

Co-Contraction of Knee Stabilizer Muscles during Sustained Squat Posture (A Yogic Posture) in Athletes

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Abstract

Simultaneous activation of muscles across a joint can be defined as muscle co-contraction. Its purpose is to augment the ligament function in maintenance of joint stability, provide resistance to rotation at a joint, and equalize the pressure distribution at the articular surface. The purpose of this study was to investigate the Co-contraction of selected knee stabilizer muscles as a measure of neuromuscular fatigue in relation to gender, performance and side (left and right) of male (n1=32) and female (n2=18) during sustained squat posture (yogic posture). Squat Posture was performed at an angle of 135°-150° because strength of knee stabilizers (muscles)

varies from angle to angle and 135° to 150° is prominent angle range having high consideration for the performance of numerous physical daily routine activities such as walking, running, cycling, stepping and driving including development of fundamental skills for different sports across all ages and sex. Vastus Medialis (VM) and Vastus Lateralis (VL) muscles from the Quadriceps group were the knee stabilizers chosen for recording the EMG simultaneously from both right and left legs as these muscles are considered important for stabilization and protection of patellofemoral joint. The statistical analysis applied were ANOVA with post hoc analysis to determine the influence of fatigue in terms of gender, performance and side (left and right). The results showed significant female dominance behavior over males in coactivation of VM and VL muscles along with bilateral Asymmetry during sustained squat posture. The results of this study would help in better understanding the changes in knee stabilizers activation strategies that can help the clinicians and trainers in planning, execution of rehabilitation related to patellofemoral joint injuries.

Keywords: Co-contraction; Fatigue; Gender; Squat; Bilateral

Introduction

Approximately one-third of musculoskeletal problems in the world accounts for knee related pain. As per the rough estimates mentioned by Pawade et al., fifty (50) percent of athlete and non-athlete physically active persons in India only has some degree of knee pathologies involving patellofemoral joint each year [1]. This dysfunction frequently affects the young adult population most probably athletes and female sedentary population [2,3]. The etiological factors related to dysfunction of patellofemoral joint are still under research while the biomechanical factors including static and dynamic unbalance stands out [2-5]. The rehabilitation treatment available to treat this syndrome includes open kinetic and closed kinetic chain exercises. Squatting exercise (yogic posture) is considered safe and effective and is most frequently employed among the closed kinetic chain exercises by clinicians/physiotherapists/others in rehabilitation and conditioning of athletes affected with or without patellofemoral joint syndrome. CKC exercises facilitate co-contraction of the leg muscles to provide stability at the knee for stance and movement [4]. Muscle co-contraction is the simultaneous contraction of the muscles acting around a joint [6]. It is an important phenomenon considered for joint stabilization that minimizes the effects of potential internal and external disturbances helping in regulating joint load [7]. There is paucity in the current literature regarding Vastus Medialis and Vastus Lateralis (VM:VL) coactivation ratios during closed chain exercises especially sustained squat posture. This posture may be useful to prevent future knee injuries related to patellofemoral joint by increasing the dynamic stability of the joint and its surrounding structures [2,5,7].

The purpose of this study was to investigate the co-contraction of selected knee stabilizer muscles as a measure of neuromuscular fatigue in relation to gender, performance and side (left and right) of

male (n1=32) and female (n2=18) during sustained squat posture. Squatting being a popular yogic Asana or posture is most frequently used for quadriceps strengthening, rehabilitation and evaluation test. Vastus Medialis (VM) and Vastus Lateralis (VL) muscles from the Quadriceps group were the knee stabilizers chosen for recording the EMG simultaneously from both right and left leg as these muscles are considered important for stabilization and protection of patellofemoral joint. The muscle balance between the VM and the VL, along with the peri-articular soft tissue structures acting on the patella, is a major component in the control of normal patellar alignment and function [8]. The measurement of co-contraction is done by the analysis of EMG activity of VM and VL muscles because EMG is widely used by researchers to assess the quality of motor coordination, motor learning stage and the level of joint stability [9-11]. Squat Posture was performed at an angle of 135°-150° because strength of knee stabilizers (muscles) varies from angle to angle and as an important consideration i.e. the angle at the knee joint between 135° to 150° for the performance of numerous physical daily routine activities such as walking, running, cycling, stepping and driving including development of fundamental

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skills for different sports across all ages and sex. We hypothesized that possible gender, side (left and right) and performance related differences would be found in co-activation ratios during isometric contraction. The results of this study would help in the understanding the significance of the gender and performance related differences in the co-activation ratio during this yogic posture. Such understanding is important for the clinicians to evaluate and manage the rehabilitation related to patellofemoral joint injuries. Changes in activation strategies of muscles can provide valuable information regarding the mechanisms that alter neuromuscular strength of fatigued muscles.

Materials and Method

Participants

The study population consisted of male (n1=32) and female (n2=18) sportsperson wherein fifty (50) healthy sportspersons engaged in different sports were recruited as volunteers for this study. Inclusion criteria for the study was subjects above 18 years of age, willing to participate in the study and not suffering from any other medical illness which might hamper functioning of their nerves and muscles, so as to make them unfit to participate in the study. Mean (\pm SD) characteristics of male subjects with regard to age were 19.8 (\pm 2.2) years, height 170.7 (\pm 8.6) cm and weight 70.4 (\pm 13.8) kg. Average Mean (\pm SD) characteristics of female subjects with regard to age were 19.3 (\pm 1.8) years, height 156.6 (\pm 6.9) cm and weight 52.7 (\pm 11.7) kg. EMG activity was recorded simultaneously from the selected muscles of both the lower limbs of all subjects during sustained squat posture.

Exclusion criteria for the subjects was having any medical conditions/contractures/deformities in the knee/ankle joint or suffering from skin condition which might impede the fixation of the electrodes on the body surface. Before participating in the study each participant was explained about the purpose and protocol to be followed for the study. Written informed consent was obtained from each participant as per ethical requirements before participating in the study.

Data acquisition

EMG Signals were acquired using four-channel wireless EMG BIOPAC Inc. (CMRR: 110 dB at 50/60 Hz, Maximum Sampling rate: 200 K samples/s and Gain: 5-50,000, Input Impedance: 2 M Ω). The skin was rubbed with cotton containing alcohol to minimize the skin impedance, thereby improving signal acquisition (Figure 1). Disposable electrodes (44 \times 32 \times 1 mm) were placed on the subject's selected muscles following standard protocols [12] to acquire EMG simultaneously from both the legs as shown in Figure 1. The inter-electrode distance was 20 mm, center to center.

After the subject preparation was complete, they were asked to perform squatting posture in order to become familiar with the protocol. Squatting posture was performed at an angle of 135°-150° because strength of knee extensor (muscles) varies at different angles and angle range from 135° to 150° angle is considered to be important for the performance of numerous physical daily routine activities such as walking, running, cycling, stepping and driving including development of fundamental skills for different sports across all ages and sex [13] Moreover in developing countries such as India squatting is widely used to perform daily tasks such as sitting on the floor while eating or preparing food or other required tasks. It is also commonly used by people for relieving themselves on a daily basis. The data acquisition software (Acqknowledge 4.1, BIOPAC systems Inc.) was set to sampling frequency of 2000 Hz to avoid the aliasing effects as per Nyquist criteria.

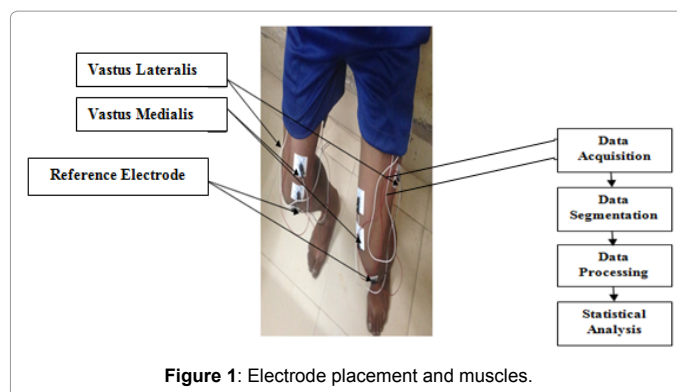


Figure 1: Electrode placement and muscles.

Data segmentation

The raw EMG data is further segmented to 30, 60 90 and 120 s for each subject, as all subjects were able to sustain minimum of 120 s squat posture. Based on median split method of maximum sustainability (duration) of the squat posture scores, subjects were divided into high performance and low performance group. The different groups formed were named as Female low performance (FLP), female high performance (FHP), Male low performance (MLP) and Male high performance (MHP). This was done to understand influence of fatigue on gender, performance and side (left and right) with progression of time.

Data processing

The raw EMG signals acquired from the subjects were quantified with the help of MATLAB. For processing of EMG signal, notch filter was applied to remove 50 Hz noise interference from the signal. Cascaded low-pass (20 Hz) and a high-pass filter (450 Hz) were then applied in order to remove other noise sources from the signal. The filtered EMG signals were rectified in order to calculate the RMS values. RMS is the square root of the arithmetic mean of the squares of the set of values. Let X_i represent the rectified EMG signal, then RMS value is represented by equation 1

$$RMS = \sqrt{\frac{1}{T-t} \sum_{i=1}^T (X_i)^2} \quad (1)$$

Where, X_i is the rectified signal and T, t is the two time intervals at which signal acquisition takes place. It is most frequently used parameter for the EMG analysis because during muscle contractions, it reflects the level of physiological activity in the motor unit [12].

Determination of co-activation ratio

The co-contraction between VM and VL muscles as indicated by the Surface EMG signal was calculated as: VM:VL = Normalized value of VM/Normalized value of VL [14,15].

Statistical Analysis

SPSS (IBM) was used for all the statistical analysis. A One-Way ANOVA was carried out to determine whether the influence of gender on co-contraction ratio with progression of time is statistically significant or not. Least significant differences (LSD) were computed to verify the differences between the groups related to VM:VL ratio (Table 1). The findings using post hoc analysis are shown in Table 1 ignoring the ANOVA table. The level of significance was set at $p < 0.05$.

Dependent Variable		Mean Difference (I-J)	Std. Error	Sig	
R30	FLP	FHP	0.184	0.196	0.354
		MLP	-0.040	0.173	0.817
		MHP	-0.031	0.173	0.858
	FHP	MLP	-0.224	0.173	0.203
		MHP	-0.215	0.173	0.222
		MLP	0.009	0.147	0.950
R60	FLP	FHP	0.155	0.210	0.463
		MLP	0.016	0.185	0.930
		MHP	0.000	0.185	0.999
	FHP	MLP	-0.139	0.185	0.457
		MHP	-0.155	0.185	0.407
		MLP	MHP	-0.016	0.157
R90	FLP	FHP	0.135	0.191	0.482
		MLP	-0.002	0.169	0.988
		MHP	.040	0.169	0.815
	FHP	MLP	-0.138	0.169	0.418
		MHP	-0.096	0.169	0.574
		MLP	MHP	0.042	0.143
R120	FLP	FHP	0.142	0.188	0.453
		MLP	-0.018	0.166	0.913
		MHP	-0.024	0.166	0.887
	FHP	MLP	-0.161	0.166	0.339
		MHP	-0.166	0.166	0.323
		MLP	MHP	-0.005	0.141
L30	FLP	FHP	-2.422*	1.063	0.027
		MLP	-0.123	0.939	0.897
		MHP	-0.569	0.939	0.548
	FHP	MLP	2.299	0.939	0.018
		MHP	1.853*	0.939	0.055
		MLP	MHP	-0.446	0.797
L60	FLP	FHP	-2.203*	1.059	0.043
		MLP	-0.134	0.936	0.887
		MHP	-0.783	0.936	0.407
	FHP	MLP	2.069	0.936	0.032
		MHP	1.420	0.936	0.136
		MLP	MHP	-0.649	0.794
L90	FLP	FHP	-1.898*	0.864	0.033
		MLP	-0.073	0.764	0.925
		MHP	-0.330	0.764	0.668
	FHP	MLP	1.826	0.764	0.021
		MHP	1.569*	0.764	0.046
		MLP	MHP	-0.257	0.648
L120	FLP	FHP	-1.805*	0.893	0.049
		MLP	-0.110	0.790	0.890
		MHP	-0.283	0.790	0.722
	FHP	MLP	1.695	0.790	0.037
		MHP	1.522*	0.790	0.060
		MLP	MHP	-0.173	0.670

Table 1: Least significant differences (LSD) applied on right and left leg with progression of time.

Significant at 0.05 levels. FLP: Female Low Performance; FHP: Female High Performance; MLP: Male Low Performance; MHP: Male High Performance

Results

The results of statistical analysis as shown in Table 1 clearly demonstrated that the significant differences were found only in left leg of male and female athletes. The summary of the findings from Table 1 of LSD analysis are as follows:

1. During first 30 s (0-30 s), co-activation ratio was statistically significant between female low and high performance athletes (0.027) in left leg. It was also statistically significant between male and female high performance athletes (0.055) in left leg.
2. During second 30 s (30-60 s), co-activation ratio was statistically significant between female low and high performance athletes (0.043) in left leg.
3. During third 30 s (60-90 s), co-activation ratio was statistically significant between female low and high performance athletes (0.033) in left leg. It was also statistically significant between male and female high performance athletes (0.046) in left leg.
4. During fourth 30 s (90-120 s), co-activation ratio was statistically significant between female low and high performance athletes (0.049) in left leg. It was also statistically significant between male and female high performance athletes (0.060) in left leg.
5. Overall there was female dominating phenomenon Figure 2.

Further analysis demonstrates gender, performance and side (left and right) related differences in the VM:VL ratio with progression of fatigue (time) during sustained squat posture in right and left leg is shown in Figure 2 through the results of descriptive statistics. Trace titles in figure referred to as FLP=Female Low Performance, FHP=Female High Performance, MLP=Male Low Performance and MHP=Male High Performance. It clearly demonstrated that during sustained squat posture, co-activation ratio of females dominated males. For both male and females, the ratio decreases with progression of fatigue (time). It is also depicted that the female high performance athletes have higher values of co-activation ratio followed male high performance athletes (Figure 3). The bilateral asymmetry is also shown in the Figure 3 as left leg having higher co-activation ratio values than that of the right leg.

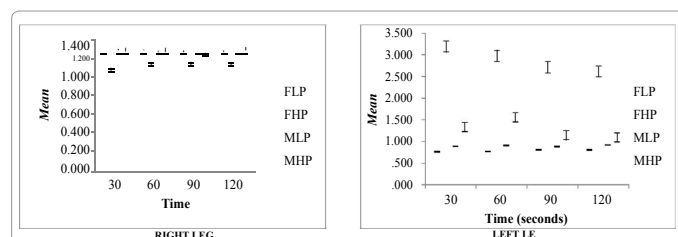


Figure 2: Gender, performance and side related difference in VM:VL ratio of right and left leg.

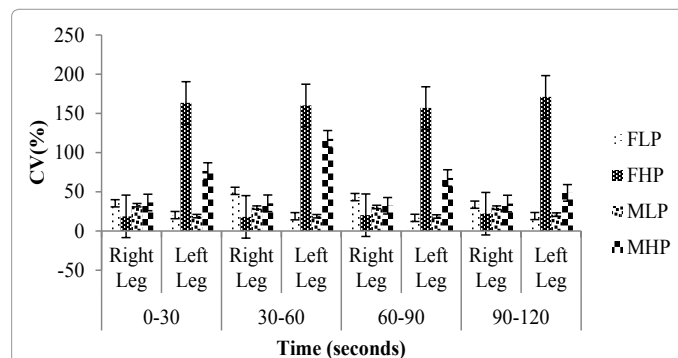


Figure 3: Coefficient of variation difference in VM:VL ratio of right and left leg.

	0-30		30-60		60-90		90-120	
	Right Leg	Left Leg	Right Leg	Left Leg	Right Leg	Left Leg	Right Leg	Left Leg
FLP	35.40	20.28	51.29	18.92	43.26	16.81	33.56	19.13
FHP	18.70	163.44	18.02	160.22	20.18	156.97	22.16	171.10
MLP	32.96	19.04	29.82	18.92	30.68	18.49	29.78	20.90
MHP	36.48	76.60	35.37	117.57	32.26	67.65	35.05	48.64

Table 2: Coefficient of variation (%) of right and left leg with progression of time.

Note: FLP: Female Low Performance; FHP: Female High Performance; MLP: Male Low Performance; MHP: Male High Performance

The coefficient of variation (%) in both right and left leg is demonstrated in Table 2. From the findings of Table 2 as illustrated in Figure 3. It is evident that FHP has higher co-activation than that of MHP, FLP and MLP at both right and left legs, hence FHP having higher chances of picking up injuries. Attribution factor FHP reflects higher muscular development asymmetry.

Discussion

Muscle co-activation is an important phenomenon for regulation of joint load that minimizes the external and internal disturbances around the joint. Our results demonstrated the decrease in the ratio with progression of fatigue (time) which is in concordance with the results reported by researchers related to fatigue [16,17]. The decrease in ratio with progression of fatigue can be understood as a good system, their pattern of motor control is affected significantly which in result decreases their ratio [18]. The interpretation of the results also depicted that initially VM has higher activation and with progression of time, VM activation decreases while VL activation increases. This shows that fatigue change the level of co-activation of VM and VL muscles as positive effect of sports participation/training toward endurance adaptation. The findings of the study collectively demonstrated gender; performance and side (left and right) related differences in co-contraction ratio. Female athletes have higher VM:VL ratio than male athletes during sustained squat (yogic) posture. It also demonstrated that high performance athletes have higher values of co-contraction than low performance athletes may be attributed to in balanced training. This indicates that female high performance athletes followed by male high performance athletes are prone to the higher risks of picking up patellofemoral injuries than compared to male and female low performance athletes respectively. This phenomenon suggest that the closed kinetic exercises employed by clinicians for rehabilitation of sportspersons from patellofemoral injuries must be designed according to gender and performance with a common strategy as normally followed may not be employed for both the genders and performance levels. These results would also be important in prevention of possible training related injuries in patellofemoral joint. It would also provide important information that would help in adjusting training protocol of athletes.

Conclusion

The following are the conclusive remarks from the study

1. The study found gender related differences with regard to co-contraction ratio of VM and VL muscles during isometric contraction in athletes.
2. Decrease in co-activation ratio is found with progression of fatigue (time) that reflects muscular endurance adaptation related to coaching.
3. Predominance (higher co-activation) of left leg over right leg across the protocol refers that left leg may have higher chances of injury.

4. Co-contraction of female is found to be superior to male athletes across the experimental protocol refers that female having higher chances of injury.
5. Performance related differences are found with regard to co-contraction ratio of VM and VL muscles during isometric contraction in athletes.

These results are in line with our hypothesis stated above. The results of this study would help in the understanding to the significance of the gender, performance and side (left and right) related differences in the co-contraction ratio. Such understanding is important for the clinicians/fitness trainer to evaluate and manage the rehabilitation related to patellofemoral joint injuries and conditioning. Changes in activation strategies of muscles can provide valuable information regarding the mechanisms that alter neuromuscular strength endurance of fatigued muscles.

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Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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