Chapter 1
Introduction
INTRODUCTION

The skeletal muscles, like the joints, are designed to contribute to the body’s needs for stability and mobility. The muscular system is one component of the musculoskeletal system, which includes not only the muscles but also the bones, joints, tendons, and other structures that permits movement. It is a form of striated muscle tissue which is under voluntary control. It represents as much as 40-50% of the total body weight and is responsible for development of tension necessary for joint movement. The size, shape and gross structure of skeletal muscle vary greatly in accordance with their particular function and workload, ranging from the 1.4 cm length of the dorsal interossei to the 30 cm length of the Sartorius muscle (Poole, 1986). An average adult male is made up of 42% of skeletal muscle and an average adult female is made up of 36% (as a percentage of body mass) (Marieb et al., 2010). Muscle serves a mobility function by producing or controlling the movement of a bony lever around a joint axis.

1.1. Structure of Skeletal Muscle

A skeletal muscle is composed of many thousands of muscle fibres. A single muscle contains many fascicles, a group of muscle fibres surrounded by connective tissue, which serve as a medium for a rich nerve and blood supply. The arrangement, number, size and type of these fibres may vary from muscle to muscle, but each fibre is a single muscle that is enclosed in a cell membrane called sarcolemma. Like other cells in the body the muscle fibre is composed of cytoplasm, which in a muscle is called sarcoplasm. The sarcoplasm contains myofibrils, which are the contractile structures of a muscle fibre and non-myofibrillar structure such as ribosomes, glycogen and mitochondria, which are require for cell metabolism. The myofibril is composed of thick myosin and thin actin myofilaments. The interaction of these two filaments is essential for a muscle contraction to occur (Scott et al., 2001).
1.2. Muscle Fibres

Three principal types of muscle fibres are found in varying proportions in human skeletal muscles. The three primary muscle fibres types are referred as type I (slow), type IIA (intermediate) and type IIB (fast). Muscle fibres are long unbranched, thread like cells which taper slightly at both ends, vary considerably in diameters.

Type I fibers (slow oxidative slow twitch): These fibers are suited for endurance and are slow to fatigue because they generate energy for ATP re-synthesis by means of a long term system of aerobic energy transfer. They tend to have a low activity level of ATPase (adenylpyrophosphatase), a slower speed of contraction with a less well developed glycolytic capacity. They contain large and numerous mitochondria and with the high levels of myoglobin that gives them a red pigmentation. They have been demonstrated to have high concentration of mitochondrial enzymes, thus they are fatigue resistant. Slow twitch muscles fire more slowly than fast twitch fibers and so are able to fire for a longer time before fatiguing. Fast twitch fibres are efficient for short bursts of speed and power and use both oxidative metabolism and anaerobic metabolism depending on the particular sub-type. These fibers are quicker to fatigue (Scott et al. 2001).
Type IIA (fast oxidative glycolytic, fast twitch-fatigue resistant): These fibres possess intermediate amount of oxidative and glycolytic enzyme, which indicate the use of both anaerobic and aerobic metabolism. These fibres have cytological properties that fall between the type I and type IIB fibres (Norkin, 2005).

Type IIB fibers (fast glycolytic, fast twitch-fast fatiguable): These fibers are well supplied with glycolytic enzymes and are poorly endowed with oxidative enzyme, which indicate a high capacity for anaerobic metabolism. These fibre are associated with relatively sparse capillary density, have few mitochondria. These muscle units generate a large amount of tension in a short time, but they fatigue rapidly (Norkin, 2005).

It must be remembered that skeletal muscles, although a mixture, can only have one type of muscle fiber within a motor unit. Maximal contractions facilitate the use of type IIB fibers which are always activated last. These fibers are used during ballistic activities but fire easily. The total number of skeletal muscle fibers has traditionally been thought not to change. It is believed that there are no sex or age differences in fiber distribution, however, relative fiber types vary considerably from muscle to muscle and person to person. Sedentary men and women (as well as young children) have 45% type II and 55% type I fibers. People at the higher end of any sports tend to demonstrate patterns of fiber distribution e.g. endurance athletes show a higher level of type I fibers. Sprint athletes, on the other hand, require large numbers of type IIB fibers. Middle distance event athletes show approximately equal distribution of the two types. This is also often the case for power athletes such as throwers and jumpers. It has been suggested that various types of exercise can induce changes in the fibers of a skeletal muscle. It is thought that if you perform endurance type events for a sustained period of time, some of the type IIB fibers transform into type IIA fibers (Yessis, 2006). However, there is no consensus on the subject. It may well be that the type IIB fibers show enhancements of the oxidative capacity after high intensity endurance training which brings them to a level at which they are able to perform oxidative metabolism as effectively as slow twitch fibers of untrained subjects. This would be brought about by an increase in mitochondrial size and number (Norkin, 2005)
1.3. **Organization of Skeletal Muscle Fibers**

Muscle fibers of the fascicles lie parallel to one another, the fascicles themselves can vary in their relationship to one another and to their tendons. The different patterns of arrangement of the fascicles produce four different types of skeletal muscles: parallel muscles, convergent muscles, pennate muscles, and sphincter muscles (Freidrich et al., 2008).

1.4. **Muscle Force**

The force applied by muscle to a bony segment is actually the resultant of many individual force vectors (muscle fibres) pulling on a common tendon. The direction of pull for any muscle is always toward the center of muscle. The length of the resultant vector is proportional to its magnitude. EMG can measure the electrical activity of muscle, which is in turn directly proportional to the motor unit activity which is in turn directly proportional to isometric muscle force. However neither electrical activity nor the number of motor units is the absolute measure of muscle force, because muscle is exquisitely sensitive to mechanical environment (length and velocity). Muscle force is proportional to physiologic cross-sectional area (PCSA), and muscle velocity is proportional to muscle fiber length. In the clinical setting strength of a muscle is measured by weights, force transducers and isokinetic devices, they actually measures the joint torque. The strength of a joint, however, is determined by a number of biomechanical parameters, including the distance between muscle insertions and pivot points and muscle size. Every muscle pulls on each of its attachments every time the muscle exerts a force. The muscle will move a segment in its direction of pull only when the torque of the muscle exceeds the opposing torques. Muscles are normally arranged in opposition so that as one group of muscles contracts, another group relaxes or lengthens. Antagonism in the transmission of nerve impulses to the muscles means that it is impossible to fully stimulate the contraction of two antagonistic muscles at any one time. During ballistic motions such as throwing, the antagonist muscles act to 'brake' the agonist muscles throughout the contraction, particularly at the end of the motion. In the example of throwing, the chest and front of the shoulder (anterior deltoid) contract to pull the arm forward, while the muscles in the back and rear of the shoulder (posterior deltoid) also contract and undergo eccentric contraction to slow the
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motion down to avoid injury. Part of the training process is learning to relax the antagonist muscles to increase the force input of the chest and anterior shoulder (Cools et al., 2004).

1.5. Types of Muscle Activity (contraction)

a. Static muscle activity
b. Dynamic muscle activity

Static muscle activity mainly involves isometric muscle contraction in which the length of the muscle remains the same while tension develops towards maximal force against an immovable resistance. It is used for muscle setting during early phase of rehabilitation. In most sports, the need for static contraction is rare and is often seen in gymnastics, wrestling, shooting and judo.

Dynamic muscle activity involves isotonic, isokinetic, open and closed chain activity. In isotonic contraction the tension in the muscle remains constant despite a change in muscle length. This can occur only when a muscle's maximal force of contraction exceeds the total load on the muscle. Isokinetic contraction involves a constant speed of contraction against a preset resistance. In this maximal resistance is provided throughout the range motion with the help of dynamometer.

Muscle strength is an excellent indicator of general health and thought to be a major factor in athletic success. An individual's physical strength is determined by two factors; the cross-sectional area of muscle fibers recruited to generate force, the intensity of recruitment and the quantitative muscle strength assessment by dynamometer. Individuals with a high proportion of slow twitch muscle fibers (type I) will be relatively weaker than a similar individual with a high proportion of fast twitch fibers (type II), but would have a greater inherent capacity for physical endurance. The genetic inheritance of muscle fiber type sets the outermost boundaries of physical strength possible (barring the use of enhancing agents such as testosterone), though the unique position within this envelope is determined by training. Individual muscle fiber ratios can be determined through a muscle biopsy. Other considerations are the ability to recruit muscle fibers for a particular activity, joint angles, and the length of each limb. For a given cross-section, shorter limbs are able to lift more weight. The ability to
gain muscle also varies person to person, based mainly upon genes dictating the amounts of hormones secreted, but also on sex, age, health of the person, and adequate nutrients in the diet.

1.6. Muscle Strength

The strength capability of the joint is denoted by the amount of moment that the muscle force can create at the joint to counter the external moment. Muscle strength is one of the key factors in successful sports performance and is an important indicator of the effectiveness of injury rehabilitation in athletes. Strength training has become an essential method for optimizing athletic performance, especially in sports where explosive strength and speed are key determinants (Baker and Newton, 2008; Cronin and Sleivert, 2005; Lopez-Segovia et al., 2010; Marques, 2010). In light of this, numerous authors have studied the strength changes produced in different athletic activities (e.g. jumps, sprints, or maximum repetitions) as a result of power-centered training (Cormie et al., 2010; Hunter and Marshall, 2002; May et al., 2010; McBride et al., 2002; Mujika et al., 2009; Pui-Lam et al., 2010; Rahimi and Behpur, 2005; Tricoli et al., 2005; Turbanski and Schmidtbleicher, 2010). To monitor the performance of athletes as well as the rehabilitation progress of injured players, various lower limb strength indices have been investigated. Strength and flexibility asymmetries between the two limbs and reciprocal strength ratio between the agonist and antagonist muscles especially in lower body reportedly play an important role in sports with asymmetric kinetic patterns (Rahnama et al., 2005; Fousekis et al., 2010). Strength and flexibility asymmetry of joints or extremities can lead to improper control of body movement (Grygorowicz et al., 2010).

1.7. Isokinetic Dynamometer

The importance and widespread use of Isokinetic dynamometry for strength measurement is evidenced by good number of references (Bennett and Stauber, 1986; Appen and Duncan 1986; Taylor et al., 1991; Alexander, 1990; Cahalan et al., 1989). Isokinetic testing is used extensively to measure muscle performance in research and clinical settings (Robert et al., 1992). Since the concept by J.J. Perrine in early 1960s, isokinetic exercise has become an integral part of rehabilitation and testing of
musculoskeletal injuries in orthopedic rehabilitation and sports physical therapy (Hislop and Perrine, 1967; Goslin et al., 1979; Molnar et al., 1974; Wyatt, 1981).

Isokinetic testing devices measure torque, which is force times the perpendicular distance from the axis of rotation (i.e. moment arm) to the line of application of that force (LeVeau, 1997). With most isokinetic testing devices, the measurement of distance is unnecessary. When a limb is attached to the device, the axis of rotation for that limb must be aligned with the mechanical axis of the machine. The moment arm for the limb and the machine are, therefore, the same. As a result, measurement of distance is unnecessary if the machine has been calibrated properly (Jules et al., 1987). The two major clinical application of isokinetic dynamometry are the quantitative determination of muscular performance and monitoring its variation following trauma intervention. (Andersson et al., 2001; Dvir, 2004).

Isokinetic contraction or exercise is defined as dynamic muscle activity performed at a constant angular velocity (Thistle, 1967). The speed of motion can be pre-selected and controlled using an isokinetic dynamometer (Watkins et al., 1983). The isokinetic dynamometer designed to create resistance in the internal mechanism of the dynamometer, when the exercising limb attempts to exceed the pre-selected speed setting; the isokinetic dynamometer applies accommodative resistance along the whole magnitude of the movement. Thus an increase in the muscle strength performed by the subject being evaluated produces an increase in the resistance but no increase in the velocity (Franco and Bittencourt, 2005). It permits the assessment at any speed ranging from 0 to 300 degree/sec.

Isokinetic exercise involves three phases of movement; acceleration, constant velocity and deceleration (Brown and Whitehurst, 2000). The acceleration phase, rate of velocity development, represents the beginning part of the motion and is performed without resistance (Brown et al., 2005). Constant velocity phase follows the acceleration phase of movement and corresponds to the matching between mechanically imposed velocity and subject's movement. By definition, the constant velocity portion of range of motion represents load range. The third phase of motion, (deceleration phase) represents slowing down of the device prior to contacting the end stop (Brown and Whitehurst, 2000). Increased angular velocity results in a reduction in load range,
thus data from the measurements that were performed at high angular velocities may not reflect load range values. From the classical force - velocity curve, there is an inverse exponential relationship between skeletal muscle contraction velocity and torque production (Widrick et al., 1996), and extra caution is required to make correct interpretation (Brown and Whitehurst, 2000).

Isokinetic evaluation is a standard tool for muscle strength evaluation. The major advantage of isokinetic evaluation is that it allows identification and quantification of physical strength impairments that cause functional limitations (Baltzopoulos, 1989). An isokinetic evaluation can identify muscle weakness at certain point in the range. Specific targeting of this range when designing an exercise protocol may reduce treatment time (Jones et al., 1996). Isokinetic exercise testing gives objective measurements of reciprocal muscle performance. It stress two types of measures: “endurance” the ability of a muscle to sustain torque over time and “strength” which is the ability of a muscle to develop tension. Torque or force (Watkins et al., 1983). Several researchers have investigated the isokinetic strength in specific joints in a number of different populations, but few have generated normative values for several joints or movement patterns in the same population (Lategan, 2011). Isokinetic dynamometers allow for both concentric and eccentric muscle testing and thus necessitate specific norms for each of these muscle actions (Davies et al., 2000, Lategan et al., 2009)

1.8. Muscle Strength and Sports

Baechle and Earle (2008) defined strength as a maximal force that a muscle or muscle group can generate at a specified velocity. Muscular strength is one of the major factors influencing the performance of sports activity. The assessment of strength of the athlete in the sports medicine setting has traditionally been in one of three modes, either isometrically, isotonically, or isokinetically, using concentric muscle contractions. From such strength measures, attempts have been made to determine how strength relates to athletic performance. However, the results of such studies have been contradictory. Studies by Berger and Henderson (1996), Cozens (1938), and Mc-Clements (1966) found significant correlations between isometric strength and functional performance, while others found no significant correlations (Clarke et al., 1954, 1957; Considine et
Several authors found that combinations of measures of isometric and isotonic strength correlated most highly with functional performance (Berger et al., 1966; Clarke et al., 1957; Cozen, 1938; Davis et al., 1982). Significant positive correlations were found by Minkoff and Kakehina (1979) between strength assessed isokinetically and functional performance, while other investigators found no such correlations (Lankhorst et al., 1985; Reizebos et al., 1983). Mero et al., (1981) and Young et al., (1995) have found a significant correlation between isometric peak force and rate of force development and performance of sprinting while Wilson et al., (1995) and Kukolj et al., (1999) have failed to find a significant relationship between static measures of neuromuscular function and dynamic performance. Brown et al., (2000) used ipsilateral agonist/antagonist muscle ratios as standards to measure the progress of rehabilitation or to assess the muscle imbalance.

Trunk muscle is evaluated in variety of population, Iwai et al., (2008) suggested sport-specific training of trunk muscles to develop sport specificity in their sports. Wrestlers have to train in trunk flexion and extension motions, and judokas need to strengthen trunk rotation and lateral flexion motions. This information will be available for athletes as well as strength and technical training coaches in wrestling, judo, and the other sports. Andersson et al., (1988) reported that male athletes showed higher peak torque values than the normals and the differences were largest in hip extension and trunk flexion. There was no difference in strength per kg body weight between female gymnasts and untrained males, except in trunk extension. Anne et al., (1992) compared lumbo-sacral sagittal range of motion and isokinetic trunk strength in three groups of women: Hockey athletes with a history of chronic low back pain, pain-free hockey athletes, and an age-matched, healthy non-athletic control group. Eccentric and concentric isokinetic trunk flexion and extension torques were measured in sitting through 60 degrees of trunk movement using a Kin-Com dynamometer set at 60 degrees /sec. and reported that the pain group had 12 degrees and 18 degrees less extension as well as 18 degrees and 24 degrees less total range of motion than the pain-free and control groups, respectively. Only peak and average eccentric extension torques were weaker in the pain group than in the non-athletic group. Perrin et al., (1991) examined...
concentric and eccentric strength of the trunk and hip flexor and extensor muscle groups in female runners and found eccentric strength at the trunk was greater than concentric strength. Similar results were found at the hip. Reciprocal muscle group ratios revealed that concentric trunk flexion was 52% of extension. Eccentric trunk flexion was 39% of extension. Concentric hip flexion was 98% of extension. Eccentric hip flexion was 103% of extension. The ratios were not significantly different. These findings establish previously unreported isokinetic strength values for the trunk and hip in female runners.

Shoulder flexion and extension peak torque was investigated by Freedson et al., (1993) using a velocity of 60°/s. They tested 1647 men between the ages of 21 and 30 years and reported values of 62 Nm (0.77 Nm/kg) and 99 Nm (1.22 Nm/kg) for flexion and extension, respectively and a flexion/extension ratio of 63%. In terms of athletes, several researchers have investigated shoulder function. Brown et al., (1988) tested 41 professional baseball players and when the dominant shoulder’s data for pitchers and position players were grouped, the following results were found. Shoulder flexion and extension values were 77 and 164 Nm, respectively, while horizontal abduction was 54 Nm and horizontal adduction, 128 Nm. Internal and external shoulder rotation (at 90° of abduction) were 137 and 84 Nm, respectively, with an external/ internal ratio of 61% for the dominant arm and 74% for the non-dominant arm.

Ellenbecker et al., (2003) studied whether bilateral differences exist in concentric elbow flexion and extension strength in elite junior tennis players at 90 degrees/s, 210 degrees/s, and 300 degrees/s and found no significant difference between extremities measured in elbow flexion/extension strength ratios in females and significant differences between extremities in this ratio were only present at 210 degrees/s in males.

Budziareck and Barbosa-Silva, (2008) studied handgrip strength, a valuable measurement to document progression of muscle strength, also revealed significant differences in strength between males and females. An investigation of 300 subjects found significant differences between male and female handgrip strength levels in both dominant hand and non-dominant hand. The use of sprint time as a measure of strength has also been used to determine gender and chronological age differences (Papaiaakovou et al., 2009). Three-hundred sixty children between 7-18 years of age were tested in the
In the 30m sprint. For all age groups males performed better on average than females, with significant differences in running speed between genders being found at 16, 17, and 18 years of age. In different sports events, estimation of wrist flexion and extension strength helps to screen the talents as well as performance development. In fact, the hand muscles play a vital role in the performance of an athlete.

Hip strength assessment plays an important role in clinical examination of the hip and groin region (Holmich et al., 2004), and clinical outcome measures quantifying hip muscle strength are needed. Jesse et al., (2004) reported that young participants generated maximum velocities of 362.8 degree/sec in hip flexion and 371.5 degree/sec in hip extension. Older participants produced 16% lower velocities in both directions. Blazewich et al., (1998) suggested that athletes who perform low-velocity, high force training concurrently with high-velocity training are superior in tests of isokinetic strength at high velocities when compared to athletes who only perform low-velocity, high force training. Burchanan et al. (2009) reported lower extremity strength profiles and gender based classification of basketball players aged 9-22 years and found peak torque mean values were higher for older vs. younger players and for men vs. women players. Based on discriminant function, knee strength measures did not adequately classify gender. Instead, total leg strength measures had correct gender classifications of 74 and 69% and suggested strength assessment and training of the whole lower extremity, not just knee musculature.

Values for concentric knee flexion and extension have been reported by various researchers on a variety of populations. Using a testing velocity of 60°/s, mean relative peak torque values for knee flexion ranged between 1.29 and 1.9 Nm/kg and between 2.28 and 3.38 Nm/kg for knee extension. Athletic populations have also been investigated. Schlinkman (1984) utilised 342 male high school football players, between the age of 15 to 17 years, to construct norms for knee flexion and extension at 60, 240 and 300°/s. He reported a knee flexion value of 128Nm (1.8 Nm/kg), a knee extension value of 235 Nm (3.38 Nm/kg), and an H/Q ratio of 54% at 60°/s.

Alexander (1990) tested concentric knee extension of elite sprinters and concluded that the sample tested produced torques that was significantly greater than those of the non-athlete subjects. Francis and Hoobler (1987) also studied earlier in this
direction. The factors that influence the dynamometric strength measurements include age (Cahalan et al., 1989), Gender (Alexander, 1990), weight (Falkel, 1978), height (Molnar and Alexander, 1973), athletic background (Bennett and Stauber, 1986), limb dominance (Weltman et al., 1988) etc.

Burnie and Brodie (1986) determined that isokinetic knee flexion/extension strength differences did not exist between the dominant and non-dominant leg in pre-adolescent males. Masuda et al., (2003) found negligible differences between the dominant and non-dominant isokinetic leg strength during knee flexion/extension, hip flexion/extension, and hip abduction/adduction in university soccer players. Neumann et al., (1988) found no difference between right and left isometric hip abduction torque across multiple hip angles in young adult men and women. In contrast to these findings, Hunter et al., (2000) found slightly higher dominant knee extension isometric torque (128.1 ± 3.0 Nm) compared to the non-dominant leg (122.3 ± 3.0 Nm) in 217 women between the ages of 20 and 89 years. Olmo et al., (2005) reported higher strength values of hamstring and quadriceps in sprinters than long distance runners. Gulin et al., (2011) found the functional Hcon/Qcon is related with the velocity of movement and normally it is 0.60. Wyatt and Edwards also investigated isokinetic strength in men (average age: 29 years) and reported a concentric knee flexion value of 130 Nm (1.68 Nm/kg), a knee extension value of 183 Nm (2.36 Nm/kg) and an H/Q ratio of 71%. Some of the lowest values were reported by Neder et al., (1999) whose sample included a randomised group of 45 men between the ages of 20 and 80 years (49.8± 18.1 yrs).

The ankle joint is normally evaluated for plantar and dorsiflexion in one of two ways: either with the knee fully extended or with the knee flexed to approximately 90. The fully extended position allows for both the gastrocnemius and soleus muscle groups to contribute to plantar flexion, while the bent knee position, reduces the contribution of the gastrocnemius muscle to plantar flexion. Woodson et al., (1995) analyzed the relationship of peak torque with work and power in the dorsiflexors and planterflexors of ankle, the correlation coefficient ranging from 0.81 to 0.97 for all speed of testing and angular velocities. Meyer (1981) using the straight knee position and a testing velocity of 30°/s, reported on 15 athletes and 15 sedentary controls and found dorsiflexion values of 35 Nm (0.47 Nm/kg) and 33 Nm (0.44 Nm/kg), respectively for
these two groups. Their plantar flexion values varied between 184 Nm (2.45 Nm/kg) for the athletes and 126 Nm (1.8 Nm/kg) for the sedentary participants, while the respective dorsiflexion/plantarflexion ratios, were 19% (athletes) and 26% (sedentary controls).

Age, gender, activity level and even nationality may play a significant role in interpreting an isokinetic evaluation, with older participants, women and sedentary individuals demonstrating significantly lower values compared to athlete (Dvir et al., 1989, 2004; Lategan, 2011). There are apparent sex differences in strength measures. When comparing absolute strength, males have considerably greater strength than females in all muscle groups tested, with females scoring about 50% lower than males for upper-body strength and about 30% lower for lower-body strength (McArdle and Katch, 2007). Sex differences in body composition play a large role in strength divergence with females requiring 12% of essential body fat and males only 3% of essential body fat. This large discrepancy in body composition allows males to have a higher portion of their bodies capable of generating force. Danneskiold et al., (2009) reported men are 1.5-2 times stronger than women, with the oldest men having strength similar to that observed among the youngest women. In all age groups, women have lower muscle strength than men. Men's muscle strength declines with age, while women's muscle strength declines from the age of 41 years.

1.9. Anthropometry and Sports

Athletics like other dynamic sports requires multifaceted factors for its success. These range from anthropometric, psychological, environmental, organic-functional, to specific sport factors like equipment, tactics, and techniques etc. (Monte, 1999) Athletic events focused on two energy demands aerobic and anaerobic. The maximum power an athlete could develop depends on the splitting of high-energy intra-muscular phosphagens along with anaerobic glycolysis (Plowman and Smith, 1999). With the innumerable variety of human physique, it has become a generalized consideration that some sports events are more suitable to individuals with specific physique than others (Reco-Sanz, 1998; Wilmore and Costill, 1999; Keogh, 1999).

Findings in various studies indicate significant differences in term of anthropometric and selected physical tests (sprinting, agility, vertical jumping, aerobic power) between young athletes of different levels or elite and non-elite athletes of
soccer (Janssens et al., 2004; Reilly et al., 2000), handball (Zarparidis et al., 2009), hockey (Elferink-Gemser et al., 2004) and volleyball (Gabbet and Georgieff, 2007; Smith et al., 1992; Thissen-Milder and Mayhew, 1991). On the other hand, recent studies have shown no significant difference in vertical jump and velocity of movement in the contact game between highly skilled and less skilled rugby players (Gabbet, 2009), as well as between winners and defeated karate players in anthropometric data and strength and vertical jump height, although winners tended to be more powerful in bench press and squat exercises (Roschel et al., 2009).

It has been well established that specific physical characteristics or anthropometric profiles indicate whether the player would be suitable for the competition at the highest level in a specific sport (Claessens et al., 1999; Bourgois et al., 2000, 2001; Reilly et al., 2000; Gabbett, 2000; Ackland et al., 2003; Slater et al., 2005). The importance of assessing sport-specific skills, as well as selected anthropometric and physiological characteristics in different sports, is vital to understanding sport performance, since the impact of high anthropometric and physical fitness qualities does not always transfer to improve playing performance (Gabbet et al., 2007). These anthropometric and morphological parameters are the sensitive indicators of physical growth and nutritional status of the athletes for their maximal performances (Wilmore and Costill, 1999; Chatterjee et al., 2006). Physical performance tests have immense impact on the success of the athletes.

Though anthropometric profiles of athletes are available, information regarding the dynamometric strength measurements of Indian athletes is scanty. To fulfill the lacunae of knowledge, in the present study an attempt will be made to assess the dynamometric strength measurements of collegiate athletes of Delhi. The athletes will be comprised of hurdlers, sprinters, middle and long-distance runners, high and long jumpers and javelin throwers.

1.10. Aims and Objectives

- To estimate the trends of dynamometric strength measurements on seven sites (viz. trunk, shoulder, elbow, wrist, hip, knee, and ankle) in the collegiate athletes of Delhi.
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- To investigate selected anthropometric characteristics in the collegiate athletes of Delhi.
- To study the performance tests in the collegiate athletes of Delhi.
- To observe the gender differences of dynamometric strength measurements, anthropometric characteristics and performance tests in the collegiate athletes of Delhi.
- To compare the dynamometric strength measurements, anthropometric characteristics and performance tests between the collegiate athletes and controls.
- To search any association of dynamometric strength measurements and anthropometric characteristics with the performance tests in the collegiate athletes of Delhi.

1.11. Hypothesis

There will be considerable differences in dynamometric strength measurements, selected anthropometric characteristics and performance tests between the collegiate athletes of Delhi and controls. Considerable sex differences would be there among these populations for dynamometric strength measurements, selected anthropometric characteristics and performance tests. And finally, there will be significant associations between strength measurements, selected anthropometric characteristics and performance tests in the collegiate athletes of Delhi.