"Role of lower extremity muscles in Gymnastic Walking on balancing beam"

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Abstract

The present study had been undertaken on seven female gymnasts with the aim to analyze the lower extremity muscles interaction during gymnastic walking on balancing beam using electromyographic (EMG) techniques and kinesiological concepts. Electromyographic (EMG) activities for the gastrocnemius, Rectus femoris, Vastus lateralis, Vastus medialis and Biceps femoris muscles during gymnastic walkingon balancing beam 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 Gastrocnemius was found highly activated in almost all the phases of the gymnastic walking on balancing beam, while the other muscles had either increasing or decreasing trends in terms of magnitude and recruitment pattern. The involvement of Vastus medialis and Rectus femoris were observed to be more on the supporting leg, whereas the muscle Biceps femoris contributed more on the leg off the ground. The sequential recruitment pattern of the muscles was discussed. The findings were likely to find utility in the scientific orientation of the training schedules for the gymnasts.

KEYWORDS: Gymnastics walking, muscle recruitment, electromyography, balancing beam, Vastus lateralis, Vastus medialis, Rectus femoris, Biceps femoris, gastrocnemius

INTRODUCTION

Artistic gymnastics propels gymnasts through the triumph of strength, agility, balance and grace through a wide range of acrobatic events on various equipment. It includes floor exercises, balancing beam, uneven bars, parallel bars, vault, rings, and pommel horse.

Both men and women compete in artistic gymnastics, but the balancing beam events are unique to female gymnasts in the Olympic Games and other international competitions. In balance beam competition, gymnasts perform various activities like walkovers, handsprings, back handsprings, saltos, back saltos, turns, split jumps etc.

Balancing Beam is the most difficult event in women's gymnastics. It is the great equalizer. A gymnast needs grace, power, control, rhythm, flexibility and mental focus to perform on the balancing beam.The balancing beam is the event of perfection. There is no room for error.A gymnast needs to build up strength and balance, if she wants to learn gymnastic skills on balancing beam.

One of the very basic skill a gymnast learns on balancing beam is gymnastic walking, which is the base of other advanced maneuvers. Walking on balancing beam is not

just a muscular action but it also involves the synchronization of joint movements and thus reflect the team work in all bodily movements.

Some authors had analyzed the human gait from various aspects and found it to be a skill, which could be improved keeping the mechanical aspects in mind. (Gard, 1997; Della et al.,2001; Kuo, 2007; Arthur et al., 2010).To learn the basic skills of gymnastic walking correctly and aesthetically, there was a need of a systematic study to analyze the role of major muscles in gymnastic walking and their interactions. Electromyography (EMG) provides easy access to physiological processes that causes the muscle to generate force, produce movement, and accomplish the countless functions that allows us to interact with the world around us (Lamontagne, 2000; Masso et al., 2010).

The present study was undertaken with the aim to analyze the lower extremity muscles interaction during gymnastic walking on the balancing beam using electromyographic (EMG) technique and kinesiological concepts.

METHODOLOGY

The study was conducted on seven female gymnasts aged between twelve and twenty-three years to analyze the lower extremity muscles involvement pattern during Gymnastic Walking on balancing beam using Electromyographic (EMG) techniques and kinesiological concepts.

The non-invasive technique of recording muscles potential from the surface of the body was employed in the preset investigation. Following fivesuperficial muscles of lower extremity from both sides (right and left) of the bodywere selected for pursuing investigation of the current study.

Vastus lateralis
Vastus medialis
Rectus femoris
Biceps femoris
Gastrocnemius

The EMG Multichannel Recorder, (Sensormedics R 612, Netherland) was used to record Electromyograms during gymnastic walking on balancing beam. 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 selected lower extremity muscles were palpated using their anatomical attachments and kinesiological concepts. The concept of lead line length (LLL) and subsidiary line length (SLL) given by Thorstensson et al., (1982) and well explained by Glass and Armstrong (1997) 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 musclesin the anatomical axis. The electrodes were sealed in position with adhesive tape. Inter-electrode distance was kept 3 cm. Reference electrodes were placed on the forehead after cleaning the surface with saline water.

To avoid the possible pull on the electrodes during the execution of gymnastic walking on balancing beam, the electrode wires were looped and taped to the skin few centimeters away from the electrode. 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 hinderance of wire during the execution of the 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 walking on balancing beam.The EMG's were recorded in the average mode.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 did not indicate sudden peaks of the EMG signal, nordid the calculations and measurement of the amplitude become easier (Dainty 1987).

Recording of MVC:

For the recording of MVC,the subject was asked to perform the specific movement of a particular muscle of the lower extremity against the maximum resistance given by a supporter using the method described by Kendal and Kendal, 1964. This was repeated thrice with the rest period of 2-3 minutes between each recording. Maximum average muscle potential developed in one second was taken as a measure of MVC.

Recording during Gymnastic walking on balancing beam:

For the process of execution of gymnastic walking on balancing beam by the subjects, five phases have 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.

For the recording of EMG,the machine was set at a speed of 25 mm per sec. and the subject was given the instruction to start the activity.The timer was set at the rate of 1 sec.

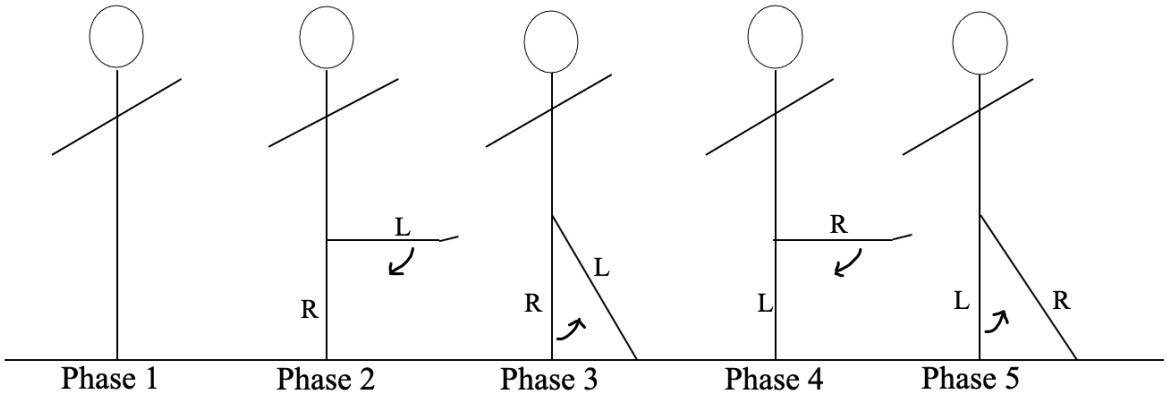

Figure 1: Various Phases of Gymnastic Walking (Where, R = Right, L = Left and → represents direction of the movement)

RESULTS: [Figure-2, Table-1]

Sequential Recruitment of the lower extremitymuscles

The activation of the four lower extremity muscles, namely, Vastus lateralis (left), Vastus medialis (right), Rectus femoris (right) and Biceps femoris (left) of the hip joint were observed to start during transitional phase 1-2 of the Gymnastic Walking activity on the balancing beam. The recruitment of Vastus lateralis (right) and Vastus medialis (left) muscles from the lower extremity started at phase 2 of the activity. However, the muscles Biceps femoris (right)and Rectus femoris (left) of the hip-joint started getting involved during phases 3 and transitional phase 4-5 respectively.

Magnitude oflower extremity muscles involvement during various phases of Gymnastic Walking Activity on balancing beam

<u>Phase 1</u>

The maximum involvement of the order of 35.05% for the left side and 26.18% for the right side of the body was exhibited by Gastrocnemius muscle at phase 1 of the gymnastic walking on balancing beam. The participation of rest of theselected muscles included in the study was noticed to be less than 10% of their respective MVCs during this phase.

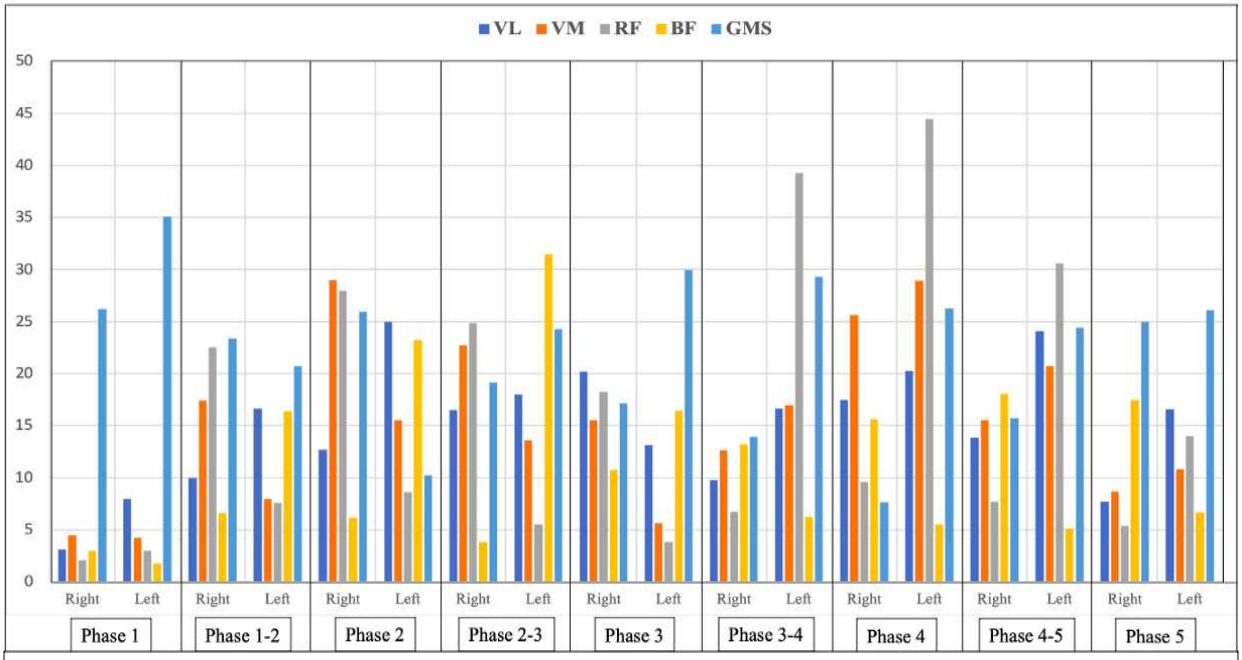

Figure 2: Magnitude of activation & recruitment pattern of lower extremity muscles during various phases of Gymnastic Walking of Balancing Beam (Where, VL=Vastus lateralis, VM=Vastus medialis, RF=Rectus femoris, BF=Biceps femoris, GMS=Gastrocnemius)

Phase 1-2

The activation level of the muscles Vastus lateralis, Vastus medialis(right), Rectus femoris(right) and Biceps femoris(left) increased and that of Gastrocnemius(left) decreased during transitional phase 1-2 as compared to phase 1 of the gymnastic walking on balancing beam. The involvement of Rectus femoris(right) and Gastrocnemius muscles were found to be more than 20% during this phase with Gastrocnemius(right) muscle showing an involvement of 23.33% of its MVC. The participation of the muscles Vastus lateralis(left), Vastus medialis(right) and Biceps femoris(left) ranged between 10%-20% of their respective MVCs. The involvements of rest of the muscles included in this study were observed to be less than 10% during this phase. A comparison of activation of muscles on right and the left sides of the body revealed the higher involvement of Vastus medialis, Rectus femoris and Gastrocnemius muscles on the right side and that of Vastus lateralis and Biceps femoris muscles on the left side of the body.

Phase 2

The activation level of all the lower extremity muscles selected in the study were found to be comparable during transitional phase 1-2 and phase 2 of Gymnastic Walking on balancing beam. From amongst the muscles studied, the activation level of Vastus medialis, Rectus femoris and Gastrocnemius muscles from the right side and Vastus lateralis and Biceps femoris muscles from the left side was noticed to be more than 20% with Vastus medialis(right) muscle showing highest involvement of the order of 29.01% of its MVC. The muscles Vastus lateralis(right). Vastus medialis(left), and Gastrocnemius(left) exhibited the involvement of less than 20% during this phase.

The activation of lower extremity muscles Vastus medialis, Rectus femoris and Gastrocnemiuswere observed to be more on the right side than the left whereasVastus lateralis and Biceps femoris muscles showed greater involvement on the left side as compared to the right side of the body.

Phase 2-3

The involvement of the lower extremity muscles Vastus lateralis(left), Vastus medialis(right) and Gastrocnemius(right) exhibited a decreasing trend and that of Biceps femoris(left) and Gastrocnemius(left) an increasing trend during transitional phase 2-3 as compared to phase 2 of the Gymnastic Walking on balancing beam. During this phase, the participation of the muscles Vastus medialis and Rectus femoris from the right side and Biceps femoris and Gastrocnemius from the left side were observed to be more than 20% of their MVCs with Biceps femoris(left) showing the maximum involvement of 31.43% of its MVC. The involvement between the range of 10%and 20% was shown by Vastus lateralis, Vastus medialis(left) and Gastrocnemius muscles during this phase. The activation of rest of the muscles selected in the study was noticed to be less than 10% during this phase.

The percent involvement of the Vastus medialis and Rectus femoris muscles were found to be more on the right side than on the left of the body, and that of Biceps femoris and Gastrocnemius muscles on the left than on the right side of the body during this phase.

Phase 3

The activation of the muscles of the lower extremity,Biceps femoris(right) and Gastrocnemius(left)were observed to increase and that of Vastus medialis, Rectus femoris(right) and Biceps femoris(left) todecrease at phase 3 than during transitional phase 2-3 of the Gymnastic Walking on Balancing Beam.

The maximum involvement of the order of 29.94% was shown by Gastrocnemius(left) muscle followed by 20.20% by Vastus lateralis(right) muscle during this phase. The muscles Vastus lateralis (left), Vastus medialis (right), Rectus femoris (right), Biceps femoris and Gastrocnemius(right) exhibited their participation between the range of 10% to 20% of their MVCs. However, the activation of rest of the muscles included in the study was found to be less than 10% of their respective MVCs during this phase.

Three selected muscles of the lower extremity, namely, Vastus lateralis, Vastus medialis and Rectus femoris showed higher involvement on the right side than on the left side whereas the involvement of Biceps femoris and Gastrocnemius muscles was observed to be more on the left side than on the right during this phase of the Gymnastic Walking activity.

Phase 3-4

The muscles, Vastus medialis(left) and Rectus femoris(left) exhibited an increase while Vastus lateralis(right), Rectus femoris(right) and Biceps femoris(left) muscles

showed a decrease in the activity during transitional phase 3-4, as compared to phase 3 of the Gymnastic Walking on balancing beam.

During this phase, the muscles Rectus femoris(left) and Gastrocnemius(left) were observed to participate by more than 20% with Rectus femoris(left) showing a maximum involvement of 39.27% of its MVC. Involvement of the other selected lower extremity muscles Vastus lateralis(left), Vastus medialis, Biceps femoris(right), and Gastrocnemius(right) was found to range between 10% and 20% of their respective MVCs. Rest of the muscles included in the present study showed an involvement of less than 10%.

A comparison of the activities of the chosen muscles on the right and left sides revealed a higher involvement of Biceps femoris muscle on the right side and that of Vastus lateralis, Rectus femoris and Gastrocnemius muscles on the left side of the body during transitional phase 3-4 of the gymnastic walking.

Phase 4

As compared to transitional phase 3-4 of Gymnastic Walking, the participation of Vastus lateralis(right), Vastus medialis and Rectus femoris(left) muscles were found toincrease and that of Gastrocnemius(right) decrease at phase 4.

The other selected lower extremity muscles Gastrocnemius(left) and Vastus medialis exhibited the involvement of more than 20% during this phase with Rectus femoris(left) muscle showing the maximum involvement of 44.47% of its MVC. The involvement of Vastus lateralis(right) and Biceps femoris(right) were observed to range between 10% and 20% of their MVCs. However, the activation of rest of the muscles of the lower extremity were found to be less than 10% during this phase.

The participation of Biceps femoris muscles was noticed to be more on the right side than the left during this phase. However,Rectus femoris and Gastrocnemius muscles exhibited higher involvement on the left side than the right-side during phase 4 of Gymnastic Walking on Balancing Beam.

Phase 4-5

As on floor, the participation of Gastrocnemius(right) muscle was found to be more during transitional phase 4-5 than phase 4 of the gymnastic walking on balancing beam. However, the other lower extremity muscles Vastus medialis and Rectus femoris(left) showed a decreasing trend during this phase.

The activation level of the four lower extremity muscles Vastus lateralis, Vastus medialis, Rectus femoris and Gastrocnemius from the left side were observed to be more than 20% of their MVCs with Rectus femoris(left) muscle exhibiting a maximum involvement of 30.60% during this phase of Gymnastic Walking activity on balancing beam. The participation of Vastus lateralis(right), Vastus medialis(right), Biceps femoris(right) and Gastrocnemius(right) muscles ranged between 10% and 20% of their MVCs. However, rest of the muscles included in the study exhibited their involvement by less than 10% during transitional phase 4-5.

The muscle Biceps femoris showed higher involvement on the right side than on the left and Vastus lateralis, Vastus medialis, Rectus femoris and Gastrocnemius muscles exhibited more percentage of involvement on the left side than on the right side during this phase.

Phase 5

As compared to the previous phase, i.e. phase 4-5, the involvement of Gastrocnemius(right) muscle was found to be more and that of Vastus lateralis, Vastus medialis and Rectus femoris(left) less at the last phase i.e. phase 5 of the gymnastic walking activity on balancing beam.

The maximum involvement of the order of 24.99% for the right side and 26.08% for the left side was exhibited by Gastrocnemius muscle. An involvement between the range of 10% and 20% was shown by Vastus lateralis(left), Vastus medialis(left), Rectus femoris(left) and Biceps femoris(right) muscles during this phase. The participation of rest of the muscles included in the study was observed to be less than 10% of their MVCs during the last phase of the activity.

The activation of Biceps femoris muscle was noticed to be more on the right side than on the left side. However, the muscles Vastus lateralis and Rectus femoris participated with higher percentage on the left side than on the right side during this phase.

Table 1: Mean and Standard Deviation (SD) values of level of activation of lower extremity muscles studied expressed as percentage of their respective MVCs values during various phases of Gymnastic Walking activity on balancing beam.

Muscles		**Percent involvement during various phases of Gymnastic Walking activity on Beam.**																	
		Phase 1		**Phase-1-2**		**Phase 2**		**Phase 2-3**		**Phase 3**		**Phase 3-4**		**Phase 4**		**Phase 4-5**		**Phase 5**	
		Right	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Vastus lateralis	Mean	3.14	7.96	9.98	16.64	12.67	25.01	16.51	17.96	20.2	13.14	9.75	16.61	17.46	20.28	13.88	24.07	7.73	16.54
	SD	3.48	10.06	5.03	13.17	10.62	14.09	8.67	13.38	13.89	13.2	6.58	17.76	11.53	19.97	7.19	25.88	7.18	9.87
Vastus medialis	Mean	4.46	4.22	17.39	7.99	29.01	15.50	22.71	13.61	15.5	5.65	12.6	16.98	25.65	28.93	15.56	20.71	8.67	10.80
	SD	4.21	4.17	8.63	3.47	18.78	6.29	12.27	8.17	9.89	8.22	8.01	12.21	13.22	16.12	9.80	11.06	7.15	6.05
Rectus femoris	Mean	2.09	2.98	22.51	7.59	27.98	8.62	24.85	5.53	18.24	3.80	6.72	39.27	9.55	44.47	7.69	30.6	5.35	13.98
	SD	3.3	2.83	13.95	3.11	11.46	2.86	11.73	3.95	6.00	3.89	2.00	16.08	4.20	18.32	4.96	16.77	5.22	6.27
Biceps femoris	Mean	2.97	1.78	6.6	16.37	6.14	23.24	3.83	31.43	10.72	16.42	13.21	6.22	15.59	5.51	18.05	5.11	17.48	6.65
	SD	4.16	3.46	4.28	9.61	5.92	16.14	3.13	8.81	20.15	14.64	5.7	6.01	11.7	4.81	9.96	2.39	13.14	5.97
Gastrocnemius	Mean	26.18	35.05	23.33	20.7	25.95	10.21	19.16	24.28	17.14	29.94	13.92	29.32	7.61	26.26	15.71	24.38	24.99	26.08
	SD	29.04	32.62	6.95	10.15	18.36	4.62	7.53	11.96	11.00	18.40	6.49	15.75	5.33	28.65	9.20	15.91	21.13	20.49

DISCUSSION

Walking is the outcome of alternating actions of the two lower extremities and involves the motion of some of the parts of the upper body to maintain balance. Walking movement appears to be very simple to the casual observer, whereas kinesiological analysis shows it to be very complex.Murray et. al., 1970; Basmajjan,1985; Kunju et al, 2009; Nor et al, 2015and many others had also emphasized the complexity of human locomotion.

Gymnastic walking activityon the balancing beamneeds afiner control of various muscles to execute the activity aesthetically while maintaining the balance. In gymnastic walking, the action observed at the hip joints consists of flexion at right angle followed by extension. Plantarflexion at ankle joint is maintained during the alternative rhythmic movements of lowerextremities. Moderate activation of Gastrocnemius muscle throughout the activity in the present study may be attributed to maintain balance on the balancing beam in standing position and to maintain plantarflexion at ankle joint.

As the activityprogressed from phase 1 to phase 3, the left leg was flexed at right angle followed by extension at hip joint.It was also supported by the Pelvic rotation, Pelvic tilt, plantar flexion and lateral pelvic displacement. A slight to moderate activation of all of the muscles studied, namely,Vastus lateralis, Vastus medialis, rectus femoris, Biceps femoris and Gastrocnemius were noticed. The involvement of the muscles Vastus medialis and Rectus femoris were observed to be more on the supportive leg (right leg). This may be attributed for maintaining dynamic balance on the right leg on a narrow beam. On the other hand, the higher contribution of Biceps femoris on the left side (the side where flexion and extension at hip joint takes place) may be due to hip extension and stabilization of pelvis during the movement.

In general, the muscular activation repeated during phase 4 to phase 5, though with variations in the magnitude of activation of various lower extremity muscles involved. However, the activation ofVastus lateralis showed a very confusing picture during similar phases of gymnastic walking on balancing beam. These variations may be ascribed to the individual characteristics, which were present to such a degree that persons were often recognized by their gaits, thus, pointing to the fact that the variations may be either structural or functional in origin. The structural differences might include variations in body proportions as well as difference in the limbs. More so, variations in the angle between the neck and the shaft of the femur and in the obliqueness of the femoral shaft might also contribute. Forward and backward distribution of weight, variations in the length of stride could also act as one of the many contributing factors. Another factor other than structural may be the innate personality of the gymnast.

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