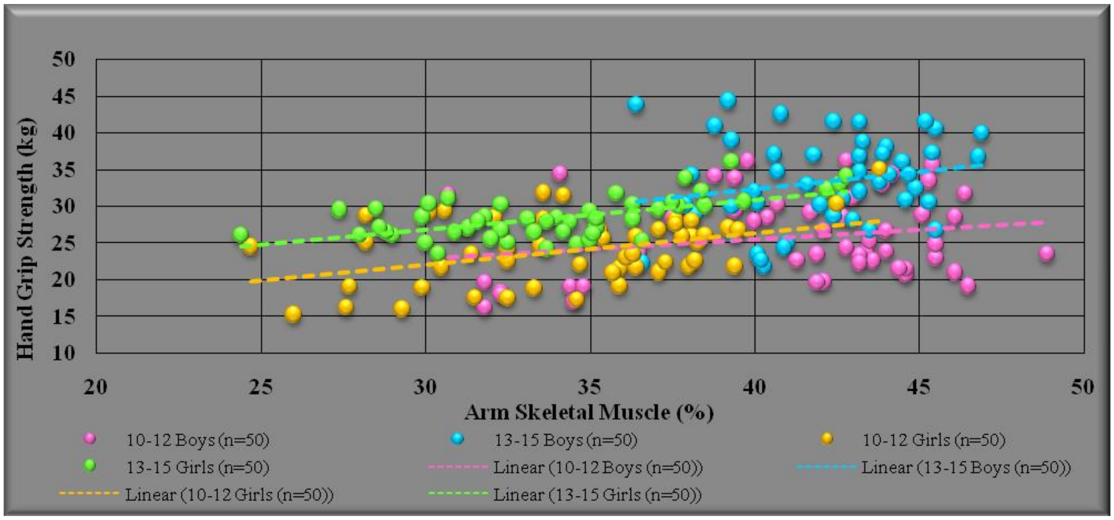

Figure 4 Scatter Graph for Correlation between Hand Grip Strength and Arm Skeletal Muscle among Subjects

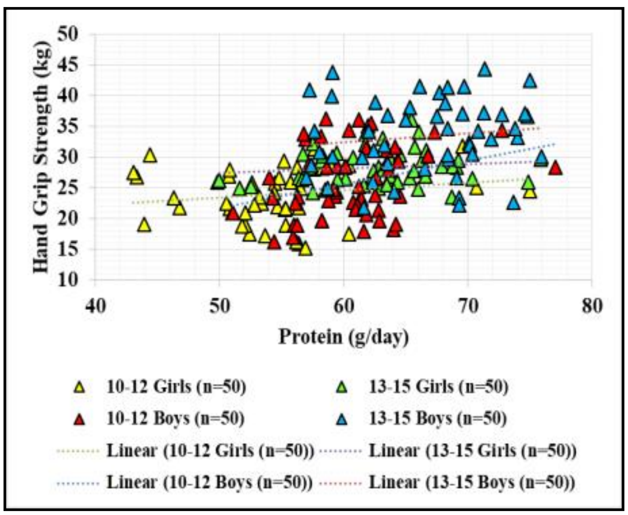

Figure 5 Binary Plot of Dietary Protein vs. Hand Grip Strength

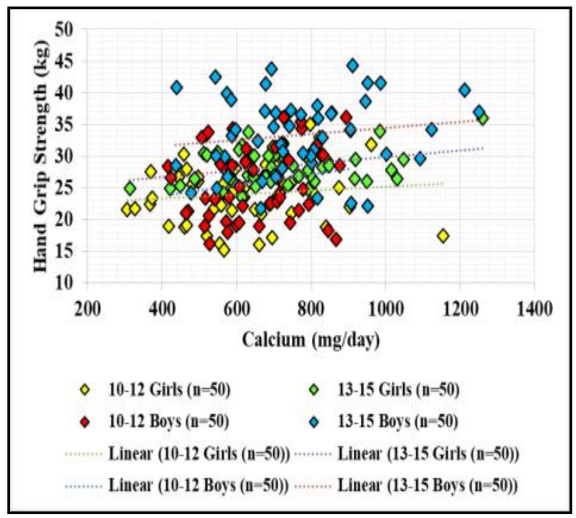

Figure 6 Binary Plot of Dietary Calcium vs. Hand Grip Strength

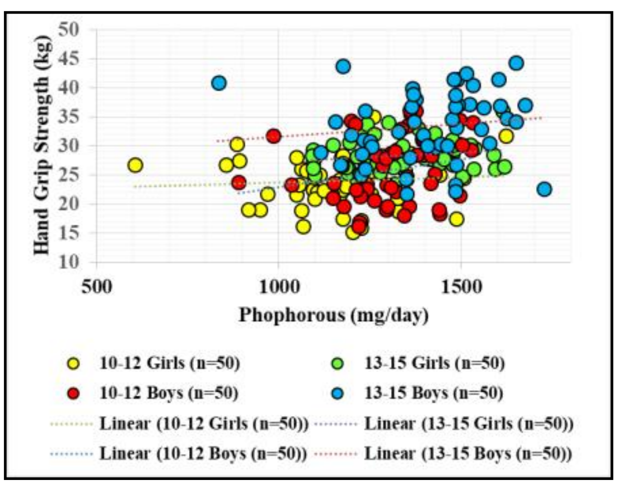

Figure 7 Binary Plot of Dietary Phosphorous vs. Hand Grip Strength

4 Discussion

The present study results have provided an exceptional insight into the impact of hand anthropometry, arm muscle mass, and nutritional profile on grip strength from the perspective of young Indian badminton athletes. However, few qualitative studies for badminton players as well as other athletes in Indian and Global scenarios were explored to complement the current literature.

4.1 Hand anthropometry

4.1.1 Arm lengths

The TAL of badminton players in the present study were longer than the gymnasts (57.08 cm; n=60) as studied by Khan and Srinivasa (2015) and basketballers (Girls: 56.30 cm, 61.84 cm, and Boys: 54.61 cm, 64.08 cm; n=400) as reported by Agrawal and Nande (2020) for the same age group. Additionally, Mishra (2016) also reported similar results while comparing the TAL between badminton (73.35 cm, n=30) and table tennis players (72.74 cm, n=30). Considering the standards as per NCHS (2016) (Girls: 32.3 cm, 34.9 cm, and Boys: 32.1 cm, 36.6 cm), all the age groups had significantly shorter UAL than the standards. However, a similar trend of higher increment in UAL through the ages in boys confirmed masculine dominance in early puberty skeletal development. Mean LAL of badminton players were lesser than Muqarram (2015) reported intervarsity (26.15 cm; n=227), national (26.57 cm; n=131), and state level (26.48 cm; n=42) Indian long-distance runners between 18 and 25 years of age and Fallahi and Jadidian (2011) recorded Iranian national and collegian grip athletes (26.86 cm; n=40) between 19 to 29 years of age.

4.1.2 Hand measures

Both PL (Girls: 1.31 cm; z=6.72, $p<0.01$ and Boys: 2.75 cm; z=11.20, $p<0.01$) and PW (Girls: 0.31 cm; z=3.87, $p<0.01$ and Boys: 0.97 cm; z=8.36, $p<0.01$) measurements revealed visible growth among both the genders as increase in age. Agrawal and Nande (2020) also reported similar increment for PL (Girls: 0.88 cm and Boys: 1.68 cm) and PW (Girls: 0.28 cm and Boys: 0.61 cm) among male (n=200) and female (n=200) basketballers whereas, Fallahi and Jadidian (2011) measured wider HS (21.24 cm) and PW (9.21 cm) among Iranian athletes (n=40) (19-29 years).

4.1.3 Arm circumferences

Among the 10-12 age group, as compared to Turkish badminton athletes (11.8 ± 0.1 years, n=72), Aydogmus and Ozcan (2020) measured higher MUAC (22.00 cm) and lower FAC (19.10 cm) than with Indian players of the present study, although Marwat et al. (2021) recorded higher MUAC (25.61 cm) and FAC (25.01 cm) among Pakistani school level badminton players as compared to Indian adolescent players. Raschka and Schmidt (2013) also assessed higher MUAC (Male: 29.2 cm and Female: 26.8 cm) and FAC (Male: 28.2 cm and Female: 25.2 cm) for senior German professional badminton players (Male: 22.70 years; n=20 and Female: 24.00 years; n=20). Considering world-class badminton players, Hume et al. (2008) observed significantly higher readings of MUAC, FAC and WC among singles (Male; 26.1 years: 30.1 cm, 27.6 cm and 16.6 cm; n=18 and Female; 25.1 years: 27.6 cm, 24.1 cm and 14.8 cm; n=20) and doubles (Male; 26.5 years: 30.9 cm, 27.3 cm and 16.3 cm; n=35 and Female; 24.5 years: 27.9 cm, 24.1 cm and 14.7 cm; n=36) players.

4.2 Body composition

4.2.1 Arm skeletal muscle

Like the present study for both the age groups, Sule and More (2020) analyzed superior higher skeletal muscle (10.75%) among elite male (n=20) and female (n=10) badminton players selected from various parts of the state of Maharashtra. Even Abian-Vicen et al. (2012) also assessed higher body muscle percentage of men’s singles players (50.2 ± 1.3 %, n=46, age 22.7 ± 4.2 years) over women’s singles players (46.5 ± 2.0 %, n=24, age 23.0 ± 5.7 years) at National Spanish badminton championship. However, the Spanish players were found to have significantly higher body muscles as compared to Indian players in the present study.

4.3 Nutrient intake

4.3.1 Protein

Protein is the foremost macronutrient for skeletal muscle growth. Masculine pre-eminence in skeletal muscle was also supported by higher protein intake observed among players. Deshpande and Nande (2018) assessed the protein intake of females (10-12 years. 48.59 ± 6.44 g/day, 13-15 years. 50.05 ± 5.83 g/day) and male (10-12 years. 53.84 ± 11.78 g/day, 13-15 years. 58.11 ± 11.72 g/day) Indian gymnasts of contemporary age groups. For this study, the protein intake tendency among all the age groups was quite higher and players were found to be consuming chicken, fish, and eggs. Foods like milk, curd, paneer/cheese, pulses, whole legumes, etc. were also responsible for the higher protein intake of players.

4.3.2 Calcium

Among various micronutrients, calcium is a vital mineral for the growth, preservation, and repairing of skeletons. It plays several important roles in regularising muscle contraction, nerve conduction, and blood coagulation (Culp 2015). Calcium rich bones are usually less susceptible to be fractured. Similar to the present study, Nande et al. (2009) also revealed an analogous deficiency with 52.89% (females: 20.45 years; n=4) and 62.2% (males: 21.87; n=4) among university and/ state level badminton players as compared with RDAs (Satyanarayana 1991).

4.3.3 Phosphorous

Phosphorous is the second most profuse mineral in the body following calcium. The foremost role of phosphorous is the formation of bones and teeth. It is also a desirable nutrient for the growth, maintenance, and restoration of cells and tissues (Moshfegh 2016). It is so ubiquitous in various foods that phosphorus deficiency may take places only at near starvation conditions or the presence of any metabolic disorder (Institute of Medicine 1997). Higher intake of phosphorous as compared to RDAs in all the age groups was due to the presence of surplus phosphates in foods preservatives and beverages such as flavored synthetic juices and nowadays it is commonly observed that adolescent players are tempted to have beverages after intense practice. Further, a close association between protein and phosphorus ingestion is observed. The dietary sources of protein usually provide phosphorus (Fouque et al. 2011). However, plant protein has a 40% to 50% lower absorption rate of organic phosphorus in comparison with animal protein (Gonzalez-Parra et al. 2012). All the groups of badminton players in the present study showed excessive intake of both protein and phosphorous in their diets. Contrary to the result of the present study, Nande et al. (2009) observed a substantial deficiency in phosphorus intake with 37.24% (females: 20.45 years; n=4) and 40.07% (males: 21.87; n=4) among university and/or state level badminton players as compared with RDAs (Satyanarayana 1991).

4.4 Physical fitness

4.4.1 Hand grip strength

HGS is the imperative parameter to assess the upper flex or musculature of the forearm and hand strength of badminton players. Compared with Turkish professional players, the HGS of the present study was found to be reasonably higher than the evaluation of Guven et al. (2017) [20.43 kg; n=15 (age: 11.20 years)] among younger groups but significantly lower than the assessment by Ozgur and Hotaman (2020) [Male: 46.10 kg; n=5 and Female: 32.45 kg; n=9 (age 15.5 years)] among older groups. Moreover, Akinbiola et al. (2017) determined significantly high HGS value in male (27.86 years) [47.07 kg; n=14] and female (23.63 years) [33.06 kg; n=8] Nigerian sub- elite badminton players.

4.5 Coefficient of correlation between various parameters

Low to moderate assenting correlations confirmed that the hand anthropometry along with arm skeletal muscle had a stimulus impression on strength and flexibility of the arm for forehand and backhand shots that affects the pace, spin, and placement of shots. Koley and Srikanth (2016) established significant positive correlations (r = 0.196 to 0.688) of handgrip strength of both hands with upper arm circumference, upper, lower, and total arm lengths, hand length, and breadth among junior and senior level Indian badminton athletes (12–25 years). Aydogmus and Ozcan (2020) also experienced similar affirmative correlations (r = 0.18 to 0.34) of MUAC and FAC with HGS in Turkish 10-12 years of badminton athletes (n=72). Even, Alahmari et al. (2019) also delineated a significant positive correlation that hand dimensions viz. hand circumference, hand span, hand length, and palm length were significantly correlated with the HGS in 6-16 years school going girls (n=100) (r = 0.521 to 0.755) and boys (n=100) (r = 0.678 to 0.804) of Saudi Arabia.

The relationship between protein intake and hand grip power signified the importance of protein intake for muscle endurance for playing different explosive shots for these players. In comparison to other grip strength games like basketball, Agrawal and Nande (2020) also reflected similar positive correlations (r = 0.0168 to 0.1634) with protein intake among the players of respective age groups of the present study. Also, a positive correlation of calcium and phosphorous with hand grip strength might indicate the fact that the growth of arm bones, which gives momentous advantages to the players for choosing forehand and backhand shots.

The limitation of the present study was represented by spatial population limitation as the samples were only collected from professional badminton academies of Nagpur city, Maharashtra, India.

5 Conclusion

Overall, the anthropometric indices of female and male badminton players were well developed as age progressed, which was evident from the results. Significant increments were noticed in arm lengths, palm length and width, and hand span, all of which are crucial for enhanced performance among badminton players. Increment in arm circumferences along with skeletal muscle showed the development of muscles continued with ascending ages. Further, a significant masculine preponderance of skeletal growth was found among these players at a young age. The nutritional profile also confirmed a good intake of protein and phosphorus which are involved in bone development and arm muscle growth. In general, apart from consistent badminton practice and fitness training right from a younger age, assenting effects of all anthropometric parameters and nutrient intake can lead to enhance the successive performance in terms of arm strength.

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Conflicts of interest

The authors affirm that they do not have any conflict of interest.

References

Abian-Vicen, J., Del Coso, J., Gonzalez-Millan, C., Salinero, J.J., & Abian, P. (2012). Analysis of dehydration and strength in elite badminton players. *PLOS ONE 7*(5), e37821. DOI: 10.1371/journal.pone.0037821.

Agrawal, R.P., & Nande, P.J. (2020). Hand anthropometry: correlation with grip strength and macronutrient intake among basketball players. *International Journal of Physical Education, Sports and Health*, *7*(1), 138-145.

Akinbiola, O.O., Adeniran, S.A., & Akinnubi, C.F. (2017). Anthropometric, physiological and performance characteristics of sub-elite Nigerian badminton players. *International Journal of Scientific & Engineering Research, 8*(8), 1872-1883.

Alahmari, K.A., Kakaraparthi, V.N., Reddy, R.S., Silvian, P.S., et al. (2019). Percentage difference of hand dimensions and their correlation with hand grip and pinch strength among school children in Saudi Arabia. *Nigerian Journal of Clinical Practice*, *22*(10), 1356-1364. DOI: 10.4103/njcp.njcp_121_19.

Aydogmus, M., & Ozcan, N. (2020). Investigation of the relationship between arm skin thickness and circumference measurement and hand grip strength of children attending with badminton sport. *Turkish Journal of Sport and Exercise*, *22*(1), 111-115. DOI: 10.15314/tsed.631132.

Bohannon, R.W. (1997). Reference values for extremity muscle strength obtained by handheld dynamometry from adults aged 20 to 79 years. *Archives of Physical Medicine and Rehabilitation*, *78*(1), 26-32. DOI: 10.1016/s0003-9993(97)90005-8.

Brown, K.A., Patel, D.R., & Darmawan, D. (2017). Participation in sports in relation to adolescent growth and development. *Translational Pediatrics*, *6*(3), 150-159. DOI: 10.21037/tp.2017.04.03.

Casanova, J.S., & Grunert, B.K. (1989). Adult prehension: Patterns and nomenclature for pinches. *Journal of Hand Therapy*, *2*(4), 231-244. DOI: 10.1016/S0894-1130(89)80037-7.

Culp, A. (2015). The power of vitamins in athletics. Available at https://training-conditioning.com/article/the-power-of-vitamins/ accessed on 2nd September, 2021.

Deshpande, P., & Nande, P. (2018). Anthropometric measurements, macronutrient intake and aerobic work power of gymnasts. *International Journal of Researches in Biosciences, Agriculture and Technology*, *VI*(Spl. 1), 61-77.

Dogra, R. (2021). 10 Reasons Why Kids Should Play Badminton. Available at https://www.piggyride.com/blog/10-reasons-why-kids-should-play-badminton, accessed on 17th October, 2021.

Duren, D.L., Sherwood, R.J., Czerwinski, S.A., Lee, M., et al. (2008). Body composition methods: comparisons and interpretation. *Journal of Diabetes Science and Technology*, *2*(6), 1139-1146. DOI: 10.1177/193229680800200623.

Fallahi, A.A., & Jadidian, A.A. (2011). The effect of hand dimensions, hand shape and some anthropometric characteristics on handgrip strength in male grip athletes and non-athletes. *Journal of Human Kinetics, 29*(2011), 151-159. DOI: 10.2478/v10078-011-0049-2.

Fink, H.H., Mikesky, A.E., & Burgoon, L.A. (2011). *Practical applications in sports nutrition*. Burlington Ma: Jones and Barlett learning.

Fouque, D., Pelletier, S., Mafra, D., & Chauveau. P. (2011). Nutrition and chronic kidney disease. *Kidney International*, *80*, 348-357. DOI: 10.1038/ki.2011.118.

Gonzalez-Parra, E., Gracia-Iguacel, C., Egido, J., & Ortiz, A. (2012). Phosphorus and nutrition in chronic kidney disease. *International Journal of Nephrology*, *Article ID 597605*, 1-5. DOI: 10.1155/2012/597605.

Gopalan, C., Rama Sastri, B.V., & Balasubramanian, S.C. (2012). Nutritive value of Indian foods. National Institute of Nutrition. Indian Council of Medical Research, Hyderabad.

Guven, F., Inceler, A., Aktas, S., Koc, S., Yilgin, A., & Er, Y. (2017). Effects of badminton training on some physical parameters in badminton players aged 10 to 12 years. *Turkish Journal of Sport and Exercise*, *19*(3), 345-349. DOI: 10.15314/tsed.349484.

Hager-Ross, C., & Rosblad, B. (2002). Norms for grip strength in children aged 4-16 years. *Acta Paediatrica*, *91*(6), 617-625. DOI: 10.1080/080352502760068990.

Hausswirth, C., & Mujika, I. (2013). *Recovery for performance in sport*. INSEP: Human Kinetics, 211.

Hoch, A.Z., Goossen, K., & Kretschmer, T. (2008). Nutritional requirements of the child and teenage athlete. *Physical Medicine and Rehabilitation Clinics of North America*, *19*(2), 373-398. DOI: 10.1016/j.pmr.2007.12.001.

Hume, P., Png, W., Aziz, A.R., Makhtar, R., et al. (2008). Differences in world badminton players' physical and proportionality characteristics between singles and doubles players. *Conference: International Convention on Science, Education and Medicine in Sport: Kinanthropometry XI: 2008 Pre-Olympic Congress Anthropometry Research*. SPRINZ, Guangzhou, China.

Indian Council of Medical Research (ICMR) (2020). Nutrient requirements for Indians: recommended dietary allowances, estimated average requirements. *A report of the expert group of the Indian Council of Medical Research*. National Institute of Nutrition, Hyderabad, India.

Institute of Medicine (1997). *Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride*. Washington, (DC): The National Academies Press (US).

Jayanthi, N.A., Pinkham, C., Durazo-Arivu, R., Dugas, L., & Luke, A. (2011). The risks of sports specialization and rapid growth in young athletes. *Clinical Journal of Sports Medicine, 21*(2), 157. DOI: 10.1097/JSM.0b013e3182114d0a.

Jones, L.A. (1989). The assessment of hand function: a critical review of techniques. *The Journal of Hand Surgery*, *14*(2), 221-228. DOI: 10.1016/0363-5023(89)90010-5.

Joseph, E., Rajpurohit, V.S., Sharma, M.R., Jadiya, M.K., & Choudhary, A. (2021). Evaluation of maximal isometric hand grip strength in different sports. *Indian Journal of Physiotherapy and Occupational Therapy*, *15*(1), 25-29.

Khan, A.A., & Srinivasa, R. (2015). Relationship of physical fitness, anthropometric and body composition variables to performance in still rings in men artistic gymnastics. *International Journal of Fitness, Health, Physical Education & Iron Games*, *2*(2), 26-34.

Koley, S., & Singh, A.P. (2010). Effect of hand dominance in grip strength in collegiate population of Amritsar, Punjab, India. *The Anthropologist*, *12*(1), 13-16. DOI:10.1080/09720073.2010.11891125.

Koley, S., & Srikanth, G.B. (2016). Correlation of hand grip strength with selected anthropometric variables in Indian junior and senior badminton players. *International Journal of Recent Scientific Research*, *7*(4), 10351-10355.

Kubota, H., & Demura, S. (2011). Gender differences and laterality in maximal handgrip strength and controlled force exertion in young adults. *Health*, *3*(11), 684-688. DOI: 10.4236/health.2011.311115.

Lee, S.Y., & Gallagher, D. (2008). Assessment methods in human body composition. *Current Opinion in Clinical Nutrition and Metabolic Care*, *11*(5), 566-572. DOI: 10.1097/MCO.0b013e32830b5f23.

Longvah, T., Ananthan, R., Bhaskarachary, K., & Venkaiah, K. (2017). Indian food composition tables. National Institute of Nutrition (Indian Council of Medical Research), Department of Health Research, Ministry of Health & Family Welfare, Government of India, Hyderabad, Telangana State, India.

Malina, R.M. (2010). Early sport specialization: roots, effectiveness, risks. *Current Sports Medicine Reports*, *9*(6), 364-371. DOI: 10.1249/JSR.0b013e3181fe3166.

Mani, P., Sethupathy, K., & Francis, A.K. (2019). Test-retest reliability of electronic hand dynamometer in health adults. *International Journal of Advanced Research*, *7*(5), 325-331. DOI: 10.21474/IJAR01/9042.

Marwat, N.M., Khan, M.A., Anjum, G.S., Khan, M.I., et al. (2021). Physical and anthropometric fitness of school level badminton players of Dera Ismail Khan (KP), Pakistan. *PalArch's Journal of Archaeology of Egypt / Egyptology*, *18*(08), 3669-3674.

Massy-Westropp, N., Rankin, W., Ahern, M., Krishnan, J., & Hearn, T.C. (2004). Measuring grip strength in normal adults: reference ranges and a comparison of electronic and hydraulic instruments. *The Journal of Hand Surgery*, *29*(3), 514-519.

Mishra, P.K. (2016). A comparative study of selected anthropometric measurements between badminton and table-tennis players of Sardar Patel University. *International Journal of Physical Education, Sports and Health*, *3*(6), 69-71.

Moshfegh, A.J., Kovalchi, A.F., & Clemens J.C. (2016). Phosphorus intake of Americans. *What We Eat In America (WWEIA)*, NHANES 2011-2012, *Brief No. 15*.

Muqarram, M. (2015). Comparative study on lower arm length of athletes at different level of competition. *Journal of Physical Education Research*, *2*(1), 40-56.

Nakandala, P., Manchanayake, J., Narampanawa, J., Neeraja, T., et al. (2019). Descriptive study of hand grip strength and factors associated with it in a group of young undergraduate students in University of Peradeniya, Srilanka who are not participating in regular physical training. *International Journal of Physiotherapy*, *6*(3), 82-88. DOI: 10.15621/ijphy/2019/v6i3/183876.

Nande, P., & Vali, S.A. (2010). Fitness evaluation test for competitive sports. *Himalaya Publishing House*.

Nande, P., Mudafale, V., & Vali, S. (2009). Micronutrient status of male & female players engaged in different sports disciplines. *Journal of Exercise Science and Physiotherapy*, *5*(1), 1-13.

National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC) and U.S. Department of Health and Human Services (2016). *Anthropometric reference data for children and adults*: United States, 2011-2014. Vital and Health Statistics, *3*(39).

Newton, R.U., & Kraemer, W.J. (1994). Developing explosive muscular power: implications for a mixed methods training strategy. *Strength and Conditioning Journal*, *16*(5), 20-31.

Nwuga, V.C. (1975). Grip strength and grip endurance in physical therapy students. *Archives of Physical Medicine & Rehabilitation*, *56*(7), 297-300.

Ozgur, B., & Hotaman, F. (2020). Relationship between some motoric and technical performance characteristics of U17 Turkish national badminton players. *Journal of Physical Education and Sport*, *20*(3), 2205-2212. DOI: 10.7752/jpes.2020.s3296.

Ozturk, A., Cicek, B., Mazicioglu, M.M., Zararsiz, G., & Kurtoglu, S. (2017). Wrist circumference and frame size percentiles in 6-17 year old Turkish children and adolescents in Kayseri. *Journal of Clinical Research in Pediatric Endocrinology*, *9*(4), 329-336. DOI: 10.4274/jcrpe.4265.

Paswan, D. (2020). An analysis of selected kinanthropometric variables between badminton and tennis players: a detailed comparative approach. *International Journal of Physical Education, Sports and Health*, *7*(4), 211-213.

Patil, S.S., Patil, S.R., Durgawale, P.M., & Kakade, S.V. (2015). Study of physical growth standards of adolescents in the age group of 10 to 15 years from Satara district of Maharashtra, India. *Journal of Krishna Institute of Medical Sciences University*, *4*(4), 42-56.

Purcell, L.K., Canadian Paediatric Society, Paediatric Sports and Exercise Medicine Section (2013). Sport nutrition for young athletes. *Paediatrics & Child Health*, *18*(4), 200-202. DOI: 10.1093/pch/18.4.200.

Raschka, C., & Schmidt, K. (2013). Sports anthropological and somatotypical comparison between higher class male and female badminton and tennis players. *Papers on Anthropology*, *XXII*, 153-161. DOI: 10.12697/poa.2013.22.17.

Ruiz, J.R., Espana-Romero, V., Ortega, F.B., Sjostrom, M., et al. (2006). Hand span influences optimal grip span in male and female teenagers. *The Journal of Hand Surgery*, *31*(8), 1367-1371. DOI: 10.1016/j.jhsa.2006.06.014.

Samson, M.M., Meeuwsen, I.B., Crowe, A., Dessens, J.A., et al. (2000). Relationships between physical performance measures, age, height and body weight in healthy adults. *Age and Ageing*, *29*(3), 235-242. DOI: 10.1093/ageing/29.3.235.

Satyanarayana, K. (1991). *Sports nutrition: put back the Pep. Nutrition* (April), NIN / ICMR, Hyderabad.

Sukumar, D. (2021). Badminton emerges as second-most played sport in India. Available at https://www.sportskeeda.com/badminton /badminton-emerges-second-most-played-sport-in-india, accessed on 16th October, 2021.

Sule, S., & More, D. (2020). Physiological and nutritional profile of elite badminton players. Available at https://www.academia.edu /43354496/Physiological_and_Nutritional_Profile_of _Elite_ Badminton_Players 1-8, accessed on 19th August, 2021.

Wagh, P.D., Birajdar, G., & Nagavekar, M. (2017). Comparison of handgrip muscle strength in sportsmen and sedentary group. *IOSR Journal of Dental and Medical Sciences*, *16*(7), 62-65. DOI: 10.9790/0853-1607046265.