Chapter 5
Discussion
DISCUSSION

Muscle strength is an excellent indicator of general health and thought to be a major factor in athletic success. Strength can be defined as the force or peak torque developed during a maximal voluntary contraction (Sale, 1991). Torque is usually defined as the force measured about a joint’s axis of rotation, and peak torque is the point in the range of motion tested at which the greatest torque is produced (Perrin, 1993). Strength was examined during dynamic actions (concentric and eccentric), rather than during static actions (isometric). Dynamic muscle strength is commonly considered as an important component in running, sprinting and other athletic activities (Eckert, 1979; Radford, 1984). Alexander (1989) suggested that, in theory, sprint performance was a direct result of the impulse (the product of the mean force and time of contact) applied by the athletes against the ground during the propulsive phase of the stride. The driving force generated during the landing phase is related to the strength of the hip extensors, knee extensors and plantar flexors (Elliott and Blanksby, 1979; Mann, 1981; Simonsen et al., 1985). Therefore, it would appear that athletes who have greater strength in these muscle groups produce faster sprinting times if time of contact remains the same. The literature regarding relationships between muscle strength and sprinting performance is extremely limited and most studies have documented only poor relationships (Berger and Blaschke, 1967; Liba, 1967; Costill et al., 1968; Berg et al., 1986; Farrar and Thorland, 1987; Manning et al., 1988; Osinski, 1988; Anderson et al., 1991). These poor relationships may, in part, be the result of inappropriate strength and speed tests, of the examination of only one joint action, or an incomplete investigation of the relationship between strength and athletes performance. Alexander (1989) studied elite sprinters and found significant correlations between 100 m sprinting times and peak torque of the concentrically contracting knee extensors and the plantar flexors acting eccentrically. In running, sprinting and hurdling, athletes require movement of various joints i.e. trunk, shoulder, elbow, wrist, hip, knee and ankle. Running involves synchronous movement of all the components of body. Athletes suffer most commonly from lower extremity injuries. Lack of trunk and hip strength may predispose athletes to lower back and lower extremity injury. A major component
of injury prevention is identification of potential risk factors and to identify these risk factors, a pre-participation physical examination is often performed. Strength assessment is the major component of physical examination.

5.1. Dynamometric Strength Measurements

5.1.1. Trunk Strength

The mantra of “core training” makes athletes believe that enhanced core stability improves their performance on the field or court (Chris Sharrock et al., 2011). According to Tse et al. (2005), the core musculature includes muscles of the trunk and pelvis that are responsible for maintaining the stability of the spine and pelvis and are critical for the transfer of energy from larger torso to smaller extremities during many sports activities. Panjabi (1992) stated that core stability was achieved by the integration of the active spinal stabilizers (muscles), passive stabilizers (spinal column), and neural control which acted together to control intervertebral joint range of motion in order to allow the performance of activities of daily living. Trunk muscles consist of abdominals (rectus abdominis) in front, paraspinals and gluteals at the back, diaphragm as the roof, obliques at the sides and the hip and pelvic girdle serving the bottom. Strong core provides a stable base and allows transfer of forces from lower body to upper body with the minimal dissipation of energy in torso. The abdominal muscle function is to resist the pull of hip flexor muscle in order to maintain proper alignment of both the pelvis and the spine (Kendall, 2005).

In the present study, trunk strength and selected anthropometric variables were studied in collegiate athletes of Delhi and controls aged 18-25 year. Athletes showed statistically significant (p<0.001) higher mean values of trunk extension and flexion strength than their control counterparts. Trends of trunk flexion and extension strength were studied in different athletic events. Male sprinters had the highest mean value of trunk extension (209.97Nm) and trunk flexion (193.94Nm) while the lowest mean value for trunk extension (153.08Nm) and flexion (151.3Nm) were found in male long distance runners. Similar trends of trunk extension and flexion strength were also studied in female athletes. Female athletes showed higher mean values than their control counterparts. Among all the category of athletes, female hurdlers had the highest
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mean values of trunk extension (194.73 Nm) and flexion (166.64 Nm) while the female sprinters showed the lowest mean value of trunk extension strength (165.49 Nm) and the lowest mean value of trunk flexion (152.78 Nm) was reported in female long jumpers. Hibbs et al., (2008) proposed that elite athletes required much higher levels of core stability for sports performance than during activities of daily living, therefore, they must have appropriate rehabilitation to enhance return to function. Results of the present study were in line with Andersson et al. (1988) where male athletes showed higher peak torque values than the controls and that appeared to be sports specific and related to long-term systematic training. According to Hodges (2003), synergistic activation patterns existed in pelvic and trunk controlling musculature. The hip musculature, with its large cross-sectional area, is involved with stabilization of the trunk as well as force and power generation during lower extremity movements in sports activities. The gluteal muscles stabilize the trunk over a planted leg in order to supply power for forward leg motions in movements such as throwing and running. For efficient and skillful movement to occur, the collective musculature of the core must be activated in precise patterns to both generate and absorb force while stabilizing the trunk. Sato and Mokha (2009) studied the effects of a 6 week core stabilization training program on ground reaction forces, stability of the lower extremity, and overall running performance in recreational and competitive runners. Their results indicated a significant improvement in 5000 meter running times with no changes in ground reaction forces or leg stability.

According to the findings of the present study, males scored significantly higher on the trunk extension and flexion strength when compared to females. This is in consistence with the findings of Leetun et al. (2004) who showed that males have greater trunk strength compared to females possibly due to bone structure and postural differences in the pelvis. It is possible that core stability may be impacted by the anatomical alignment of the female pelvis which affects the angulation of muscular attachments. Subtle changes in the angle of pull of the core musculature on the pelvis may result in decreased ability to control the trunk. Brophy et al. (2009) showed that male soccer players had a stronger abdominal strength and thus trunk (core) control as compared to their female counterparts. Wilson et al. (2006), likewise, demonstrated that
males had higher normalized and peak isometric muscle torques of the trunk, hip, knee during a 45 degree single-leg squat than females in all studied muscle groups.

5.1.2. Shoulder Strength

Shoulder has a very important role in many sports activities, especially in overhead sports (Cools et al. 2004). The muscles and joints of the shoulder allow it to move through a remarkable range of motion, making it one of the most mobile joints in the human body. The muscles that are responsible for movement in the shoulder flexion are pectoralis major, coracobrachialis, biceps brachii, anterior fibers of deltoid and for shoulder extension are latissimus dorsi and teres major, long head of triceps, posterior fibers of the deltoid (Chaurasia, 2010). In the shoulder balance between the muscles of rotator cuff is essential to maintain joint stability and normal shoulder function (Ainsworth et al. 2007). Several studies describe the relations between medial and lateral rotators of shoulder.

The present study focused on shoulder flexion and extension strength in collegiate athletes of Delhi. It has been reported that shoulder flexors showed higher peak torque values than shoulder extensors. Male athletes showed statistically significant (p<0.001) higher mean values of right and left shoulder extension and flexion strength than their control counterparts. Among all the athletes, male javelin throwers showed the highest mean values for shoulder extension strength and the lowest extension strength was reported in hurdlers in dominant shoulder and male long distance runners in non-dominant shoulder. On the other hand, shoulder flexion strength was reported to be the highest in male hurdlers and the lowest in male long distance runners. In female athletes, the highest mean value of shoulder extension strength was reported in javelin throwers and the lowest in hurdlers in dominant shoulder and long jumpers in non-dominant shoulder, while shoulder flexion strength was the highest in hurdlers and lowest in sprinters.

The shoulder is significantly stressed in overhead athletes, especially during distinct phases of throwing motion in addition to the glenohumeral motion, scapular function has to be seen as a major contributor to transfer the kinetic energy from the lower limbs and trunk to the upper extremity. It is well known that boys can throw more
far and more skilfully than girls; due to environmental and biological factors (Thomas et al., 1994). Results of the present study were in agreement with their findings where male athletes had highest mean values than female athletes. Alexander (1989) found that females are significantly weaker in upper body muscle groups. Ives et al. (1993) suggested that some gender differences in performances were based on neuromuscular coordination mechanism. The results of the present study also indicated that the average peak strength of shoulder flexion and extension was significantly higher in the dominant shoulder than that of the non-dominant shoulder and it was also observed that the javelin throwers male and female both showed higher peak torque for shoulder extensors. It is believed that these tasks may evoke peripheral and central adaptations that are essential for functional stability (Swanik et al., 2002).

5.1.3. Elbow Strength

The elbow joint is the synovial hinge joint between the humerus in the upper arm and the radius and ulna in the forearm which allows the hand to be moved towards and away from the body. Muscles of elbow flexion are biceps brachii (prime mover), brachialis and brachioradialis. Brachialis acts exclusively as an elbow flexor and is one of the few muscles in the human body with a single function, brachioradialis acts essentially as an elbow flexor but also supinates during extreme pronation and pronates during extreme supination, Biceps brachii is the main elbow flexor but, as a biarticular muscle, also plays important secondary roles as a stabiliser at the shoulder and as a supinator. Elbow extension is simply bringing the forearm back to anatomical position. This action is performed by triceps brachii with a negligible assistance from anconeus. The stability of the elbow depends on the bony architecture, the collateral ligaments (medial and lateral), and dynamic forces from the extensive musculature that crosses the joint. The contribution made by each component depends on the position of the joint (Richards, 2010). Further, it must be remembered that both the radiohumeral joint and the ulnohumeral joint play a significant role in stress distribution. In sport injuries of the elbow, it is not only the transmission of load through the joint that is important but also the angular velocities for various activities. The elbow flexors and extensors are commonly incorporated into resistive exercise programme due to their important function in overhead activities (Buckley et al., 1988, Morris et al., 1989, Rodosky et al., 1994, Roetert et al., 1995).
The present study focused on strength measurement of elbow in different category of collegiate athletes of Delhi and controls aged 18-25 years. It has been found that athletes showed higher mean values of elbow flexion and extension than non-athletes. It has been reported that elbow flexors showed higher peak torque values than elbow extensors. Male javelin throwers showed the highest mean value of elbow extension in dominant arm while hurdlers in non-dominant arm and the lowest mean value for elbow extension were reported in long distance runners. Elbow flexion was reported to be the highest in hurdlers in both the arms and the lowest in javelin throwers. Morris et al. (1989) found that the pronator teres and triceps play significant roles in power production for the serve. Gallagher et al. (1997) used isokinetic dynamometer to measure elbow flexion and extension muscular performance and found that in normal uninjured males, no bilateral differences in elbow extension strength but significantly greater elbow flexion peak torque differences and work values on the dominant elbow. Females demonstrated the highest mean values of elbow flexion strength in hurdlers and extension strength in javelin throwers, while the lowest mean values for elbow extension were found in long jumpers and long distance runners and for elbow flexion in long distance runners. The present study also suggested that there were no bilateral differences in elbow flexion and extension strength. Ellenbecker et al. (2003) conducted a study to determine whether bilateral differences existed in concentric elbow flexion and extension strength in elite junior tennis players and found no significant difference between extremities in elbow flexion muscular performance in males and in elbow flexion or extension peak torque and single repetition work values in females.

5.1.4. Wrist Strength

Wrist is the complex of eight bones. The two major movements of wrist are flexion (palmar flexion, tilting towards the palm) and extension (dorsiflexion, tilting towards the back of the hand). These movements take place through a transverse axis passing through the capitate bone. Muscles that extend the wrist include extensor digitorum, extensor carpi radialis longus, extensor carpi radialis brevis, extensor indicis, extensor pollicis longus, extensor digiti minimi, extensor carpi ulnaris. Muscles that flex the wrist include palmaris longus, flexor digitorum superficialis, flexor
digitorum profundus, flexor carpi ulnaris, flexor pollicis longus, flexor carpi radialis, abductor pollicis longus (Chaurasia, 2010).

The findings of the present study showed that wrist extension and flexion strength was higher in athletes as compared to non-athletes of the same age group. In various athletic activities, the javelin throwers showed the highest mean values in wrist extension strength in both males and females and the lowest mean values in male and female long distance runners while wrist flexion strength was reported to be the highest in male javelin throwers and in females in hurdlers where as the lowest mean value were reported in male and female long distance runners. Armour and Elliot (1989) explained that female throwers kept the wrist in flexion throughout the forward swing while the male subjects were able to initially flex, then extended and finally flexed the wrist prior to release. This difference in male and female players regarding the wrist strength might be due to inability of female throwers to grasp the javelin more comfortably because of shorter hand span. Results of the present study suggested that there were not much bilateral differences in elbow flexion and extension. Ellenbecker et al. (2006) determined laterality differences in wrist extension/flexion and forearm supination/pronation strength in elite female tennis players. Results showed significantly greater dominant arm wrist extension/flexion and forearm pronation strength was significantly less in dominant side than forearm supination strength. Greater dominant arm wrist extension/flexion and forearm pronation strength was common and normal in young elite female tennis players. Kelley et al. (1994) were able to show that, in patients suffering from lateral epicondylitis, there was increased electromyographic activity in the wrist extensors and pronator teres at the point of ball impact and follow through compared with uninjured individuals. These strength relations indicate sports specific muscular adaptations in the dominant extremity. Isokinetic strength testing can be used to measure wrist and forearm strength dynamically and provide a more detailed estimate of muscular strength and agonist/antagonists muscle balance.

5.1.5. Hip Strength

The hip muscles act on three mutually perpendicular main axes, all of which pass through the centre of the femoral, resulting in three degrees and three pair of
principal directions: lateral and rotation around a longitudinal axis (along the thigh); abduction and adduction around a sagittal axis (forward-backward) and flexion and extension around a transverse axis (left-right). It should be noted that some of the hip muscles also act on either the vertebral joints or the knee joint, with their extensive areas of origin or insertion, different part of individual muscles participate in very different movements and the range of movement varies with the position of the hip joint. Hip extensor muscles are gluteus maximus, dorsal fibers of gluteus medius and minimus; adductor magnus; and piriformis and other thigh muscles extend the hip include semimembranosus, semitendinosus, and long head of biceps femoris. Maximal extension is inhibited by the iliofemoral ligament. Hip flexion is produced by iliopsoas (with psoas major from vertebral column); tensor fascia latae, pectineus, adductor longus, adductor brevis, and gracilis. Thigh muscles acting as hip flexors: rectus femoris and sartorius. Maximal flexion is inhibited by the thigh coming in contact with the chest (Last’s, 1972).

In this study athletes showed the highest hip extension and flexion strength than non-athletes. Male long jumpers showed the highest mean values of hip extension strength in dominant lower extremity while sprinters in non-dominant lower extremity, while the lowest mean values for hip extension strength were reported in long distance runners. In females, the highest hip extension strength was reported in hurdlers and the lowest in long distance runners. The hip flexor muscles are well trained in sprinters, especially eccentric hip flexion which occurs at toe off to decelerate the rapidly extending hip and to initiate swing forward during recovery. Hip flexion strength was also measured for all the subjects in this study, athletes showed higher mean values than non-athletes. Male javelin throwers and sprinters showed the highest mean values for hip flexion strength while in females, the highest mean values were noted in hurdlers. The lowest mean value for hip flexion strength was reported both in male and female long distance runners. Mann (1985) concluded that the main muscle group that appears to increase the speed of gait was the hip flexors. It has been noted that the hip flexors are important during the swing phase, when the opposite leg is in contact with the ground, which is an indication of knee lifting, and that the hip extensors are important during the extension of the leg in the ground contact phase (Mann and Sprague, 1983).

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However, no statistically significant correlations were found between the hip extensors and 15 m sprint time, but were found with 30±35 m sprint time, it was possible that the actions of the hip extensors became more important as sprint speed was increased. Sara et al. (2012) demonstrated that hip flexors and extensors were generally stronger than hip abductors and adductors. Ford et al. (2013) determined the relationship between hip isokinetic strength and thorax and pelvic motion during treadmill running in collegiate cross-country runners, they found moderate correlations in hip extensor and hip abductor strength and pelvic and thorax motion during running in collegiate runners. Alexander (1990) estimated descriptive strength of the major muscle groups of the lower limbs (hip, knee, and ankle joints) for a group of elite sprinters by comparing both the eccentric and concentric and the agonist and antagonist peak torques and reported that the peak torque values for the knee joint were found to be substantially larger than those reported for non-athletes and comparable to those for other athletic populations. No comparable scores were located for the results of the hip and ankle scores. Satkunskiene et al. (2009) studied the changes produced in seven high-level sprinters after eight weeks of power training and found that their stride length and frequency, speed over a 40-meter sprint, and other biomechanical variables related to running technique improved significantly in these athletes.

5.1.6. Knee Strength

The knee joint joins the thigh with the leg and consists of two articulations: one between the femur and tibia, and the other between the femur and patella. It is the largest joint in the human body. The knee permits flexion and extension about a virtual transverse axis, as well as a slight medial and lateral rotation about the axis of the lower leg in the flexed position. Knee extension is mainly produced by quadriceps and knee flexion by semimembranosus, semitendinosus, biceps femoris, gracilis, sartorius, popliteus and gastrocnemius muscles (Kendall, 2005).

The results of the present study indicated that the mean value were higher in athletes than non-athletes. Among all the athletes, male hurdlers showed the highest knee extension strength and the lowest in dominant extremity was reported in sprinters and in non–dominant extremity in long distance runners. In case of knee flexion the highest mean value was reported in male sprinters where as the lowest was found in
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long distance runners. The knee flexion strength of sprinters were 185.78 Nm (right) and 174.36 Nm (left) these results were similar to knee flexor torque 169 Nm reported by Alexander (1990). The male sprinters appeared to have the highest peak torque values for hamstrings and these values were substantially higher than those reported for non-athletic subjects (Francis and Hoobler, 1987). The hamstring primarily acts during support phase of sprinting: eccentrically at foot strike than concentrically during push off phase. Female hurdles showed the highest mean value of knee flexion as well as extension strength and the lowest was reported in long distance runners. In contrast, Thorstensson et al., (1977) noted that knee extensor torque appeared to be the most significant difference between sprinters and the other athletes. Read et al. (1990) studied the comparison of hamstring/quadriceps isokinetic strength ratios and power in tennis, squash, and track athletes. There was no significant difference between sports, and wide individual differences occurred. Analysis of power showed a significantly higher work output by track athletes than squash and tennis players, but, unlike hamstring/quadriceps ratio, no significant difference between preferred and non-preferred leg. Power between preferred and non preferred legs was the same but the torque ratio differed indicating that the hamstrings provided proportionately more work in the non-preferred leg at higher speeds. Results of present study also suggested that the male athletes have higher mean values than female athletes. Speechly et al. (1996) have suggested that when comparisons on performances were made in runners, females were 9-11% slower than their male counterparts. Dauty et al. (2001) conducted a study to define the test-retest reproducibility for measuring the peak torque of the knee flexors according to the isokinetic concentric and eccentric muscle action in volleyball players. Results showed an excellent reproducibility for isokinetic concentric peak torque at 180°/s and very good reproducibility for isokinetic eccentric peak torque at 30 and 60°/s. These results indicated that knee flexion strength at these velocities might be used to estimate the performance of volleyball players. Marinho et al. (2002) conducted a study to dynamically evaluate the peak torque, total work, and average power of the knee flexor and extensor muscles of jumpers and runners and compared them to those of a non-athletic population and suggested that in the non-athlete group, there was higher asymmetry between the dominant and non-dominant members. The jumpers had the highest values of the evaluated parameters of all groups, whereas parameters for the
runners were intermediate between non-athletes and jumpers. Peak torques in the dominant leg at all angular velocities seemed higher than the non-dominant leg, however, no significant differences were revealed. These results are in agreement with the study of Rahnama et al. (2005) that reported no significant differences between the two legs in knee extensors at three different velocities among elite soccer players. Gender-related factors include anatomy, hormonal profile, ligament laxity, and the effect of menstrual cycles on the knee strength. Typically women have a laxity of the ligaments around the knee joint (Loes et al., 2000; Dugan, 2005) which may impact upon knee strength. Blazevich and Jenkins (2002) highlighted the benefits of power training in terms of variables such as 20-meter sprints or maximal strength in the squat. Thus, after a seven-week training program based on lower-limb exercises (i.e. squats, knee extensions and flexions, and hip extensions and flexions) at 30–50% of one repetition maximum (1RM), the performance of these athletes improved significantly in terms of the 20-meter sprint, squat, strength, and isokinetic hip extension and flexion torque at high velocity.

5.1.7. Ankle Strength

The ankle, or talocrural region is the region where the foot and the leg meet. The ankle includes three joints: the ankle joint, the subtalar joint and the inferior tibiofibular joint. The movements produced at this joint are dorsiflexion and plantarflexion of the foot. Dorsiflexion muscles are tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneus tertius. The movement in the opposite direction of dorsiflexion is plantarflexion. The plantarflexion muscles are gastrocnemius, soleus, plantaris, popliteus and tibialis posterior (Kendall, 2005).

In the present study athletes showed higher values in ankle extension (planter flexion) and flexion (dorsiflexion) strength than their control counterparts. Results of the present study were similar with Chi et al. (1994) where non-athletic subjects had substantially lower endurance capability in both planter and dorsiflexors as measured by the endurance ratio than athletes. This implied that identifiable specialization in particular muscles resulted from training or participating in specialized sports. Male sprinters showed higher mean values of ankle extension strength while ankle flexion strength was highest in sprinters (in non-dominant extremity) and hurdlers (in dominant
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extremity) where as the lowest in long distance runners (both flexion and extension). Female hurdlers showed the highest mean values of ankle extension and flexion strength and the lowest mean values of ankle flexion and extension strength were noted in long distance runners. Peak torque values of ankle extension (planter flexors) were higher than ankle flexion (dorsiflexors). Smith et al. (1996) reported that ankle planter flexors were the primary power generator during running and sprinting activities. The plantar flexor work substantially during the acceleration phase of sprinting, muscle fibres of sprinters (fast twitch fibres) have been reported to had faster fibre conduction velocities than those of distance runners (Sadoyama et al., 1988). The knee extensors and plantar flexors of sprinters were thicker, had smaller pennation angles and longer muscle fascicles than those of distance runners and non-sprinters (Lee et al., 2009; Kumagai et al., 2000; Fukashiro et al., 2001). Similar differences in muscle architecture have been documented between highly skilled sprinters and less-skilled sprinters (Kumagai et al. 2000), although Karamanidis et al. (2011) failed to identify such differences in a similar study.

5.2. Anthropometric Characteristics

5.2.1. Height, Weight, BMI

In the present study, height was studied in collegiate athletes of Delhi and controls aged 18-25 year. Both male and female athletes showed higher mean values of height than their control counterparts. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of height was also studied in different athletic events; male hurdlers reported the highest mean value for height (177.54cm) and the lowest in middle distance runners (172.78cm) while in female athletes highest mean value for height (174.9cm) was reported in long distance runners and the lowest in javelin throwers (159.42cm). Tanner et al.1981 concluded males on average were taller than females, which has been suggested to be an important determinant of muscle mass and force development due to greater bone length. In case of body weight both male and female athletes showed higher mean values of body weight than their control counterparts. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of body weight was also studied in different athletic events;
male javelin throwers reported the highest mean value for body weight (67.93kg) and the lowest in long jumpers (64.92kg) while in female athletes highest mean value for body weight was reported in (61.9kg) long distance runners and the lowest in javelin throwers (55.28kg). Nelson and Evans (1988) reported that low body weight enhances performance for distance runners. So far BMI is concerned, collegiate athletes had lower mean values of body mass index (kg/m$^2$) than controls. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of body mass index (kg/m$^2$) was also studied in different athletic events; male middle distance runners reported the highest mean value for body mass index (22.76 kg/m$^2$) and the lowest in sprinters (20.25 kg/m$^2$) while in female athletes highest mean value for body mass index was reported in long jumpers (22.32 kg/m$^2$) and the lowest in long distance runners (21.27 kg/m$^2$). Niels Uth (2005) compared the anthropometry of sprinters and people belonging to the normal population and reported that height and body mass (BM) distribution of sprinters (42 men and 44 women) were statistically compared to the distributions of American and Danish normal populations. The results showed that there was significantly less BM and height variability among male sprinters than among the normal male population while female sprinters showed less BM variability than the normal female populations. On average the American normal population was shorter than the sprinters. There was no height difference between the sprinters and the Danish normal population. Both male and female sprinters had lower body mass index (BMI) than the normal populations. Sprinters are generally lighter in BM than normal populations. These anthropometric characteristics typical of sprinters might be explained, in part, by the influence the anthropometric characteristics have on relative muscle strength and step length. Clayton et al. (2011) found significant relationships between trunk flexion and body weight, BMI, percent body fat, fat weight, and body weight. The complexity of core musculature must be considered when selecting assessments of core strength, with special attention to their impact on sport specific movements. Barandun et al. (2012) demonstrated that percent body fat, not body mass index, is relevant to predict race times in marathoners. This finding is in contrast with that of Hoffman and Fogard (2011) for 161 km ultramarathoners and Rust et al. (2011) for half marathoners in whom body mass index was predictive of race times.
5.2.2. **Breadth Measurements**

In the present study, humerus biepiconylyar diameter was studied in collegiate athletes of Delhi and controls aged 18-25 year. Both male and female athletes showed lower mean values of humerus biepiconylyar diameter than their control counterparts. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of humerus biepiconylyar diameter was also studied in different athletic events; male javelin throwers showed the highest mean value for humerus biepiconylyar diameter (6.35cm) and the lowest in long distance runners (5.1cm) while in female athletes also the highest mean value for humerus biepiconylyar diameter (5.29cm) was reported in javelin throwers and the lowest in long jumpers (4.45cm). So far femur biepiconylyar diameter is concerned, male athletes showed higher mean values than control males while female athletes showed lower mean values than control females. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of femur biepiconylyar diameter was also studied in different athletic events; male javelin throwers showed the highest mean value (8.84cm) and the lowest in long jumpers (7.1cm) while in female athletes, the highest mean value for femur biepiconylyar diameter (7.37cm) was reported in hurdlers and the lowest in long jumpers (6.51cm). In case of shoulder width, male athletes showed lower mean values than control males while female athletes showed higher mean values than control females. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of shoulder width was also studied in different athletic events. Male sprinters showed the highest mean value for shoulder width (42.44cm) and the lowest in long distance runners (36.67cm) while in female athletes highest mean value for shoulder width (43.1) was reported in hurdlers as well as sprinters and the lowest in long distance runners (39.85cm). Bale *et al.*, (1986) concluded that there was no significant difference found between the most able and less able groups of distance runners for either bone widths or circumferences.

5.2.3. **Circumferential Measurements**

In the present study, upper arm circumference was studied in collegiate athletes of Delhi and controls aged 18-25 year. Male athletes showed higher mean values of
upper arm circumference than control males while female athletes showed lower mean values than control females. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of upper arm circumference was also studied in various athletic events; male javelin throwers reported the highest mean value for upper arm circumference (32.8cm) followed by hurdlers, sprinters, middle distance runners, long jumpers and the lowest in long distance runners (29.7cm) while in female athletes, the highest mean value for upper arm circumference (29.93cm) was reported in long distance runners followed by javelin throwers, hurdlers, middle distance runners, long jumpers and the lowest in sprinters (23.29cm). In case of chest circumference, male athletes showed higher mean values than control males while female athletes showed lower mean values than control females. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of chest circumference was also studied in various athletic events; male javelin throwers reported the highest mean value for chest circumference (97.48cm) and the lowest in sprinters (93.04cm) while in female athletes highest mean value for chest circumference (92.5cm) was found in long distance runners and the lowest in hurdlers (86.26cm). So far hip circumference is concerned male athletes showed higher mean values than control males while female athletes showed lower mean values than control females. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of hip circumference was also studied in various athletic events; male javelin throwers reported the highest mean value for hip circumference (100.88cm) and the lowest in long distance runners (96.83cm) while in female athletes, the highest mean value for this trait was found in javelin throwers (94.44cm) and the lowest in long jumpers (91.57cm). In case of wrist circumference, male athletes showed lower mean values than control males while female athletes showed higher mean values than control females. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of wrist circumference was also studied in various athletic events; male javelin throwers reported the highest mean value for wrist circumference (17.72cm) and the lowest in long distance runners (13.62cm) while in female athletes highest mean value for wrist circumference was found in long jumpers (16.3cm) and javelin throwers (16.13cm) and the lowest in long distance runners (15.23cm). In case of ankle circumference, male and female athletes showed higher mean values than their control counterparts. It has been
also reported that male athletes showed higher mean values for the trait as compared to female athletes. A trend of ankle circumference was also studied in various athletic events; male sprinters reported the highest mean value for ankle circumference (24.11cm) and the lowest in long distance runners (21.7cm) while in female athletes, the highest mean value for this trait was found in middle distance runners (22.7cm) and the lowest in long distance runners (21.75cm). Kong Heer 2008 demonstrated that the top runners were characterized with small calf circumference, with the mean of 34 ± 2.3 cm. The slim limbs may contribute to their outstanding performance by lowering the moment of inertia which could reduce the muscular effort of legs. Vučetić et al. (2005) studied the anthropometric and morphological characteristics of 46 national level track-and-field athletes. 20 morphological body measures were taken on a sample of 15 sprinters, 13 endurance sprinters, 9 middle-distance runners and 9 long-distance runners. Statistical analysis showed significant differences, between the athletes of various running events for the measures of body volume and body fat, and no significant difference in the variables of longitudinal and transversal dimensions of the skeleton. Further, they showed significantly higher thigh and lower leg circumference in sprinters, as well as greater upper arm skinfold in middle-distance runners. The mesomorphic component was a dominant characteristic of body constitution of the runners in all events, whereas the ectomorphic component was the least. Ebrahim et al. (2011) examined the relationship between physical parameters, of the body segment and the 100-meter sprinting performance. Thirty three female subjects aged 19 to 25 years participated at this study. Pearson’s correlation analysis found that there was no significant relationship between the 100-meter sprinting performance and the selected anthropometric variables (p>0.05). The results suggested that physical parameters measures of the body segments variables were poor predictors of sprinting performance.

5.2.4. Skinfold Measurements

In the present study, for all five skinfold measurement, male and female athletes showed lesser mean values than their control counterparts. It was also reported that female athletes have higher mean values for biceps skinfold measurement than their male counterparts. In case of biceps skinfold, male long distance runners reported the highest mean value for biceps skinfold (4.27mm) and the lowest in middle distance
runners (3.39mm) while in female athletes highest mean value for biceps skinfold was found in javelin throwers (4.32mm) and the lowest in hurdlers (3.52mm). In case of triceps skinfold, male long distance runners reported the highest mean value for triceps skinfold (4.62mm) and the lowest in middle distance runners (3.21mm) while in female athletes highest mean value for triceps skinfold was found in long distance runners (3.66mm) and the lowest in long jumpers (3.27mm). So far subscapular skinfold is concerned, male long distance runners reported the highest mean value for subscapular skinfold (5.1mm) and the lowest in middle distance runners (4.04mm) while in female athletes highest mean value for subscapular skinfold was found in long distance runners (4.5mm) and the lowest in sprinters (4.12mm). In case of suprailiac skinfold, male sprinters reported the highest mean value for suprailiac skinfold (4.23mm) and the lowest in middle distance runners (3.52mm) while in female athletes highest mean value for suprailiac skinfold was found in long jumpers (3.73mm) and the lowest in hurdlers (3.54mm). So far calf skinfold is concerned, male long distance runners reported the highest mean value for calf skinfold (5.28mm) and the lowest in hurdlers (4.4mm) while in female athletes highest mean value for calf skinfold was found in javelin throwers (4.3mm) and the lowest in hurdlers (4.09mm). Legaz et al. (2005) suggested that training resulted in a significant increase in performance and decreases in sum of six skinfolds, studied and the ratio of extremity to trunk skinfold. Tsolakis et al. (2010) investigated the differences in selected anthropometric, strength-power parameters and functional characteristics of fencing performance between elite and sub-elite fencers and found significant differences between the two groups in sitting height, triceps, subscapular, and quadriceps dominant skinfold thickness, absolute and body mass-dependent expressions of leg functional power characteristics of fencing performance: “time of lunge” and time of the “shuttle test”.

5.2.5. Body Composition Components

The results of the present study suggested that in case of percent body fat, male and female athletes showed lesser mean values than controls. Female athletes showed higher mean values for the trait as compared to male athletes. In case of various athletic events; male middle distance runners reported the highest mean value for percent body fat (18.04) and the lowest in hurdlers (16.03) but no significant variations in javelin
throwers, long distance runners, long jumpers and sprinters were found while in female athletes highest mean value for percent body fat was found in long jumpers (27.11) and the lowest in long distance runners (24.27) and there was also no significant variation in middle distance runners, javelin throwers, sprinters and hurdlers. Reilly et al. (2000) reported that players who attained better performances in sprint tests tended to have a lower percentage of body fat. Bale et al. (1985) described low percentage of body fat in elite marathon runners. Hetland et al. (1998) demonstrated that regional and total body fat correlated inversely with performance in an incremental treadmill test in long-distance runners. Eston et al. (2005) confirmed that lower body skinfold were highly correlated with percent body fat in fit and healthy young men. Body fat levels are higher among the normal population given that sprinters often have lower body fat levels (Abe et al., 2001; Kumagai et al., 2000; WHO, 1998).

In case of percent lean body mass, male and female athletes showed higher mean values of percent lean body mass than their control counterparts. Male athletes showed higher mean values for the trait as compared to female athletes. A trend of percent lean body mass was also studied in various athletic events; male hurdlers reported the highest mean value for percent lean body mass (83.97) and the lowest in middle distance runners (81.96), while in female athletes, the highest mean value for percent lean body mass was found in long distance runners (75.72) and the lowest in long jumpers (72.88). Hoshikawa et al. (2010) investigated the event-related differences in the cross-sectional areas and torque generation capabilities of the quadriceps femoris and hamstrings in male high school athletes. Subjects were soccer players (n=32), volleyball players (n=21), rowers (n=29), karate athletes (n=18), sumo wrestlers (n=15), sprinters (n=22), throwers (n=16), and non-athletes (n=20). The cross-sectional areas and quadriceps femoris and hamstrings at the mid-thigh were determined using magnetic resonance imaging. In addition, isokinetic torques during knee extension and flexion were determined at a pre-set velocity of 1.05 rad/sec. Cross-sectional areas relative to lean body mass (2/3) for quadriceps femoris did not differ among the groups, but that for hamstring was higher in sprinters, soccer players, throwers, and karate athletes than in sumo wrestlers, rowers, volleyball players, and non-athletes. Knee extension torque relative to the cross-sectional areas of quadriceps femoris was higher
in karate athletes, soccer players, and rowers than in non-athletes, but the corresponding value for knee flexion did not differ among groups. Thus, the present study indicated that, at least in male high school athletes, the event-related differences in lean body mass and the muscularity of quadriceps femoris and hamstrings produced the corresponding differences in the cross-sectional areas of the reciprocal muscle groups and knee extension and flexion torques, respectively. However, specific profiles related to competitive and/or training styles exist in hamstrings cross-sectional area and knee extension torque, which cannot be explained by the magnitude of lean body mass and quadriceps femoris cross-sectional area, respectively. Nutter et al. (1987) reported low to moderate correlations between isokinetic strength and body size or body composition measurements.

5.3. Performance Tests

In case of performance tests, results of the present study showed that male and female athletes showed higher mean values for sit and reach test and multistage test than their control counterparts. Male athletes showed higher mean values for sit and reach test and multistage test than female athletes. A trend of sit and reach test was also studied in various athletic events; male long jumpers reported the highest mean value for this trait (40.09cm) followed by sprinters, long distance runners, hurdlers, middle distance runners and the lowest in javelin throwers (37.93cm) while in female athletes, the highest mean value was found in long jumpers (39.1cm) followed by sprinters, hurdlers, middle distance runners, javelin throwers and the lowest in long distance runners (35.66cm). Athletes with a high degree of flexibility traditionally present improved proficiency in movements. Flexibility throughout the full range of motion must be aptly supported by muscles (Bradley and Portas, 2007; Ozcaldiran, 2008). So far multistage test was concerned, male sprinters reported the highest mean value for multistage (8.18 level) followed by long jumpers, javelin throwers, middle distance runners, hurdlers and the lowest in long distance runners (7.2 level), while in female athletes, the highest mean value for multistage test was found in javelin throwers (6.69 level) followed by middle distance runners, long jumpers, hurdlers, sprinters and the lowest in long distance runners (6.15 level). Alexander (1989) studied elite sprinters and found significant correlations between 100 m sprinting times and peak torque of the
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Anderson et al. (1991) conducted a study to compare the relationships among isometric, isotonic and isokinetic concentric and eccentric quadriceps and hamstring forces and three components of athletic performance in collegiate aged, male athletes. Bilateral quadriceps and hamstring muscle torque were obtained (n=39) using a kincom for concentric (rate at 60 degree/sec and 180 degree/sec) eccentric (rate at 30 degree/sec and 90 degree/sec), isotonic and isometric (knee angle at 60 degree) contractions. Athletic performance was assessed using vertical jump performance, 40-yard dash time and agility run time. The best predictor of 40-yard dash time was the right peak isokinetic concentric hamstring force at 60 degree/sec (r = 0.57; P<0.05). The best predictor of agility runtime was the left mean isokinetic eccentric hamstring force at 90 degree/sec (r = 0.58; P<0.05). There were no significant correlation between any quadriceps or hamstring force and vertical jump. It was concluded that isokinetic eccentric quadriceps and hamstring forces were no better predictors of athletic performance than muscle forces assessed in other ways. However, they may be more predictive of some specific components of performance.

5.4. Pearson’s Correlation Coefficients

5.4.1. Trunk Strength

In male athletes, significant positive correlations (p<0.002 - 0.001) of trunk extension and flexion strength were found with sit and reach test, multistage test, humerus and femur biepiconylar diameters, upper arm, wrist and ankle circumferences, shoulder width, while significant negative correlations (p<0.001) was noted in almost all skinfold measurements. In female athletes, significant positive correlations (p<0.04 - 0.001) of trunk extension strength were noted with multistage test, humerus and femur biepiconylar diameters and upper arm circumference, and of trunk flexion strength with femur biepiconylar diameter, upper arm circumference. Statistically significant negative correlations (p<0.04 - 0.001) of trunk extension strength were found with shoulder width and four skinfold measurements viz. biceps, triceps, suprailiac and calf skinfolds, and significant negative correlations (p<0.001) of trunk flexion strength with hip circumference, shoulder width, biceps and suprailiac skinfolds. When both male and female athletes data were pooled, significant positive correlations (p<0.001) of trunk
extension and flexion strength were found with sit and reach test, multistage test and with all anthropometric variables studied, except body mass index and suprailiac skinfold. Sinaki et al. (2001) reported that in both males and females, there was more loss of trunk extensor strength than appendicular muscle strength with increasing age. Reduction in trunk extension strength in women coincided with increased body mass index in older age. In women, there was a negative correlation between body weight and level of physical activity, whereas this finding was not evident in men. This cross-sectional study showed that physiologic reduction of muscle strength, which began early in life, later stopped and that muscle strength even improved, despite the aging process. Therefore, strengthening exercises at any age is encouraged to prevent the impact of several age-related musculoskeletal challenges. Clayton et al. (2011) demonstrated significant correlations with isokinetic trunk (core) strength and multiple measures of athletic performance in male collegiate baseball athletes ($r = .680; P \leq 0.05$).

5.4.2. Shoulder Strength

In male athletes, significant positive correlations ($p<0.001$) of shoulder extension (right dominant) strength were observed with humerus and femur biepiconylar diameters, wrist circumference and ankle circumference, and of shoulder flexion (right dominant) with three circumferencial measurements, viz. upper arm, hip and wrist. On the other hand, significant negative correlations ($p<0.004 \text{–} 0.001$) of shoulder extension (right dominant) were found with chest circumference and suprailiac skinfold, and of shoulder flexion (right dominant) with four skinfold measurements. In female athletes, significant positive correlations ($p<0.02 \text{–} 0.001$) of shoulder extension (right dominant) were seen with humerus biepiconylar diameter, chest circumference and biceps skinfold, and of shoulder flexion (right dominant) with femur biepiconylar diameter, upper arm circumference, while statistically significant negative correlations ($p<0.05 \text{–} 0.001$) of shoulder extension (right dominant) were found with femur biepiconylar diameter and upper arm circumference and of shoulder flexion (right dominant) with chest circumference, hip circumference, shoulder width, biceps, suprailiac and calf skinfolds. When both male and female athletes data were pooled, significant positive correlations ($p<0.001$) of shoulder extension and flexion strength were found with sit and reach test, multistage test and with all anthropometric variables.
studied, except body mass index, triceps and subscapular skinfold and significant negative correlations (p<0.001) was observed with biceps skinfold.

5.4.3. Elbow Strength

In the context of Pearson’s product moment correlation, in male athletes significant positive correlations (p<0.05 – 0.001) of elbow extension strength (right dominant) with multistage test, femur biepiconylar diameter, wrist and ankle circumference, shoulder width and of elbow flexion (right dominant) with upper arm and wrist circumferences while significant negative correlations (p<0.01 – 0.001) of elbow extension strength (right dominant) were found with height, bodyweight and three skinfolds viz. triceps, subscapular and calf, and of elbow flexion (right dominant) significant negative correlations (p<0.04 – 0.001) were noted in humerus and femur biepiconylar diameters and calf skinfold. In female athletes, significant positive correlations (p<0.03) of elbow extension strength (right dominant) was observed with biceps skinfold only and of elbow flexion (right dominant) with humerus biepiconylar diameter, upper arm and ankle circumferences, while statistically significant negative correlations (p<0.02 – 0.003) of elbow extension strength (right dominant) were found with body weight and calf skinfold and of elbow flexion strength (right dominant) with chest and hip circumferences, biceps and calf skinfolds. When both male and female athletes data were pooled, significant positive correlations of elbow extension and flexion strength were found with sit and reach test, multistage test and with all anthropometric variables studied, except body mass index and significant negative correlations (p<0.001) was observed in percent body fat.

5.4.4. Wrist Strength

In male athletes, significant positive correlations (p<0.01 – 0.001) of wrist extension strength (right dominant) were observed with femur biepiconylar diameter, wrist circumference, shoulder width and of wrist flexion strength (right dominant) with three circumferential measurements viz. upper arm, chest and hip. On the other hand, significant negative correlations (p<0.01 – 0.001) of wrist extension strength (right dominant) were noted with subscapular and calf skinfolds, and of wrist flexion strength (right dominant) with multistage test, humerus and femur biepiconylar diameters, ankle circumference and suprailiac skinfold, while in female athletes significant positive
correlations (p<0.02) of wrist extension strength (right dominant) was noted with sit and reach test, biepiconylar diameter humerus and of wrist flexion strength (right dominant) were observed in humerus biepiconylar diameter, upper arm and ankle circumferences, biceps skinfold, while significant negative correlations (p<0.05 – 0.005) of wrist extension strength (right dominant) was noted with body weight and calf skinfold and of wrist flexion strength (right dominant) was observed in chest and hip circumferences, and calf skinfold. When both male and female athletes data were pooled, significant positive correlations (p<0.01 – 0.001) of wrist extension strength (right dominant) were observed with multistage test and most of the anthropometric variables, except height, body weight, body mass index, chest circumference and shoulder width, and of wrist flexion strength (right dominant) with sit and reach test and most of the anthropometric variables, except body mass index and humerus and femur biepiconylar diameters while statistically significant negative correlations (p<0.01 – 0.001) was noted with percent body fat. Viitasalo et al. (1985) reported that grip strength was found to have the highest correlation with chronological age and to be least affected by the anthropometric variables among the strength variables studied.

5.4.5. Hip Strength

In the context of Pearson’s product moment correlation, in male athletes significant positive correlations (p<0.05 – 0.001) of hip extension (right dominant) with sit and reach test, humerus and femur biepiconylar diameters, wrist circumference, shoulder width, and of hip flexion (right dominant) with humerus and femur biepiconylar diameters, wrist circumference, shoulder width, while significant negative correlations (p<0.001) of hip extension (right dominant) was noted only in calf skinfold, and hip flexion (right dominant) was noted with upper arm and hip circumferences and three circumferential measurements viz. biceps, triceps and calf. In female athletes, significant positive correlations (p<0.03 – 0.001) of hip extension (right dominant) were observed with sit and reach test, upper arm, wrist and ankle circumferences, and hip flexion (right dominant) were observed with wrist and ankle circumferences, shoulder width and significant negative correlations (p<0.03 – 0.001) of hip extension (right dominant) was noted with height, body weight, chest and hip circumferences, biceps and calf skinfolds, and of hip flexion (right dominant) (p<0.05 – 0.001) were seen in
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5.4.6. Knee Strength

In male athletes, significant positive correlations (p<0.01 – 0.001) of knee extension strength (right dominant) were noted with upper arm and wrist circumferences and of knee flexion strength (right dominant) were seen with multistage test, humerus and femur biepiconylar diameters, wrist and ankle circumferences, shoulder width and suprailiac skinfold while significant negative correlations (p<0.04 – 0.001) of knee extension strength (right dominant) were found with sit and reach test, humerus and femur biepiconylar diameters, suprailiac and calf skinfolds, and of knee flexion strength (right dominant) with chest and hip circumferences and three skinfold measurements viz. biceps, triceps and calf. On the other hand, in female athletes, significant positive correlations (p<0.04 – 0.001) of knee extension strength (right dominant) were observed with multistage test, body mass index, percent body fat, humerus biepiconylar diameter, wrist circumference, and of knee flexion strength (right dominant) was noted with humerus biepiconylar diameter, while significant negative correlations of knee extension strength (right dominant) were found with percent lean body mass, chest circumference, biceps and suprailiac skinfolds, and of knee flexion strength (right dominant) was noted with biceps and triceps skinfolds. When both male and female athletes data were pooled, significant positive correlations of knee extension and flexion strength were found with sit and reach test, multistage test and most of the anthropometric variables, and significant negative correlations (p<0.001) was found in percent body fat and biceps skinfold. Players who attained better performances in sprint tests tended to have a lower percentage of body fat and by inference a higher fat free mass percentage. Anderson et al. (1991) conducted a study to compare the relationships among isometric, isotonic and isokinetic concentric and eccentric quadriceps and hamstring forces and three components of athletic performance in collegiate aged, male athletes. Bilateral quadriceps and hamstring muscle torque were obtained (n=39) using a
Discussion

Kincom for concentric (rate at 60 degree/sec and 180 degree/sec) eccentric (rate at 30 degree/sec and 90 degree/sec), isometric and isometric (knee angle at 60 degree) contractions. Athletic performance was assessed using vertical jump performance, 40-yard dash time and agility run time. The best predictor of 40-yard dash time was the right peak isokinetic concentric hamstring force at 60 degree/sec ($r = 0.57; P<0.05$). The best predictor of agility runtime was the left mean isokinetic eccentric hamstring force at 90 degree/sec ($r = 0.58; P<0.05$). There were no significant correlation between any quadriceps or hamstring force and vertical jump. It was concluded that isokinetic eccentric quadriceps and hamstring forces were no better predictors of athletic performance than muscle forces assessed in isometric and isotonic contraction. However, they may be more predictive of some specific components of performance.

5.4.7. Ankle Strength

In the context of Pearson’s product-moment correlations, in male athletes, significant positive correlations ($p<0.01–0.001$) of ankle extension strength (right dominant) were observed with sit and reach test, multistage test, humerus and femur biceps anular diameters, wrist and ankle circumferences, shoulder width, and of ankle flexion strength (right dominant) were noted with wrist and ankle circumferences and shoulder width, while significant negative correlations ($p<0.01–0.001$) were observed with chest circumference, biceps, triceps and calf skinfolds, and of ankle flexion strength were found with triceples, subscapular and calf skinfolds ($p<0.01–0.001$). In female athletes, positive correlations ($p<0.02–0.001$) of ankle extension strength (right dominant) were observed with body mass index, percent body fat, humerus biceps anular diameter, ankle circumference, shoulder width, and of ankle flexion strength was found with ankle circumference, while significant negative correlations ($p<0.008–0.001$) of ankle extension strength (right dominant) were noted with height, body weight, percent lean body mass, chest circumference and biceps and triceps skinfolds, and of ankle flexion strength (right dominant) were noted with height, chest and hip circumferences and biceps skinfold. When both male and female athletes data were pooled, significant positive ($p<0.03–0.001$) correlations of ankle extension and flexion strength were observed with sit and reach test, multistage test and most of the anthropometric variables and significant negative correlations ($p<0.001$) was noted with percent body
fat and biceps skinfold. Woodson et al. (1995) has analyzed the relationship of peak torque with work and power on the muscles surrounding the ankle with correlation coefficients being reported, ranging from 0.81 to 0.97. No studies to date have examined this relationship for muscles surrounding the ankle joint.

Results of present study showed that athletes possessed higher muscle strength than their control counterparts. Male athletes exhibited significantly (p<0.05) greater muscle strength of trunk and peripheral joints, differences in anthropometric measures, performed better on multistage test and possessed good flexibility than their female counterparts. Neu et al. (2002) observed that males posses greater muscle mass and force generation capability as compared with the girls. Round et al. (1999) reported that the testosterone level in males could explain most of the gender differences. Miller et al. (1993) suggested that the greater strength of the men primarily is caused by their larger muscles. Tanner et al. (1981) concluded males on average were taller than females, which has been suggested to be an important determinant of muscle mass and force development due to greater bone length. It is generally accepted that increased flexibility enhances sports performance. Nutter et al. (1987) reported low to moderate correlations between isokinetic strength and body size or body composition components.

5.5. **Strength of the Study**

1. To the best of our knowledge, the present study was the first of its kind reporting the dynamometric strength measurements of seven sites in collegiate athletes of Delhi covering large age groups from 18 to 25 years.

2. The large sample size comprising of 522 collegiate athletes (378 male and 144 female) was one of the unique criteria of the study. As many as six sports events, viz. sprinters, hurdlers, middle distance runners, long distance runners, long jumpers and javelin throwers) were involved in the study. No such study was reported earlier covering such a vast Indian athletes data.

3. The findings of the study can be used as the base line values of the various dynamometric strength measurements for the athletes of different events studied, especially for Indian context.
4. The findings of the present study can be used to assess the muscle strength of various joints studied in the athletes to keep the injuries at bay and to enhance their performance with establishing proper training programs.

5. Correlations of seven strength measurements with eighteen anthropometric characteristics and two physical performance tests have been explored in this study. Such a vast number of strength measurements and anthropometric characteristics were not included in any earlier studies to search the correlations among themselves. Considering the significant contributions of anthropometric variables towards the strength measurements, special attention may be taken to those anthropometric variables too.

6. It was obvious that the strength measurements would have strong correlations with the physical performance tests studied. The findings of the present study may help the trainers, physical therapists and sports medicine personals to identify the joints to improve the strength through training programs in specific events.

7. To support as well as criticize the present findings, a wide range of very recent references have been used.

5.6. Limitations of the Study

1. Age groups from 18-25 years were taken.

2. As many as six sporting events were selected for the study

3. Athletes from various colleges of Delhi were considered.