SUMMARY AND CONCLUSION

Man principally differs from all other primates by his attainment of truly erect posture and biped mode of locomotion. In fact, posture is a biomechanical interaction between the organism and gravity. When human stands erect, a specific disposition of muscular attachment is necessary to provide adequate leverage for balancing the body in their erect posture and for working efficiently upon the limbs in its movements. Back strength is one of the important characteristics to keep the individuals at bay from back pain. Low back pain has been recognized as a common phenomenon that affects public health (Maniakis and Gray, 2000). Approximately 90% of all people experience low back pain at some point of time in their lives (Frymoyer, 1988) and up to 50% of working adults have back pain every year (Nachemson, 1992). Back plays a huge role in how entire body functions because it attaches to hips, abdominals, chest, shoulders and neck. Strength is one of the most practical measures to evaluate physical fitness of a person. It can be defined as the maximum force which can be exerted against an immovable object (static or isometric strength), the heaviest weight which can be lifted or lowered (dynamic strength), or the maximum torque which can be developed against a pre-set rate-limiting device (isokinetic strength) (Thompson, 1994). The maintenance of erect upright posture and the performance of voluntary movements are highly integrated harmonious functions of muscle, soft issue and central-peripheral nervous system. A number of studies reveal that muscle strength is critical to health and well-being (Kraus and Hirschland, 1953, McDonagh and Davies, 1984, Astrand and Rodahl, 1986). Several external factors, viz. altitude (Ruff and Strughold, 1942), position of exerting strength (Teraoka, 1979), diet (Keys et al., 1950) and internal factors, viz. age, sex (Mathiowetz, 1985), height, weight (Schmidt and Toews, 1970) etc. influence the maximum force that can be exerted by a muscle (Berne and Levy, 1983). A person’s maximum strength decreases with increasing age (Frontera et al., 1988, Lexell et al., 1988; Roy and Pal, 2001). The decline in strength in muscles of the lower extremities may be associated with gait disorders, falls, and hip fractures. Weakness of low back muscles may be related to problems such as disc herniation and chronic low back pain of soft tissue origin.
Summary and Conclusion

The prediction of back strength would be useful to determine the relative force level of a given exercise and pre injury back strength. The importance of studying back strength is immense as the number of patients with back pain is increasing at alarming rate. But literature related to back strength is scanty, especially in Indian context. Thus the present study was planned.

6.1 Aims and Objectives

The aims of the present study were:

- To estimate the back strength as normative value in Indian population covering a wide age range.
- To study the gender differences on the basis of back strength in various age groups.
- To search any association of back strength with different anthropometric variables of the studied population.
- To estimate the back strength of sports persons of different sports events for performance enhancement.

6.2 Hypothesis

Normative values of back strength of Indian population would differ between two sexes. There would be some associations between back strength and different anthropometric variables. There would be considerable differences in back strength in sports persons of various sports events.

6.3 Materials and Methods

Sample Selection

A total of 1087 individuals were considered as samples for the present study. Of those, 662 normal healthy individuals from both sexes, aged 13-18 years were selected purposively from Jalandhar, Punjab. The power of the study was 90%, α = 0.05. These subjects were further subdivided into three categories, viz. early-adolescents, mid-adolescents and late-adolescents. To estimate the back strength of early-adolescents (n=221, 110 boy and 111 girl students) of 13-14 years age group and mid-adolescents (n= 218, 107 boy and 111 girl students) of age group 15-16 years, samples were
selected from different schools of Jalandhar, namely Apeejay School and M.G.N School, Jalandhar. Late-adolescents (n=223, 110 boy and 113 girl students) of age group 17-18 years were selected from different schools and colleges of Jalandhar, namely Apeejay School, M.G.N School and Apeejay College. Initially, the study was planned to consider the subjects from age 6-18 years, but due to some ethical complications the subjects from age 6-12 years were excluded. Finally, the subjects aged 13-18 years were considered for the present study. Apart from these, 425 sports persons, viz. 211 volleyball players (115 males and 96 females) and 214 hockey players (112 males and 102 females) aged 18-25 years were also considered as samples. These samples were taken from inter-university level competitions organized in and around Jalandhar and Amritsar, Punjab, India. An adequate number of controls were also taken for comparisons.

6.4 Methods

**Back strength Measurement**

The back strength was measured using back-leg-chest dynamometer. The subject was positioned with body erect and knees bent so that grasped-hand rests at proper height. Then straightening the knees and lifting the chain of the dynamometer, pulling force was applied on the handle. The body was inclined forward at an angle of 60 degrees. The strength of the back muscles was recorded on the dial of the dynamometer as the best of three trials in kg. All subjects were tested after 3 minutes of independent warm-up. Thirty seconds time interval was maintained between each back strength testing.

**Anthropometric Measurements**

Apart from the estimation of back strength, as many as 17 anthropometric variables namely, height, body weight, body mass index, biceps skinfold, triceps skinfold, subscapular skinfold, suprailiac skinfold, calf skinfold, humerus biepicondylar diameter, femur biepicondylar diameter, upper arm circumference, chest circumference, hip circumference, knee height, buttock-knee length, percent body fat and percent lean body mass were measured. All the anthropometric measurements were taken on each subject by following standard technique given by Lohman *et al.* (1988). All the instruments were calibrated before taking the measurements.
6.5 Results and Discussion

Trends of Back Strength and Selected Anthropometric Variables

In the present study the trends of back strength and selected anthropometric variables were studied in adolescents of Jalandhar aged 13-18 years. There were continuous increments in mean values of back strength in boy and girl students as the chronological age advanced from 13 to 18 years. Boys had the minimum mean value of back strength (24.17kg) in age group 13 years (early adolescence) and the maximum (101.50kg) in 18 years (late adolescence). The similar trend of back strength was reported in girl students too (minimum 4.93 kg in 13 years and maximum 12.90kg in 18 years). The maximum annual increment of back strength was reported in age group 16-17 years, followed by 15-16 years, 14-15 years, 17-18 years and the least in 13-14 years in boy and girl students. Strength generally improves with age during adolescent period (Malina et al., 2004). Changes in some measures of the static strength between 6-18 years are reported by Malina and Roche (1983). The data was derived from a longitudinal sample from 11-18 years of age. Strength increases linearly with age until 13-14 years in boys, where there is acceleration in strength development, the adolescent strength spurt. In girls, strength improves linearly with age at 16-17 years. When strength data of girls are related to the adolescent growth spurt in height, girls do, on average, show a growth spurt in strength but it is not as intense as the spurt in boys.

The gender difference in strength is consistent. The marked acceleration of gender development during the male adolescent growth spurt magnifies the gender difference. With increasing age during adolescence, the percentage of girls whose performance on strength tests equals or exceeds that of boys declines considerably. After 16 years of age, few girls perform as high as the average strength of boys, and, conversely, few boys perform as low as the average strength of girls (Malina et al., 2004). Age trends and gender differences in other measures of static strength are similar to those for pulling strength. Although growth studies generally stop at 18 years of age, strength continues to increase into the third decade of life, especially in males (Roy and Pal, 2001).

The physiological and neuromuscular basis of changes in muscular strength in childhood and adolescence has not received much attention. Evidence is limited to
small samples of children and adolescents. Quadriceps muscles torque increases significantly between 11 and 16 years. Gender differences are small at 11 years of age but are magnified at 16 years of age. Relative increase in torque from 11-16 years of age are larger in boys (Harrison et al., 1988). Some research findings suggested changes in muscle dynamics with age during childhood and adolescence (Kraus and Hirschland, 1953; Malina and Roche, 1983; Malina et al., 2004). They also suggested an important role for the maturation of muscle tissue per se an integral factor in strength and performance. Muscular endurance appears to show an increased pace of development in boys but not in girls. This difference may, in part, reflect a learning effect as the youngsters get adjusted to the test situation. Changes in body size, physique, and body composition associated with growth and maturation are important factors that affect strength and motor performance. During adolescence, performance of boys, on average, show a marked improvement, so gender differences are magnified.

In the present study, there was an increase in the mean values of almost all the anthropometric variables with the progression of age both in case of boy and girl students. Boy students showed higher mean values for height than girl students in all age groups except age 13 years. A continuous increase in height was observed in boy students up to 18 years. Similar trends were observed in girl students too, showing continuous increments of height up to the age of 18 years. The linear growth in the body weight was found to be proportionate to the height of the students. For weight, the mean values continued to rise up to 18 years both for boy students (except age group 15 and 17 years) and girl students (except age group 17 years). However, boy students showed higher mean values in all the age groups studied. Though, it was reported earlier that in pre-adolescence, most of the body components such as, height, weight also increased significantly in girls than boys (Tanner and Marshall, 1968). In case of BMI, no specific trend was found both in boy and girl students. Similar to earlier findings (Chinn et al., 1992), the present study also showed that BMI was strongly associated with height in adolescents.

After entering puberty, the growth rate of boys becomes higher than girls and it continues up to the age of 18 years, resulting in the boys becoming taller (Gokhale and Kirschner, 2003). The differences in the size between boy and girl students partly
Summary and Conclusion

comes about because of the later occurrence of male growth spurt allowing an extra period for growth, even at the slow pre-pubertal velocity and partly due to the greater intensity of the growth spurt itself (Harrison et al., 1988). Greater body height means greater bone length, which is an important determinant of muscle strength (Schoenau et al., 2000; Neu et al., 2002). The peak velocity of growth in height averages about 10 cm a year in boys and slightly less in girls. In boys, the growth spurt takes place on the average between 12 years and 6 months and 15 years and 6 months of age, and in girls some 2 years earlier (Harrison et al., 1988). After puberty, testosterone increases the thickness of bones by increasing the bone matrix and deposition of calcium. It is because of the protein anabolic activity of testosterone. In addition to increase in the size and strength of bones, testosterone also causes early fusion of epiphyses of long bones with shaft causing increase in height of an individual (Sembulingam, 2013).

Correlations of Back Strength with Selected Anthropometric Variables

Bivariate Correlation

In the context of simple Karl Pearson’s product moment correlation, significant correlations (p<0.05-0.001) of back strength were found with almost all the anthropometric variables studied. Back strength showed statistically significant positive correlations (p<0.05-0.01) with height, body weight, BMI, biceps skinfold, humerus and femur biepicondylar diameters, all the three circumferential measurements (viz. upper arm, chest and hip circumferences), knee height and percent lean body mass, and negative correlations (p<0.05-0.01) in suprailiac skinfold and percent body fat in age group 13-14 years. In age group 15 -16 years, statistically significant positive correlations (p<0.05-0.001) of back strength were found with height, body weight, humerus and femur biepicondylar diameters, chest and hip circumferences, knee height, buttock-knee length and percent lean body mass, and negative correlations (p<0.05-0.001) with subscapular and suprailiac skinfolds and percent body fat. In age group 17-18 years, significant positive correlations (p<0.039-0.001) of back strength were found with height, body weight, BMI, humerus biepicondylar diameter, all three circumferential measurements (viz. upper arm, chest and hip circumferences), knee height, buttock-knee length and percent lean body mass, and significant negative correlations (p<0.02-0.001) with biceps, triceps, subscapular and suprailiac skinfold measurements, femur biepicondylar diameter and percent body fat.
Statistically significant positive correlations (p<0.026-0.001) of height were found with body weight, BMI, calf circumference, humerus and femur biepicondylar diameters, upper arm and hip circumferences, knee height, buttock-knee length and percent lean body mass and significant negative correlations (p<0.001) with biceps, triceps and suprailiac skinfolds and percent body fat in boy and girl students. Significant positive correlations (p<0.001) of body weight were found with BMI, triceps and subscapular skinfolds, humerus biepicondylar diameter, upper arm, chest and hip circumferences, knee height and buttock-knee length. In case of BMI, significant positive correlations (p<0.001) were found with biceps, triceps, subscapular and suprailiac skinfolds, humerus biepicondylar diameter, chest and hip circumferences, knee height, buttock-knee length and percent body fat, and significant negative correlations (p<0.001) with BMI and percent lean body mass in boy and girl students. BMI has been considered as an indicator of obesity in children and adults (Martorell et al., 2000). It has also been associated with height, weight and skinfolds, other factors such as, parent’s BMI, level of education and native place (Freeman et al., 1995; Gulliford et al., 2001). It has also been reported that the highest rate of weight gain is followed by the highest rate of height gain during the adolescent growth spurt. This leads to acceleration in BMI shortly after reaching the peak height velocity. This rise is more associated with the pubertal development than chronological age (Riley et al., 1989; Riley, 1990). Significant positive correlations (p<0.005-0.001) were found in biceps skinfold with triceps, subscapular and suprailiac skinfolds, chest and hip circumferences and percent body fat, and significant negative correlations (p<0.008-0.001) with calf skinfold, humerus biepicondylar diameter, knee height, buttock-knee length and percent lean body mass. Significant positive correlations (p<0.001) were found in triceps skinfold with subscapular and suprailiac skinfolds, chest and hip circumferences and percent body fat, and significant negative correlations (p<0.002-0.001) were found with upper arm circumference, knee height and percent body fat. Significant positive correlations (p<0.001) of suprailiac skinfold were found with chest and hip circumferences and percent body fat and significant negative correlations (p<0.01-0.001) with humerus biepicondylar diameter, upper arm circumference, knee height and percent lean body mass in boy and girl students. Significant positive
correlations (p<0.008-0.001) of calf skinfold were reported with upper arm, chest and hip circumferences and buttock-knee length. Significant positive correlations (p<0.001) of humerus biepicondylar diameter were recorded with upper arm, chest and hip circumferences, knee height, buttock-knee length and percent lean body mass and significant negative correlations (p<0.001) with percent body fat. No significant correlations of femur biepicondylar diameter were found with any of the variables studied. Significant positive correlations (p<0.001) were found in upper arm circumference with chest and hip circumferences, knee height, buttock-knee length and percent lean body mass and significant negative correlations (p<0.001) with percent body fat. Significant positive correlations (p<0.001) of chest circumference were found with hip circumference, knee height, buttock-knee length, percent body fat and percent lean body mass. Significant positive correlations (p<0.001) of hip circumference were noted with knee height, buttock-knee length and percent body fat and significant negative correlations (p<0.001) with percent lean body mass. Significant positive correlations (p<0.001) of knee height were found with buttock-knee length and percent lean body mass and significant negative correlations (p<0.001) with percent body fat. Significant positive correlations (p<0.021) of buttock-knee length were noted with percent lean body mass and significant negative correlations (p<0.001) with percent body fat. Significant negative correlations (p< 0.001) of percent body fat were observed with percent lean body mass. An association between the increase in lean body mass and bone mass in children has been reported (Nelson et al., 1997). In a longitudinal study, Hulthen et al. (2001) reported a continuous increase of lean body mass in both healthy males and females between 19 and 21 years of age. It was in contrast with a cross-sectional study of children and young adults aged 4-26 years, conducted by Ogle et al. (1995) where they reported that lean body mass increased until the age of 16.6 and 13.4 years in males and females respectively. They found a close correlation between the increase in lean body mass and the increase in muscle strength.

Linear Regression

Linear regressions (R^2) of back strength with selected anthropometric variables in boy and girl students of age 13-18 years in different age groups showed statistically
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significant correlations (p<0.047-0.001) with all the variables except triceps, subscapular and calf skinfolds, upper arm circumference and buttock-knee length in age group 13-18 years, BMI, biceps, triceps and calf skinfolds, upper arm and hip circumferences and age group 15-16 years and calf skinfold and femur biepicondylar diameter in age group 17-18 years. Linear regression co-efficient (beta) of back strength showed significant linear regression in 12 sets each out of 17 sets of anthropometric variables in age groups 13-14 years and 15-16 years and 15 sets out of 17 in age group 17-18 years.

Multiple Regressions

Multiple regressions of back strength with selected anthropometric variables in boy and girl students of age groups 13-18 years showed that subscapular and suprailiac skinfold correlated significantly (p<0.055-0.012) ($R^2=620$) in age group 13-14 years. In the age group 15-16 years also, only height, biceps skinfold, humerus biepicondylar diameter and chest circumference showed significant correlations (p<0.045-0.006) with back strength ($R^2=0.634$). In the age group 17-18 years, significant correlations (p<0.007-0.001) of back strength were observed with body weight and BMI ($R^2=0.75$).

Evaluation of Back Strength in Sports Persons

Physical characteristics and body composition have been known to be fundamental in athletic performance. Specific athletic events require different body types, weight, height, flexibility, and strength for maximal performance (Reco-Sanz, 1998; Wilmore and Costill, 1999; Keogh, 1999). Today it has been widely accepted by the experts that top performance in sports is achieved if an athlete possesses the basic anthropometric characteristics suitable for the event. Therefore, the athletes in a particular sport must possess such typical characteristics which are of advantage to their performance (Claessens et al., 1999; Bourgois et al., 2000; Reilly et al., 2000 a, b; Mondal and Yadav, 2013). Body composition also makes an important contribution to an individual’s level of physical fitness for performance, particularly in such sports that require one to carry one’s body weight over a distance, which is facilitated by a large proportion of active tissue (muscle) in relation to a small proportion of fat tissue. (Ackland et al., 2003)
Volleyball

Volleyball is a popular Olympic sport, originated in the United States played between two teams on a court. Volleyball has been described as an “interval” sport with both aerobic and anaerobic components. At higher skill levels, technical performance may be limited by physical characteristics, e.g. physical fitness, and performance characteristics, such as speed and vertical jump skills (Dopsaj et al., 2012).

It was found that the male volleyball players had greater mean values in back strength, height, body weight, humerus and femur biepicondylar diameters, chest and hip circumferences, knee height, buttock-knee length and percent lean body mass, and lesser mean values in BMI, all the five skinfold measurements (viz. biceps, triceps, subscapular, suprailiac and calf), upper arm circumference and percent body fat than their control counterparts. However, statistically significant differences (p<0.004-0.001) were found in all the variables, except upper arm, chest and hip circumferences and knee height between male volleyball players and controls. In volleyball, team competes by manicures handling the ball above the head, height is considered to be the most important physical attribute. In the present study, the mean height of the male players (181.93 cm, ± 7.83) was greater than the male volleyball players of West Bengal, India (73.10 cm ± 4.19) (Bandyopadhyay, 2007), but lesser than the English (191.00 cm ± 5.0) (Duncan et al., 2006), while in female players, the mean height (159.67 cm ± 5.83) was lesser than the American (176.70 cm, ±4.60) (Ferris et al., 1995) and Japanese (168.70 cm, ± 5.89) (Tsunawake et al., 2003) female volleyball players. In the study, significantly greater body weight among volleyball players might be disadvantageous for them in attaining a good jumping height as they have to lift a greater weight.

Female volleyball players had greater mean values in back strength, height, calf skinfold, humerus and femur biepicondylar diameters, chest and hip circumferences, knee height, buttock-knee length and percent lean body mass, and lesser mean values in body weight, BMI, biceps, triceps, subscapular and suprailiac skinfolds, upper arm circumference and percent body fat than their control counterparts. However, statistically significant differences (p<0.039-0.001) were observed only in biceps skinfold, femur biepicondylar diameter, percent body fat and percent lean body mass.
between female volleyball players and controls. In the present study, volleyball players (both male and female) have significantly higher mean values for back strength than their control counterparts. These differences were probably due to regular physical exercise and strenuous training programs of the volleyball players.

Male volleyball players had greater mean values in back strength, height, body weight, BMI, humerus and femur biepicondylar diameters, upper arm, chest and hip circumferences, knee height, buttock-knee length and percent lean body mass, and lesser mean values in all the skinfold measurements (viz. biceps, triceps, subscapular, suprailliac and calf) and percent body fat than female volleyball players. However, statistically significant differences (p<0.002-0.001) were found in all the variables, except BMI and hip circumference between male and female volleyball players.

In fact, jumping and landing require great amount of back strength in volleyball players. Strong back muscles help to lift the body in jumping as well as proper landing. To avoid game specific injuries and greater success in game, estimation of back strength is essential. As per the requirements of the players, strengthening exercises of the back muscles should be provided to the players in the training programs.

Hockey

Field hockey is an intermittent endurance sport involving short sprinting as well as movement with and without ball (Manna et al., 2009). Successful performance in field hockey is influenced by morphological and anthropometric characteristics such as body size and composition, functional parameters (physical capacity) (Bale et al., 1986; Fedotova et al., 1990; Mokha and Sidhu, 1987; Seluyanov and Sarsaniya, 1991; Withers and Roberts, 1981; Scott, 1991; Singh et al., 2010) and fitness (explosive strength, maximum speed, anaerobic and aerobic capacity, agility) (Bril, 1980; Ayrapetyanz and Godik, 1991; Nikitushkin and Guba, 1998; Volkov and Filin, 1983). Studies relating to back strength of field hockey players are less reported. As in field hockey, players are to bend forward to the ground for the maximum groundwork and to cover a wider range all around during the game (Sodhi, 1991) and maximum strain comes over the back muscles as well as abdominal muscles during the entire duration of the game. These back extensors get fatigued and sore as the game goes on. Although some players may
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have weakness in their back extensors, more often this discomfort is related to muscle imbalance. Muscle imbalance in field hockey players may also result in sore or tight hips. The most common muscle imbalance in hockey players is tightness of the hip flexors. Thus, evaluation of back strength is essential to the hockey players not only for their maximal performance but to avoid the sports specific injuries too.

In the present study male hockey players showed greater mean values in back strength, height, humerus biepicondylar diameter, chest and hip circumferences, knee height, buttock-knee length and percent lean body mass, and lesser mean values in body weight, BMI, and all the five skinfold measurements (viz. biceps, triceps, subscapular, suprailiac and calf), upper arm circumference and percent body fat than their control counterparts. However, statistically significant differences (p<0.028-0.001) were found in all the variables, except height between male hockey players and controls. These differences were, might be, due to, regular physical exercise and training effects of male hockey players. Bandopadhyay (2007) reported in the same line that hockey players had significantly higher lean body mass and mesomorphy, but lesser skinfold thickness, girth measurements, percent body fat and endomorphy than sedentary individuals.

Female hockey players showed greater mean values in back strength, height, body weight, humerus biepicondylar diameter, upper arm and chest circumferences, knee height, buttock-knee length and percent lean body mass, and lesser mean values in BMI, and all the five skinfold measurements (viz. biceps, triceps, subscapular, suprailiac and calf), hip circumference and percent body fat than their control counterparts. However, statistically significant differences (p<0.011-0.001) were noted in all the variables, except height, body weight, BMI, femur biepicondylar diameter, upper arm, chest and hip circumferences, percent body fat and percent lean body mass between female hockey players and controls. These differences were, might be, due to, once again regular physical exercise and training effects of female hockey players. Age, experience, lean body mass, modified sit and reach test, shoulder rotation, isometric leg strength and balance are key physical parameters for volleyball players (Melrose et al., 2007).

Male hockey players had greater mean values in back strength, height, body weight, BMI, biceps skinfold, humerus and femur biepicondylar diameters, upper arm, chest and hip circumferences, buttock-knee length and percent body fat and lesser mean
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values in triceps, subscapular, suprailiac and calf skinfold measurements, knee height and percent lean body mass than their female counterparts. However, significant differences (p<0.033-0.001) were found in back strength, height, body weight, triceps and calf skinfolds, humerus and femur biepicondylar diameters and buttock-knee length between male and female hockey players. These differences were due to sexual dimorphisms. Maximum gender differences between the hockey players were observed in pulling strength (females: 53% of male values) and vertical jump (66%) (Fuster et al., 1998).

The findings of the present study carry immense practical applications and should be useful in future investigation in player selection, talent identification in field hockey and training program development.

Conclusions

The findings of the present study were concluded as follows:

1. In the present study, both boy and girl students showed an increase in back strength with age. The increase in back strength with age was significantly greater in boy students than their girl counterparts in all age groups.

2. The maximum annual increments of back strength were recorded in age group 16-17 years in boy students and 13-14 years in girl students.

3. Statistically significant differences (p<0.05-0.001) in back strength were found in all age groups between boy and girl students.

4. So far anthropometric variables were concerned, statistically significant differences (p<0.05-0.001) were found in all age groups in height (except age group 13 years), biceps skinfold (except age groups 12 and 14 years), triceps and subscapular skinfolds (except age groups 13 and 14 years), suprailiac skinfold and calf skinfold (except age groups 14, 17 and 18 years), percent body fat and percent lean body mass between boy and girl students. Statistically significant differences (p<0.05-0.001) were found in body weight between boy and girl students only in age groups 17 and 18 years.

5. Statistically significant differences (p<0.05-0.001) were found in all age groups between boy and girl students in humerus and femur biepicondylar diameters.
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(except age group 17 years), upper arm and hip circumferences only in age
groups 17 and 18 years and in chest circumference in age group 17 years.

6. Statistically significant differences (p<0.05-0.001) were found in knee height in
age groups 15, 17 and 18 years and in buttock-knee length in age groups 16, 17
and 18 years between boy and girl students.

7. Back strength was found to have significant positive correlations (p<0.001) with
height, body weight, BMI, humerus biepicondylar diameter, upper arm, chest
and hip circumferences, knee height, buttock-knee length and percent lean body
mass; and significant negative correlations (p<0.001) in biceps, triceps,
subscapular and suprailiac skinfolds, and percent body fat in age group 13-18
years.

8. Significant positive correlations (p<0.001) of height were found with body
weight, BMI, calf skinfold, humerus and femur biepicondylar diameters, upper
arm, chest and hip circumferences, knee height, buttock-knee length and percent
lean body mass; and significant negative correlations (p<0.001) in biceps,
triceps, subscapular and suprailiac skinfolds, and percent body fat, in age group
13-18 years.

9. Significant positive correlations (p<0.001) of body weight were found with
BMI, triceps, subscapular and calf skinfolds, humerus biepicondylar diameter,
upper arm, chest and hip circumferences, knee height and buttock-knee length in
age group 13-18 years.

10. Significant positive correlations (p<0.001) of BMI were found with biceps,
triceps, subscapular and suprailiac skinfolds, humerus biepicondylar diameter,
upper arm, chest and hip circumferences, knee height, buttock-knee length and
percent body fat; and significant negative correlations (p<0.001) with percent
lean body mass in age group 13-18 years.

11. Significant positive correlations (p<0.001) of biceps skinfold were found with
triceps, subscapular and suprailiac skinfolds, chest and hip circumferences and
percent body fat; and significant negative correlations (p<0.001) with calf
skinfold, humerus biepicondylar diameter, upper arm circumference, knee
height, buttock-knee length and percent lean body mass in age group 13-18 years.

12. Significant positive correlations (p<0.001) of triceps skinfold were found with subscapular and suprailliac skinfolds, chest and hip circumferences and percent body fat; and significant negative correlations (p<0.001) with upper arm circumference, knee height and percent lean body mass in age group 13-18 years.

13. Significant positive correlations (p<0.001) of subscapular skinfold were found with suprailliac and calf skinfolds, humerus biepicondylar diameter, chest and hip circumferences and percent body fat; and significant negative correlations (p<0.001) with percent lean body mass in age group 13-18 years.

14. Significant positive correlations (p<0.001) of suprailliac skinfold were found with chest and hip circumferences and percent body fat; and significant negative correlations (p<0.001) with humerus biepicondylar diameter, upper arm circumference, knee height and percent lean body mass in age group 13-18 years.

15. Significant positive correlations (p<0.001) of calf skinfold were found with upper arm, chest and hip circumferences and buttock-knee length in age group 13-18 years.

16. Significant positive correlations (p<0.001) of humerus biepicondylar diameter were found with upper arm, chest and hip circumferences, knee height, buttock-knee length and percent lean body mass; and significant negative correlations (p<0.001) with percent body fat in age group 13-18 years.

17. Significant positive correlations (p<0.001) of upper arm circumference were found with chest and hip circumferences, knee height, buttock-knee length and percent lean body mass; and significant negative correlations (p<0.001) with percent body fat in age group 13-18 years.

18. Significant positive correlations (p<0.001) of chest circumference were found with hip circumference, knee height, buttock-knee length, percent body fat and percent lean body mass in age group 13-18 years.
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19. Significant positive correlations (p<0.001) of hip circumference were found with knee height, buttock-knee length and percent body fat; and significant negative correlations (p<0.001) with percent lean body mass in age group 13-18 years.

20. Significant positive correlations (p<0.001) of knee height were found with buttock-knee length and percent lean body mass; and significant negative correlations (p<0.001) with percent body fat in age group 13-18 years.

21. Significant positive correlations (p<0.001) of buttock-knee length were found with percent lean body mass; and significant negative correlations (p<0.001) with percent body fat in age group 13-18 years.

22. Significant negative correlations (p<0.001) of percent body fat were found with percent lean body mass in age group 13-18 years.

23. Statistically significant differences (p<0.001) in back strength were found in inter-university male and female volleyball players and their control counterparts (except between female volleyball players and controls) and between male and female hockey players and their control counterparts.