"Interactions of lower extremity muscles during Forward Walkover activity on floor - an Electromyographic analysis"

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Abstract

The particular role of a muscle in a given movement depends upon the requirement of that movement. Even when the movements are controlled voluntarily, the individual muscle is not controlled voluntarily. In various sports actions, the muscle involvement pattern is theoretically analyzed by identifying the sequential movements involved in that action and then finding the probable muscle involvement using its anatomical attachments and, deriving its direction of action. Using electromyographic (EMG) techniques, the activity of a number of muscles in the sports actions can be established in relation to each other, with real time sequence and to exact degree of involvement. The present endeavor had been undertaken with the aim to analyze some lower extremity muscles interaction during Forward Walkover activity on floor using electromyographic techniques and kinesiological concepts. Electromyographic activities for different muscles during the activity had been analyzed using a multichannel recorder (Sensormedics, R612, Netherlands). The signal conditioning was made through a coupler (Direct/Average EMG type 9852A) preamplifier (type820), and amplifier (type 412). The muscles, namely, Gastrocnemius, Vastus lateralis and Vastus medialis were observed to be highly active during the Forward Walkover activity on floor. However, Biceps femoris and Rectus femoris muscles showed moderate activation during this activity. The sequential recruitment pattern of the muscles is discussed. The findings are likely to find utility in designing scientific orientated training schedules by sports scientists and coaches for the gymnasts.

KEYWORDS: Gymnastics, Muscle Recruitment, Lower extremity muscles, Electromyography, Forward Walkover

INTRODUCTION

All forms of movements performed by an individual constitute a category of motor skills of moving the body on ground or on any other resistant surface. Some movements are caused by the action of a single muscle, but majority of the movements are caused by the action of the muscles in groups. Even a simple movement such as holding a pen or blinking of eyes, requires the coordinated action of a relatively large number of muscles, each performing its own particular task in a single well- integrated manner. The muscles can play various roles in movements. They can act as prime mover (agonist), antagonists, synergists, stabilizers or neutralizers. The muscles of bi-axial and tri-axial joints can cause movements involving more than one axis, yet only one of their actions may be needed for the movement in question.

A muscle cannot voluntarily select to effect one of its movement and not another, it must depend upon the other muscles to contract and prevent the unwanted movement. The particular role of a muscle in a given movement depends upon the requirement of that movement. Even when the movements are controlled voluntarily, the individual muscles are not controlled voluntarily. So, it is very difficult to find out the role of different muscles even if it seems very simple to the casual observer.

Variety of methods is used to study the action of muscles. Theoretically, the muscular involvement pattern in an action is found by using their anatomical attachments, nature of the joint and location of the muscle. The inspection and palpation are the commonly used methods to determine the action of the muscles. But this technique needs experience and its use is limited to superficial muscles only. Better information can be gained by this method only in combination with the dissection of the cadaver and inspection and palpation of living subjects. Additionally, when the force of muscle contraction is weak, it is sometimes difficult to feel its contraction, but if the movement is performed against resistance, the contraction may be stronger and more easily felt. But again, the wrong conclusion may be drawn that the muscle is the major mover for the action involved, when actually it comes into action only as an assistant under the conditions of heavy resistance.

The other method used to study a muscular action is the electrical stimulation of the muscles. But all these methods can explain the muscle action during the single actions only. In complex actions, which involve more than one movement at different joints and where the action occurs very quickly, these methods cannot provide the real insight of what is happening with different muscles.

In various sports actions, the muscle involvement pattern is theoretically analyzed by identifying the sequential movements involved in that action and then finding the probable muscle involvement using their anatomical attachments and, deriving their direction of action. But such definitions neither can analyze the real sequence of muscular action, nor can it reveal the complex combinations of muscular actions in various sports techniques.

Using electromyographic(EMG) techniques, the activity of a number of muscles in the sports actions can be established in relation to each other, with real time sequence and to exact degree of involvement. Basmajian(1985)told that it surpassed all the older methods of studying muscular action in that it revealed what the individual muscles were actually doing not just what they 'can do' or 'probably do'. Some attempts had been made to analyze the muscle involvement pattern in various exercises and games using EMG techniques (Goswami et al., 1993, Numela et al., 1994; Mohan et al., 1995; Koukoubis et al., 1995, Dyson et al., 1996; Hancock and Hawkins, 1996; Handel et al., 1997; Rokite et al., 1998; Resmusses et al., 2001 and Jesus et al., 2008; Dionisio et al., 2008;Bernasconi et al., 2009; Lee et al., 2015). However, such types of studies in the gymnastics are very few. The present study was undertaken with the aim to analyze somelower extremity muscle interactions during Forward Walkover activity on floor using electromyography (EMG) technique.

METHODOLOGY

The study was conducted on seven female gymnasts ranging in age between twelve to twenty-three years to analyze the leg muscle involvement pattern during forward walkover (FWO) on floor using Electromyographic (EMG) techniques. All the subjects were observed to possess a good degree of skill in various gymnastic activities as evidenced by their previous performances.

Selection of Muscles:
Following superficial muscles of lower extremity (from right and left side) were included for pursuing investigation of the study:

Rectus femoris
Vastus lateralis
Vastus medialis
Biceps femoris
Gastrocnemius

Instrumentation:
The EMG Multichannel Recorder, (Sensormedics R 612, Netherland) was used to obtain Electromyograms during gymnastic activities (plate 1 and 2). The signal conditioning was made through a coupler (Direct/Average EMG type 9852A), Preamplifier (type 820) and amplifier (type 412). Bipolar surface electrodes were used to obtain the electrical signals from the muscles. The electrodes were silver/silver chloride type (Sensormedics, Netherland) with a contact diameter of 8 mm.

Procedure:
For the placement of electrodes, the muscles were palpated using their anatomical attachments and kinesiological concepts. It was difficult to standardize the electrode position due to wide variations in the muscle size and length. In an attempt to standardize the electrode placement position, Thorstensson et al., 1982 had described the use of lead line length (LLL) and subsidiary line length (SLL). In the present study this concept was applied to standardize the lead positions. The skin surface above the belly of the muscles was rubbed with saline water until the surface became red. The electrodes were filled with the electrode gel and placed over the center of the belly of the muscles and in the anatomical axis. The electrodes were sealed in position with adhesive tape. Inter-electrode distance was kept 3 cm.

To avoid the possible pull on the electrodes during the execution of gymnastic activities, the electrode wires were looped and taped to the skin few cm away from the electrode. Reference electrodes were placed on the forehead after cleaning the surface with saline water. An adjustable elastic belt was put around the waist of the subject and the electrode wires and the plugs were inserted inside the belt to avoid the pull on the electrodes and hindrances of wire during the execution of activity

EMG Recordings:

All the EMG activities were recorded on a continuous chart paper. EMG signals were recorded during maximum voluntary contraction (MVC) and during selected gymnastic activities using EMG, Multichannel Recorder (Sensor-medics R612, Netherland). The EMG's were recorded in the average mode. The mode gives the linear envelop of the average EMG signal. The signal was rectified and filtered for the range of 5.3 Hz to 1 kHz and the recording was proportional to the average number, amplitude and duration of EMG pulses (Harding and Sen, 1969). Although recording in average mode had notindicated sudden peaks of the EMG signal, nevertheless the calculations and measurement of the amplitude became easier (Dainty 1987). The gain of amplification was selected according to the level of activity of the muscle. Prior to each session of recording calibration of pen deflection of the recorder was made.

Recording of MVC:

For the recording of MVC, the subject was asked to perform the specific movement of a particular muscle against maximum resistance given by the supporter (Method described by Kendal and Kendal, 1964 and the EMG was recorded. The movement was repeated thrice and a rest period of 2-3 minutes was given between each recording. Maximum average muscle potential developed in one second was taken as a measure of MVC. Such recordings of 2-3 muscles were taken per day to minimize the effect of fatigue. Chart speed was fixed at 10 mm per second for the recordings of MVC.

Recording during Forward Walkover:

For the process of execution of Forward Walkover on floor by the subjects, four phases had been marked as shown in Fig. 1. After each phase, a mark was put on the moving graph using a manual marker attached with the machine. It was done to facilitate the explanation of the results obtained and their interaction pattern during the execution of the activity.

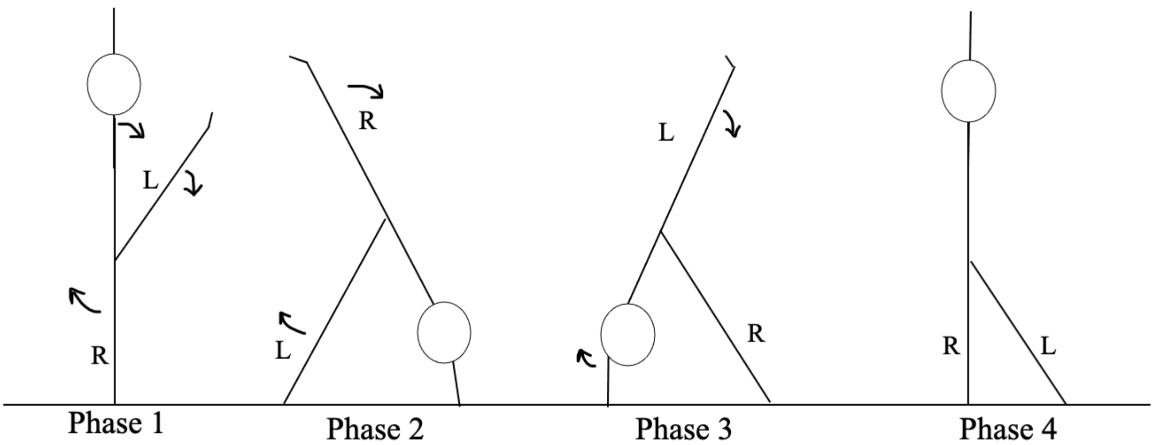

Figure 1: Various Phases of Forward Walkover on floor (Where, R = Right, L = Left and ⟶ represents direction of the movement)

For the recording of EMG during Forward Walkover on floor , the details about the gymnast and gymnastic activity like name, sex, age of the gymnast, date and time of recording and marking of different phases etc. were written on the chart paper. The machine was set at a speed of 25 mm per sec. and the subject was given the instruction to start the activity. For the EMG recording during Forward Walkover on floor, a supporter was asked to handle the wires and was moved with the gymnast to avoid the hinderances of wires in the execution of the activity. The timer was set at the rate of 1 sec.

RESULTS

The results related to the involvement of muscles were expressed in the form of percentage of MVC. For the purpose of sequential recruitment, a muscle was considered to be active only if it exhibited an involvement of more than 20% of its MVC. A muscle showing an involvement of more than 40% of its MVC was considered as highly active (main contributory muscle) and that between 20% and 40% of its MVC was said to be moderately active whereas, a muscle exhibiting an activation of less than 20% of MVC was considered as slightly less active.

Percent involvement of the musclesincluded in the study during Forward Walkover activity on Floor [Fig. 2, Table 1]:

The muscles Gastrocnemius, Vastus lateralis and Vastus medialis muscles were observed to be highly involved during the Forward Walkover activity on floor. The Rectus femoris muscles showed moderate activation during this activity, however the activation level of Biceps Femoris muscle was observed to be much lower (i.e. of the order of 10%-20% of their respective MVCs).

Sequential Recruitment of the muscles

None of the muscles included in the study was observed to be involved more than 10% of MVC valuesat the first phase of the Forward Walkover activity on floor. The muscles Vastus lateralis(left), Vastusmedialis(left),Rectus femoris(left), Biceps femoris(left) and Gastrocnemius got recruited during transitional phase 1-2 followed by Vastus lateralis(right), Vastus medialis(right), Rectus femoris(right) and Biceps femoris(right) muscles during phase 2 of the activity. These muscles remained active till the completion of the activity.

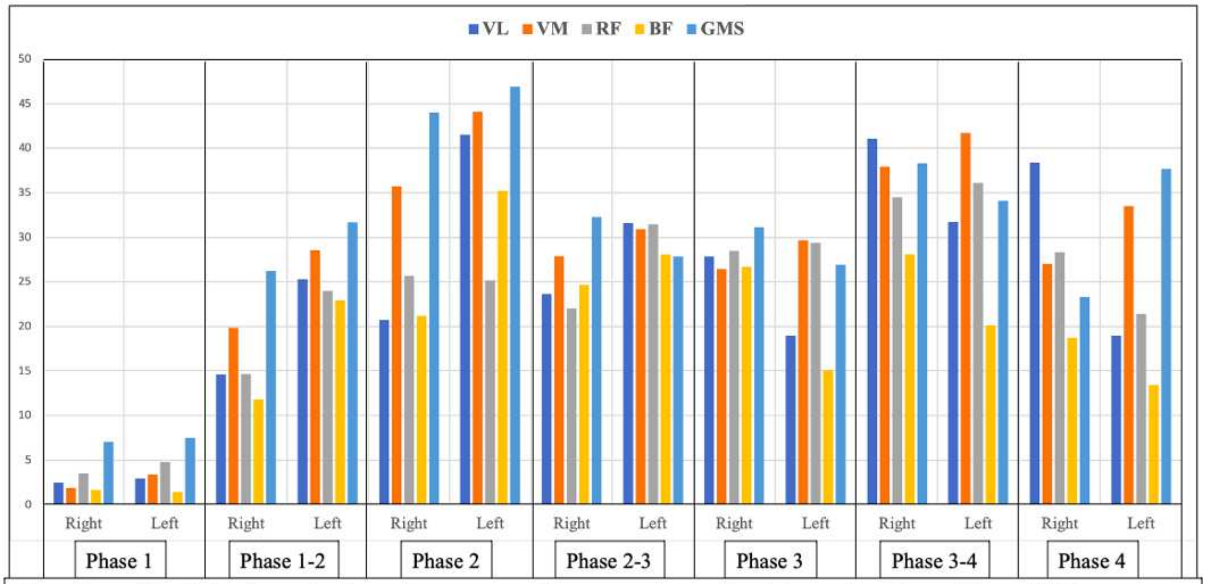

Figure 2: Magnitude of activation & recruitment pattern of lower extremity muscles during various phases of Forward Walkover activity on the floor (Where, VL=Vastus lateralis, VM=Vastus medialis, RF=Rectus femoris, BF=Biceps femoris, GMS=Gastrocnemius)

Magnitude of muscle involvement during various phases of FWO activity on floor

Phase 1

The involvement of all the muscles was found to be less than ten percent of their MVCs during phase 1. TheGastrocnemius muscle showed maximum contribution of 7.02% for right side and 7.53% for the left side of the body respectively.

Phase 1-2

All of the muscles included in the study showed a considerable increase in the involvement from phase 1 to transitional phase 1-2 of Forward Walkover activity on floor. The maximum activity of 26.23% on the right side and 31.70% on the left side was shown by Gastrocnemius muscle, followed by Vastus medialis, Vastus lateralis, Rectus femoris and Biceps femoris muscles respectively. Activity of all these muscles was observed to be more on the left side (range between 22.96% and 31.70%) than the right side (range between 11.78% and 26.23%).

Phase 2

At phase 2, the activity of all the muscles in terms of their involvement as percent of MVC increased as compared to transitional phase 1-2. The contribution of all the muscleswas observed to be more than 20% of their MVCs during this phase. The maximum activity of 44.04% for right and 46.88% for left side was shown by Gastrocnemius muscle followed by 35.74% for right side and 44.11% for left side of the body in case of Vastus medialis. Percent involvement was found to be more on the left side than the right of all of the muscles included in the study except Rectus femoris.

Phase 2-3

In case of lower extremity, the percent involvement of the muscles studied showed a decreasing trend except for Rectus femoris(left) and Biceps femoris(right) muscles. Involvement of the leg muscles was found to range between 21.95% (Rectus femoris) and 32.26% (Gastrocnemius) on the right side, and between 27.80% (Gastrocnemius) and 31.57% (Vastus lateralis) on the left side of the body. Involvement of all of the muscles included in the study was found to be more on the left side than the right except Gastrocnemius muscle.

Phase 3

All of the muscles included here except Vastus lateralis(right), Rectus femoris(right) and Biceps femoris(right) showed a decreasing trend at phase 3 as compared to transitional phase 2-3 of the activity. Involvement of all the muscleswas found to range between 15.11% (for Biceps femorisleftmuscle) and 31.18% (for Gastrocnemiusright muscle) during this phase.

Phase 3 - 4

Involvement of the muscles studied here showed an increasing trend during transitional phase 3-4 as compared to phase 3. Magnitude of activations of these muscles during Forward Walkover activity on floor was found to range between

20.13% (Biceps femorisleft)and 41.71% (Vastus medialisleft). Activity of the leg muscles in terms of percentage of maximum was observed to be more on the right side than the left side of the body except for Vastus medialis muscle.

Phase 4

As compared to transitional phase 3-4, the percent involvement during Forward Walkover activity on floor in relation to the MVC of all the muscles studied here exceptGastrocnemius(left) decreased at phase 4. The percent involvement of Vastus lateralis(right), Vastus medialis, Rectus femoris and Gastrocnemius muscles was observed to range between 20% and 40% with maximum value of 38.38% shown by Vastus lateralis(right) muscle. However, the magnitude of activity of rest of the muscles was noticed to be less than 20% of their MVCs during the last phase of Forward Walkover activity on floor.

Activities of Vastus lateralis, Rectus femoris and Biceps femoris muscles were observed to be of greater degree on the right side than the left side of the body. However, the musclesVastus medialis and Gastrocnemius showed relatively greater activity on the left than the right side of the body.

Table-1: Mean andStandard Deviation(SD) values of level of activation of various muscles of lower extremity expressed as percentage of their respective MVC values during the various phases of Forward Walkover activity on Floor.

Muscles		**Percent involvement of the muscles during various phases of Forward Walkover activity on Floor.**													
		Phase 1		**Phase-1-2**		**Phase 2**		**Phase 2-3**		**Phase 3**		**Phase 3-4**		**Phase 4**	
		Right	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Vastus lateralis	Mean	2.44	2.89	14.61	25.29	20.69	41.50	23.58	31.57	27.82	18.92	41.04	31.73	38.38	18.92
	SD	2.90	3.71	13.60	10.96	14.45	20.98	9.54	13.20	21.19	9.90	17.80	13.20	26.62	9.92
Vastus medialis	Mean	1.90	3.39	19.85	28.55	35.74	44.11	27.86	30.94	26.43	29.70	37.91	41.71	27.00	33.54
	SD	3.13	6.50	10.72	14.85	20.48	27.27	12.67	11.62	25.62	21.02	18.64	18.03	17.02	20.07
Rectus femoris	Mean	3.47	4.79	14.64	23.97	25.71	25.14	21.95	31.42	28.48	29.40	34.49	36.07	28.37	21.41
	SD	3.32	6.55	12.20	19.57	23.75	22.28	15.36	15.76	18.66	20.58	18.15	8.94	11.53	12.85
Biceps femoris	Mean	1.69	1.42	11.78	22.96	21.20	35.23	24.66	28.04	26.68	15.11	28.10	20.13	18.72	13.38
	SD	1.95	3.49	10.09	25.07	19.58	39.49	15.46	25.15	19.53	15.26	30.39	10.74	25.25	6.77
Gastrocnemius	Mean	7.02	7.53	26.23	31.70	44.04	46.88	32.26	27.80	31.18	26.90	38.33	34.09	23.33	37.67
	SD	7.91	8.39	13.08	10.34	25.03	22.72	15.28	19.80	12.04	19.48	24.01	17.81	16.69	22.72

DISCUSSION

During forward walkover activity on the floor, the legs were lifted above torso and were rotated fully in such a way that the gymnast both started and finished in a standing upright position.

At the starting position of Forward Walkover activity, that is, phase 1, both of the arms and left leg were flexed, all of the muscles studied were observed to show less than 10% activity. The present EMG study revealed the moderate involvement (i.e. between 20% and 40% of MVC) of all of the muscles from the left side of the body during transition from phase 1 to phase 2. The movement analysis of the lower extremity depicted extension of left leg and hyperextension of right leg at hip joint. Both of the feet were planter flexed. The underlined objective of this transitional phase was to start shifting body weight on shoulders and left leg. This explained the reasons behind the more activity of muscles from the left side than the right side of the body.

The attainment of phase 2 of the Forward Walkover activity on floor is characterized by touching the hands on the floor with hyper extension at wrist joints while maintaining flexion at shoulder joints and extension at elbow joints, readiness of the left foot for take-off along with plantar flexion at both feet. The muscles which were highly active (i.e. more than 40% of MVC) comprised of Vastus lateralis (left), Vastus medialis (left) and Gastrocnemius.

The involvement of the muscle Gastrocnemius during Forward Walkover activity on floor had shown an increasing trend from the beginning till phase 2 of the activity.During phase 2 to phase 3 of the activity, the body weight was borne by the shoulder joint, both the legs were off the floor, completely split, stretched and straight. It was accomplished by the rotation of trunk at shoulder joints and that of legs at hip joint. The percent involvement of the muscles studied here except Rectus femoris and Biceps femoris showed a decreasing trend during this phase of the activity.

At phase 3, when the right leg touched the floor, the body weight started shifting from the arms to the right leg. At this phase, Vastus lateralis (right), Vastus medialis (left) had been observed to be maximally active to facilitate the subject to attain this dynamic posture.

During transitional phase 3-4, the gymnast pushed off the floor with her hands, keeping the head extended. Once the foot of the first leg (i.e. right leg) was on the floor, she pulled her hips up over this leg to shift the body weight on lower extremity. As the trunk moves up, the second leg (left) completed the rotation and touched the floor. Progression of the activity to phase4 indicated the shifting of body weight from hands to both the legs. The present EMG study of the muscles revealed the same level of activation of the musclesto enable shifting and stabilizing the body weight on lower extremity.

To sum up, the Vastus lateralis, Vastus medialis and Gastrocnemius muscles were observed to be the main contributory muscles during Forward Walkover activity on floor. In general, the involvement of the muscles from the lower extremity region was observed to be constant throughout the activity with moderate involvement (between 20% to 40% of MVC).

The results of the study, in general, identified the specific group of muscles involved during the forward walkover activity along with their degrees of involvement. The findings were likely to find utility in the scientific orientation of the training schedules for the gymnasts. A strong interaction between the gymnast's trainer and the sports scientists working in the laboratories can pave the way for the individualization of the training schedules.

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