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ABSTRACT

The preliminary study was aimed to compare Electromyographic (EMG) activity, Quadriceps: Hamstring coactivation (Q: H) ratio and 1- Repetition maximum (RM) squat changes of dominant leg muscles in collegiate football and volleyball players during different forms of exercises. Surface EMG analysis was carried out in 24 university level trained male players, football (n=12) and volleyball (n=12) while performing the following exercises: unilateral bridges, lunges, lateral step up to a 20.32 cm (8 inch) platform, quadruped arm/ lower extremity lift in the first session. The EMG activities of vastus medialis obliquus (VMO) and hamstrings muscles of dominant leg of the players of both groups were recorded using Power Lab EMG system (Lab Chart, AD instruments, ML-818, Australia). On the next session, 1-RM squat tests were also performed on the same players of both groups. In footballers, the lateral step-up, lunges and quadruped arm/ lower extremity lift and in volleyball players, only lunges produced EMG levels greater than 45% maximum voluntary isometric contraction (MVIC) in the VMO, which suggests that they may be beneficial for strengthening that muscle. All the exercises produced EMG levels less than 45% MVIC in hamstrings in both groups of players, so they may be more beneficial for training endurance and stabilization. The study also revealed smallest Q: H coactivation ratio in all exercises in volleyball players suggesting more hamstring activity than quadriceps but in footballers, moderate Q:H coactivation ratios

Key Words: Electromyography, Quadriceps: Hamstring coactivation ratio, Vastus medialis obliquus, Maximum voluntary isometric contraction, Root mean square, Repetition maximum.
were obtained establishing the quadriceps dominant activation in all these exercises. The 1-RM squat testing also showed significantly greater value ($p=0.00$) in football players than volleyball players. The findings in this study may be used to select specific exercises to enhance a core training programme depending on the individual needs of an athlete or as per the requirement of the specific sport.

**INTRODUCTION**

Football and volleyball are most popular sports worldwide. Football is one of those sports that require good strength, balance, stamina and flexibility. Similarly, volleyball players’ performance also depends on overall fitness i.e. strength, flexibility and balance. Sports related requirement for a football player are jumping, sudden acceleration, landing in different position, step forward, kicking a ball and sliding tackle in different ways (29). According to Orchard et al (40) kicking motion was divided into the phases of run-up/approach, backswing, wind-up, forward swing, follow through and recovery. And the most active muscle group studied was the quadriceps of the kicking leg, which acted eccentrically in the wind-up phase and then concentrically in the forward swing. The hamstrings of the kicking leg concentrically initiated the backswing and showed variable eccentric activity during the follow through. Mc Crudden and Reilly (37) compared EMG findings in punt kicking of a soccer ball with drop kicking and found similar muscle activity. Imbalance in quadriceps and hamstring strength is most common cause of injury (18). Certain muscle injuries are also common in footballers: Quadriceps (32%), hamstring (28%), adductor (19%), groin (12%) (45). Dopsaj (20) conducted a comparison study to measure the extent of flexibility among different sports and found that soccer player suffered injuries most often 64-52% of total no. of injuries and volleyball player made only 3% of injury due to good amount of flexibility than soccer. Volleyball is the sport with different technical skill and different training procedure. Quadriceps and hamstring muscles involve in several important motor abilities such as running and jumping (6). White et al (47) emphasized the importance of the relationship between the quadriceps and hamstrings and in the interaction of this musculature with the knee and suggested that the success of co activation plays a large role in providing stability to the knee and supporting the anterior cruciate ligament (ACL) in counteraction of anterior tibial translation. Muscular imbalance and muscular activation patterns affect stabilization of the knee. Low hamstring to quadriceps (H: Q) ratio may be important factor in knee injury (9). Magalhaes et al (35) noted difference in H: Q muscle ratio among soccer and volleyball players. Kovacs et al (32) reported that the most common mechanism of knee injury is asymmetrical landing when one foot contacts ground before the
other. The jump landing sequence is the most common source of injury in volleyball (13). The role of vastus medialis and rectus femoris is similar in squat jump and vertical jump (14).

Electromyographic (EMG) analysis is an important tool in providing information about muscular function (10). EMG is done by 2 methods including surface and needle method. The superficial method is recommended for investing the whole muscle activity (11). EMG values of individuals were also widely used to evaluate the muscle functions (19, 7). Aydin et al (3) compare EMG activities of knee extensor muscles (vastus lateralis and vastus medialis) between sprinters and soccer players during counter-movement jump (CMJ) performance. The Maximum Voluntary Contraction (MVC) is a measure of strength. The peak force produced by a muscle as it contracts while pulling against an immovable object. The most common method of normalization is to compare the myoelectrical activity of a given contraction to the activity of maximal voluntary isometric contraction (MVIC) (49).

To strengthen knee muscle (Quadriceps, Hamstring) in footballers and volleyball players certain strengthening exercise must be introduced in their training schedule. Ekstorm et al (21) conducted an EMG analysis of different muscles during 9 rehabilitation exercises: the lateral step-up and the lunge exercises produced EMG levels greater than 45% maximum voluntary isometric contraction (MVIC) in the vastus medialis obliquus (VMO), which suggests that they may be beneficial for strengthening and lowering the rate of injuries. The exercises that may provide a strengthening stimulus for certain muscles would be the side-bridge, the lateral step-up, the lunge, and possibly the quadruped arm/lower extremity lift. Pincivero et al (41) recorded the EMG signal amplitude of the vastus medialis and lateralis muscles during the lunge exercise, and found peak muscle activity of 150% to 175% MVC. The study of Arnason et al (2) proved that the reduction of risk of professional footballer’s injury can be done by strength training. The use of 1-Repetition Maximum (RM) testing in resistance training is to quantify the strength in order to prescribe training programme (42). Ryman (43) proved that there is a strong correlation between vertical jump test and 1- RM testing. Marques (36) observed substantial increase in performance following 12 week resistance training intervention. McGuigan and Winchester (38) found that correlation between power clean 1- RM and squat 1RM during isometric and dynamic strength testing in college football players. Aagaard et al (1) stated that H: Q ratio is effective to describe strength relationship means concentric quadriceps compare with eccentric hamstring and vice versa. Imbalance in strength of quadriceps and hamstring is common cause of injury (18). Most of the time athlete focused on development of quadriceps muscles only and hypertrophy on quadriceps occur, hamstring play major role in balancing quadriceps activity, it stabilises the knee joint, in absence of balancing leads to ACL injuries (34).

As per literature, until today there is no such data available which can affectively
shows the comparison of muscular activity of lower limb of male trained footballers and volleyball players during various exercises. To fulfill the lacunae of literature, the present study was undertaken i) to compare electromyographic activity and strength changes of dominant leg muscles (Hamstring, vastus medialis obliquus) of both forms of sports during different types of exercises, ii) to compare the differences in quadriceps: hamstrings (Q:H) coactivation ratios among the exercises in both groups so as to identify the exercises that encourage more balanced activation thereby enhancing clinical decision making and iii) to compare the differences of 1-RM squat testing of leg muscles on the basis of which we can say how trained athlete can be prevented from injury and find out what level of training will improve performance in sports.

MATERIALS AND METHODS

Subjects: The present study was carried out on 12 trained footballers (age =20±1.41 years, height=172.58± 2.97 cm, weight= 67.23± 3.54 kg and BMI= 22.59± 1.51) and 12 trained volleyball players (age =20.83±2.71 years, height=172± 3.05 cm, weight= 65.58± 4.78 kg and BMI= 22.18± 1.58). These subjects were recruited from Sports complex, University of Jamia Millia Islamia, New Delhi, India. The players of the present study were at least of collegiate level performer with minimum of 2-3 years formal training history. They had no history of lower extremity surgery within the 2 years before the study, no symptoms of injury at the time of testing, and could perform the exercises without low back and extremity pain and no other neurological and pathological condition like hypertension and diabetes etc. The players were belonged to almost same socio- economic status with similar dietary habits and got trained in same kind of environment/ climatic condition. Hence, they were considered as homogeneous. All data were collected in two testing sessions on the dominant limb of the player, which was defined as the limb used to kick a ball. Data were collected in physiotherapy research lab, CPRS, Jamia Millia Islamia, New Delhi. Prior to initial testing a complete explanation of the purposes, procedures and potential risks and benefits of the tests were explained to all the subjects and a signed consent was obtained from them. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the University’s Institutional Human Ethical Board.

Procedures: All subjects attended lab for 2 sessions, the first session trial intended to collect demographic data, fill consent form, EMG recording of the dominant leg muscles during different exercises. All subjects were taught the proper
technique for all exercises and given time to practice until they felt comfortable performing the exercises correctly. This protocol was same for both groups (volleyball and footballers). The decimal age was calculated from the date of birth recorded from original birth certificate, produced by the subjects at the time of testing. The physical characteristics including height (to the nearest 0.1 cm) and weight (to the nearest 0.1 kg) were measured by digital stadiometer (Seca 242, Itin Scale Co., Inc., USA) and body composition analyzer (Tanita BF-350, Tanita Corporation of America Inc., USA) respectively. BMI was calculated from height and weight of each of the subject separately (48). Exercises were chosen for this study because of their common use in lower extremity rehabilitation and injury prevention programs and athletes training program. These exercises are unilateral bridges, lunges, lateral step up to a 20.32 cm (8 inch) platform, quadruped arm/lower extremity lift.

**Lateral step up to a 20.32 cm (8 inch) platform:** Subject stood at the side of 8 inch platform with non dominant leg’s knee extended and foot dorsiflexed, only heel of supported limb was in contact with the ground. In order to maintain the balance, subject can take support slightly. The tested leg was placed on platform. Dominant leg which has to be tested was remaining in maximum knee flexion position. Subject instructed to maintain upright position of trunk, head, pelvic throughout the exercises. Then the subject was instructed to come back to his starting position.

**Unilateral bridging:** Subject was instructed to lie down supine in crook line position (both knee flexed), then the subject was instructed to tight the abdominal in and raised non dominant limb. Supported limb was dominant limb and the opposite hip extended so that trunk was in neutral position. The position was hold for 5 second and was repeated 3 times.

**Quadruped arm/ Lower extremity lift:** Subject was instructed to come on both knees and hand, then the subject was instructed to tight the abdominals in order to stabilize the spine, then to raise the dominant leg and the opposite arm. The position was hold for 5 second and was repeated 3 times.

**Lunges:** Subject was instructed to stand straight and then take one step ahead and lower the body to maximum knee flexion that was hold for 5 seconds and repeated for 3 times, 30 secs rest was allowed between each trial.

**EMG recording and data sampling:** Preamplified active surface EMG electrodes (Agcl silver) with inter electrode distance of 20 mm, an amplification factor of 10,000 (20–450 Hz) and the band pass filtered from 10-500 HZ are used to measure activation of the VMO and hamstrings muscles of dominant leg of
the players of both the groups while performing the following exercises: unilateral bridges, lunges, lateral step up to a 20.32 cm (8 inch) platform, quadruped arm/lower extremity lift. The EMG activity of the muscle was recorded using Power Lab EMG system (Lab Chart, AD instruments, ML-818, Australia). Prior to electrode placement, each subject was familiarized to the procedures by being instructed in and practicing the muscle tests and exercises to be performed. Once assured that the subjects could correctly perform the muscle tests and exercises, the sites for electrode placement were prepared by abrading the skin with fine sandpaper and cleansing the area with 70% isopropyl alcohol. Shaving of hair was performed if necessary. In order to reduce cable movement artefact, cables were secured using elastic bands (12). Konard (31) said that the quality of an EMG measurement strongly depends on skin preparation and electrode placement. The following steps were taken to minimize EMG signal cross-talk between muscles. The electrodes were positioned well within the borders of the muscles and applied in parallel arrangement to the muscle fibers, with a center-to-center inter electrode distance of 20 mm. The skin impedance was checked with an ohm meter attached to the connecting snap of each electrode pair and was judged acceptable if less than 5000 Ω (17). EMG electrodes were placed on the desired investigated muscles. A general electrode placement was used for the entire hamstring muscle group midway between the gluteal fold and the popliteal line on the posterior surface of the knee in the center of the posterior thigh (17). Electrodes were also placed at a 55° oblique angle over the center of the muscle belly of the VMO muscle, 2 cm medially from the superior rim of the patella (17). For normalization of the EMG data, a maximum voluntary isometric contraction (mVIC) was performed for each muscle and the EMG amplitude recorded. The test positions were consistent with those demonstrated in manual muscle testing books commonly used by physical therapists, but in some cases additional manual resistance was applied (28, 30). Manual resistance was applied gradually up to the maximum amount, and then held for 5 seconds. Each muscle test was repeated 3 times, with a 30-second rest period between. Proper electrode placement was also confirmed by observing the EMG signal amplitude during the manual muscle tests. The MVIC of the hamstring muscles was performed in the prone position, with the knee flexed 45° with resistance applied just above the ankle (28). The MVIC of VMO was performed in the sitting position, with the knee flexed between 45° to 60° and resistance applied just above the ankle (16, 50). After completing MVIC for each muscles 1 minute rest was given to subject to avoid fatigue. Then the subject performed 4 exercises like unilateral bridges, lunges, lateral step up to a 20.32 cm (8 inch) platform, quadruped arm/Lower extremity lift randomly. Rest periods of 30 seconds were allowed between repetitions of the exercises (3 trials/exercise were performed) and a 1-minute rest period was given between exercises. Considering these rest periods and the fact that the exercises did not always activate the same muscle to
high levels, we felt that fatigue was not a factor in this study. Following data collection, 2 of the exercises were repeated a second time in 13 subjects randomly to determine if there was consistency in the EMG recordings. During data collection, the raw EMG recordings were monitored. The raw EMG data were full-wave rectified, processed using a root-mean-square (RMS) algorithm. The amplitude was calculated from a 2-second window centered about the peak activity for each of the MVICs and exercises and the mean EMG signal amplitudes for the quadriceps (VMO) and hamstrings were calculated and averaged. The maximum EMG signal amplitude during the MVIC of each muscle was recorded and represented 100% muscle activity. The muscle activity recorded during the exercises was then expressed as a percentage of the MVIC.

On the next session, 1-RM tests were performed using methods previously described by Hoffman (26). Upon arrival at the research laboratory, participants prepared for exercise by performing a 5-minute warm-up. All participants wore their own comfortable shorts, T-shirts, and athletic shoes. The squat exercise required the subject to place an Olympic bar across the trapezius muscle at a self-selected location. Each subject descended to the parallel position which was attained when the greater trochanter of the femur reached the same level as the knee. The subject then ascended until full knee extension. As they became familiar with the techniques, they selected a weight to lift for the 1-RM test and a weight that would fatigue them in 10 or fewer repetitions for the squat. Prior to the 1-RM attempt, they performed several warm-up repetitions with light weights. For the 1-RM test, if the subject was successful, 5 to 20 lbs was added for the next attempt. This step was repeated until the subject could not lift the weight; thus the maximum weight lifted successfully was recorded as the 1-RM. This procedure was achieved in 3 to 6 attempts, with 3 to 5 min rest between attempts (33). Estimated Wathen (46) equation has been used to predict 1 RM. The basis of the formula is the strong association between 1-RM and number of repetitions (10 or fewer) needed to reach fatigue.

Data Analysis

Mean, standard deviations (±SD) for all the selected variables were calculated. The assumption of normality was verified using the Shapiro-Wilk W-test. One tailed student t-test was also performed among the selected parameters between Footballers and Volleyball players. The significance level was defined as $p<0.05$. Data were analyzed using the Statistical Package for Social Science (version 21.0, SPSS, Inc., Chicago, IL). The significance level was defined as $p<0.05$. 
RESULT

Table 1 represent the normalized EMG activity (% MVIC) of VMO muscles of dominant leg of football and volleyball players in different forms of exercises. In footballers, EMG activities of VMO muscle showed significantly greater activation in unilateral bridging (p=0.04), lateral step up (p=0.00) and quadruped one arm/leg lift (p=0.02) than volleyball players. EMG activities of VMO muscle in footballers showed the greatest activity but insignificant in lunges (p=3.3) compared to the volleyball players.

<table>
<thead>
<tr>
<th>Exercises</th>
<th>Footballer (n=12)</th>
<th>Volleyballer (n=12)</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral bridging</td>
<td>35.68±17.70</td>
<td>24.92 ±9.95</td>
<td>0.04*</td>
</tr>
<tr>
<td>Lateral step up</td>
<td>48.11±13.80</td>
<td>26.7 ±13.48</td>
<td>0.00*</td>
</tr>
<tr>
<td>Lunges</td>
<td>77.09±12.03</td>
<td>48.42 ±16.32</td>
<td>3.3NS</td>
</tr>
<tr>
<td>Quadriped one arm /</td>
<td>49.16±20.23</td>
<td>35.16 ±11.22</td>
<td>0.02*</td>
</tr>
<tr>
<td>leg lift</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values expressed as mean ± SD (percentage of maximum voluntary isometric contraction); n=12 for each group; *P<0.05; NS=not significant.

Table 2 represent the normalize EMG activity (% MVIC) of hamstring muscles of dominant leg of football and volleyball players in different form of exercises. In volleyball players, EMG activities of hamstring muscle showed significantly greater activation in unilateral bridging (p=0.00), lateral step up (p=0.02) and lunges (p=0.01) than footballers. However EMG activities of hamstring muscle in footballers showed the greatest activity but insignificant in quadruped one arm/leg lift (p=0.1) compared to the volleyball players.
**Table 2. Normalized EMG activity (% Maximal Voluntary Isometric Contraction) of Hamstring muscles in both sports group (n=24) during different form of exercises**

<table>
<thead>
<tr>
<th>Exercises</th>
<th>Footballer (n=12)</th>
<th>Volleyballer (n=12)</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral bridging</td>
<td>9.44 ± 5.37</td>
<td>19.88 ± 8.35</td>
<td>0.00*</td>
</tr>
<tr>
<td>Lateral step up</td>
<td>9.41 ± 4.58</td>
<td>20.21 ± 16.05</td>
<td>0.02*</td>
</tr>
<tr>
<td>Lungs</td>
<td>12.9 ± 8.01</td>
<td>24.45 ± 16.13</td>
<td>0.01*</td>
</tr>
<tr>
<td>Quadriped one arm / leg lift</td>
<td>41.43 ± 23.62</td>
<td>31.75 ± 10.67</td>
<td>0.1NS</td>
</tr>
</tbody>
</table>

Values expressed as mean ± SD (percentage of maximum voluntary isometric contraction); n=12 for each group; *P<0.05; NS=not significant.

Table 3 represent the calculated quadriceps (VMO): hamstring (Q: H) coactivation ratio of dominant leg of football and volleyball players in different form of exercises. The football players showed more significant Q: H coactivation ratio for unilateral bridging (p=0.05), lateral step up (p=0.00), lunges (p=0.00) and quadruped one arm/ leg lift (p=0.01) than volleyball players.

**Table 3. Calculated Quadriceps (VMO): Hamstring (Q:H) coactivation ratio in both Sports group (n=24) during different form of exercises**

<table>
<thead>
<tr>
<th>Exercises</th>
<th>Footballer (n=12)</th>
<th>Volleyballer (n=12)</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral bridging</td>
<td>3.87 ± 2.86</td>
<td>1.64 ± 0.91</td>
<td>0.05*</td>
</tr>
<tr>
<td>Lateral step up</td>
<td>4.75 ± 2.28</td>
<td>2.17 ± 1.22</td>
<td>0.00*</td>
</tr>
<tr>
<td>Lungs</td>
<td>5.74 ± 2.66</td>
<td>2.58 ± 2.10</td>
<td>0.00*</td>
</tr>
<tr>
<td>Quadriped one arm / leg lift</td>
<td>1.52 ± 0.74</td>
<td>1.12 ± 0.34</td>
<td>0.01*</td>
</tr>
</tbody>
</table>

Values expressed as mean ± SD of Q:H coactivation ratio; n=12 for each group; * means significant at P<0.05.
Table 4 represent the 1 RM squat testing which showed significantly greater value (p=0.00) in football players than volleyball players.

<table>
<thead>
<tr>
<th></th>
<th>Footballer (n=12)</th>
<th>Volleyballer (n=12)</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1RM squat test (kg)</td>
<td>72.5 ±14.66</td>
<td>46.67 ±15.68</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

Values expressed as mean ± SD (kg); n=12 for each group; * means significant at P<0.05.

DISCUSSION

To our knowledge, this study provided the most comprehensive comparison between EMG changes and strength changes of VMO and hamstring muscle during different form of exercises in football and volleyball players. EMG is a technique used in monitoring electrical activity and action potential (23). Fukuda et al (23) concluded that there is a linear relationship between force and RMS value of EMG in hamstring and quadriceps. It makes possible to record muscular activity; on that basis force parameter and muscular action in particular activity can be easily measured (22, 15). When muscle starts to contract and relax, the EMG established suitable programme, evaluation of technical development and sportsmanship (44). In this study, EMG activity of VMO and hamstring muscles measured during different form of exercises, those activities produces higher EMG activity are signifying for the more force production of that muscle and such activities are best suited for strength development and these activities should be incorporated in the training schedule. In the present study, both the groups performed similar kind of exercises but despite of that they showed dissimilar EMG activity suggesting that there are some factors which are responsible for these differences like individual variability, age, muscle girth and number of training hours.

In the present study, EMG activities of VMO muscle (Table 1) of footballers showed significant (p<0.05) greater activation in unilateral bridging, lateral step up and quadruped one arm/ leg lift than volleyball players. EMG activities of VMO muscle in footballers showed the greatest activity but insignificant in lunges compared to the volleyball players. The major requirements of football are jumping, running, sprinting, kicking skills. Orchard et al (40) concluded that quadriceps is most active muscle which acted eccentrically during wind up and concentrically during forward swing. It is more active in kicking leg than stance leg. Hence
footballers utilize quadriceps muscle very frequently as a result of which they get hypertrophied. Hence the EMG activity of VMO was more in footballers compared to the volleyball players in these exercises. Ekstrom et al (21) concluded that those activities produced more than 45% of MVIC are good for strength development and less than 45% is better for endurance development and VMO activity is greater during lateral step up and lunges. Ayotte et al (4) also found 55% of MVIC in VMO during lateral step up. In the present study, it was observed that the EMG activity of VMO is more than 45% of MVIC in lateral step up (footballers), quadruped one arm/leg lift (footballers) and lunges (both footballers and volleyball players). Based on these findings it can be hypothesized that these exercises could be beneficial if included in the training regime of footballers and volleyball players for strengthening of VMO muscles.

In the present study, EMG activities of hamstring muscle (Table 2) showed significant (p<0.05) greater activation in unilateral bridging, lateral step up and lunges in volleyball players than footballers. However EMG activities of hamstring muscle in footballers showed the greatest activity but insignificant in quadruped one arm/leg lift compared to the volleyball players. Charoenpanicha et al (14) suggested that semitendinosus which is part of hamstring muscle activated during vertical stop jump and landing required dissipation of the kinetic energy and maintain stability. Bai et al (5) suggested that hamstring muscle activated prior to quadriceps during “landing from rotation jump”. “It is known well that the muscle activities of hamstrings lead to posterior movement of tibia and reduce ACL injury”. Increased muscle activity before and after initial contact is important for stabilization. In the present study, it was observed that the EMG activity of hamstring is less than 45% of MVIC in all form of exercises (both footballers and volleyball players). Based on these findings it can be hypothesized that these exercises could be beneficial for the development of endurance and stabilization training in footballers and volleyball players.

Begalle et al (8), categorised the various exercises on the basis of Q: H coactivation ratio. Those exercises are come under the range of (2.87±1.77 to 3.64±1.57) considered as smallest co activation exercises. It suggested that greater hamstring activity and lower quadriceps activity (most balanced). The present study revealed that all exercises lunges, quadruped one arm/leg lift, lateral step up, and unilateral bridging ranging from 1.12±0.34 to 2.58±2.10 (table 3) for volleyball players, which indicated more hamstring activity than quadriceps (more balanced). Our study also presented lower value (1.52±0.74) for quadruped one arm /leg lift in footballer which is again considered as smallest co activation ration. Begalle et al (8) provided range for moderate coactivation ratio 5.26±4.43 to 5.52±2.89 and suggested that 5 times greater quadriceps activity than hamstring. Our study also indicated that three exercises like lunges, unilateral bridging and lateral step up ranging from 3.87±2.86 to 5.74±2.66 (table 3) for football players which clearly
establishes the quadriceps dominant activation in these exercises.

Resistance training is a part of training programme to improve power and athletics performance (43). Maximum strength determined the sprint performance and jumping height (39). In volleyball players, correlation between 1 RM squat and vertical jump tests was high ($r= 0.68 & 0.88$) and it has suggested that maximum squat strength will cause 40% of vertical jump performance (43). Maximum strength & power testing are common associated to evaluate strength of an athlete and validity that is established (26). Hoffmann et al (27) also said that just after performing 1 RM Squat test within 5 minute vertical jump performance improved in footballers due to post activation of muscles. The result of the present study revealed that footballers have greater 1 RM values (table 4) than volley ball players supported the above finding. Footballers are more engaged in running and jogging which produce adaptation in muscles. The increase in 1 RM values observed in footballers may also be due to alterations in neural factors caused by the intensity of training (25). There is also a possibility that hypertrophy in leg muscles may account for the increase in 1 RM because changes in body composition (reduced fat mass) is likely in this phase of the training cycle (pre-season). It has also been suggested that a possible response to strength training may be consolidation of the tissue as the muscle fibres increase in girth at the expense of extracellular spaces (24). However, we do not have data to discriminate between changes in muscle cross sectional area or neural activity as the mechanism (s) behind increased leg strength.

**CONCLUSIONS**

The unilateral-bridge and quadruped arm/lower extremity lift exercises provide muscle activation without external loading for training endurance and stabilization of the trunk and hips. The lateral step-up and lunge exercises provide adequate stimulus to the vastus medialis obliquus muscle for strength and endurance training. The findings in this study may be used to select specific exercises to enhance a core training programme. Lunges, unilateral bridging and lateral step up exercises in footballers should be used with care if the goal is to facilitate coactivation but could be desirable when the goal is quadriceps strengthening. Use of the unilateral bridging, lateral step up, lunges in volleyball players and quadruped one arm/ leg lift in both football and volleyball players is encouraged to help facilitate a more balanced Q:H coactivation ratio during rehabilitation.
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REFERENCES


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