"Contribution of trunk muscles during Forward Walkover activity on floor using EMG techniques"

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Abstract

Competitive gymnastics is a technical sport, which involves very complex body movements like rolling, turning, springing, twisting, bending, and tucking etc. on floor, and on different apparatuses. The gymnastic performance is known to be strongly linked with the vestibular control of skill. Walkovers, both forward and backward, are the basic maneuvers in the gymnast's skills. It is important to analyze the movements involved in these basic gymnastic activities and to find out which muscle is acting at a particular instant of time and to what extent. The present endeavor had been undertaken with the aim to analyze the contribution of sometrunk muscles during Forward Walkover activity on floor using electromyographic (EMG) techniques and kinesiological concepts. A multichannel recorder (Sensormedics, R612, Netherlands) was used to record the EMG activities for different muscles during the Forward Walk over activity on floor. The signal conditioning was made through a coupler (Direct/Average EMG type 9852A) preamplifier (type820), and amplifier (type 412). The muscles Trapezius middle, Trapezius upper and Erector Spinae muscles were observed to be highly involved during the Forward Walkover on floor. Trapezius lower and Rectusabdominis muscles showed moderate activation during this activity, however the activation of the rest of the muscles namely, Latissimus dorsi and Pectoralis major were observed to be low (i.e. of the order of 10%-20% of their respective MVCs). The findings are likely to find utility for the sports scientists and coaches for designing training schedules for the gymnasts.

KEYWORDS: Gymnastics, Trunk muscles, Muscle Recruitment, Electromyography, Forward Walkover

INTRODUCTION

Competitive gymnastics is a technical sport, which involves very complex body movements like rolling, turning, springing, twisting, bending, and tucking etc. on floor, and on different apparatuses. The successful performance of a gymnast depends upon the execution of intricate combination of simple and complicated movements requiring high degree of strength, flexibility, speed, co-ordination, balance and rhythm in space and time on various apparatuses as well as on floor. A well-rounded gymnast must be able to perform a wide array of athletic maneuvers, including walkovers, cartwheels, handspring, somersaults, leaps etc.

The gymnastic performance is known to be strongly linked with the vestibular control of skill. Walkovers, both forward and backward, are the basic maneuvers in the gymnast's skills. In forward walkover, the gymnast lifts her legs above her torso in a back bridge position. The legs rotate fully, so that the gymnast starts and finishes in the same position, i.e. Standing upright position. Forward walkover is performed on

both floor and balancing beam in competitive gymnastics. This is the base of learning a wide set of gymnastic skills.

It is important to establish different aspects required for the learning of basic motor skills like Forward Walkover in gymnastics. Analysis of the role of major muscles in gymnastic activities, their interaction, relative intensity and duration of muscle involvement to a specific gymnastic skill or a set of skills would enable the coaches to know about the major muscles required for that skill. It will be helpful in imparting training to develop the specific muscle groups in the right proportion.

Action of muscles can be studied by variety of methods. But most of themethods explain the muscle action during the simple actions only. In complex actions, like gymnastic skills, which involve more than one movement at different joints and where the action occurs very quickly, these methods cannot provide the real insight of the activity of different muscles.

The electromyographic (EMG) techniqueis able to analyze the exact muscle involvement pattern even in complex and fast sports activities. Using 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 the degree of involvement. Basmajian (1985) said that it surpasses all the older methods of studying muscular action in that it reveals what the individual muscles are actually doing not just what they 'can do' or 'probably do'. Some attempts have been made by various researchers to analyze the muscle involvement pattern in various sports [Herman, 1962; Helga, 1975; Eriksson et al., 1978; Anderson, 1974; Dyhre Poulson, 1987; Vointino et al., 1990; Anderson, 1991; Goswami et al., 1993, Numela et al., 1994; Koukoubis et al., 1995, Dyson et al., 1996; Hancock and Hawkins, 1996; Handel et al., 1997; Rokite et al., 1998; Koh el al. 2011].

The present study was undertaken with the aim to analyze the interaction of selected musclesof trunk region duringForward Walkover activity on floor using kinesiological concepts and electromyographic (EMG) techniques.

METHODOLOGY

The study was conducted on seven female gymnasts ranging in age between twelve to twenty-three years. All the subjects were observed to possess a good degree of skill in basic gymnastic activities.

Following superficial muscles of trunk region from both sides of the body (right and left) were included in the study:

Trapezius upper
Trapezius middle
Trapezius lower
Pectoralis major
Latissimus dorsi
Erector Spinae
Rectus abdominis

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

Procedure:
The muscles were palpated using their anatomical attachments and kinesiological concepts for the purpose of placement of electrodes. To standardize the position of electrodes, the concept of lead line length (LLL) and subsidiary line length (SLL), as described by Thorstensson et al. (1982), was used. After rubbing the surface of skin with saline water, the electrodes filled with the electrode gel were placed over the center of the belly of the muscles at a distance of 3 cm in the anatomical axis. Reference electrodes were placed on the forehead.The electrodes were sealed in position with adhesive tape. The electrode wires were looped and taped to the skin few cm away from the electrode and plugged in the elastic waist belt to avoid the possible pull on the electrodes during the execution of Forward Walkover activity.

EMG Recordings:
EMG signals were recorded during maximum voluntary contraction (MVC) and during Forward Walkover activity on a continuous chart paper. The EMG's were recorded in the average mode, which 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 is proportional to the average number, amplitude and duration of EMG pulses (Harding and Sen, 1969). 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.

EMG Recording of Maximum Voluntary Contraction (MVC):
Maximum Voluntary Contraction of each muscle was recorded against maximum resistance given by the supporter as per the method described by Kendal and Kendal (1964). The procedure was repeated thrice and a rest period of 2-3 minutes was given between each recording. Chart speed was fixed at 10 mm per second for the recordings of MVC. Maximum average muscle potential developed in one second was taken as a measure of MVC.

Recording during Forward Walkover:

For the process of execution of Forward Walkover on floor,four phases had been marked on the graph during the activity as shown in Fig. 1. It was done to analyze the of the muscle interaction pattern during the execution of the activity.

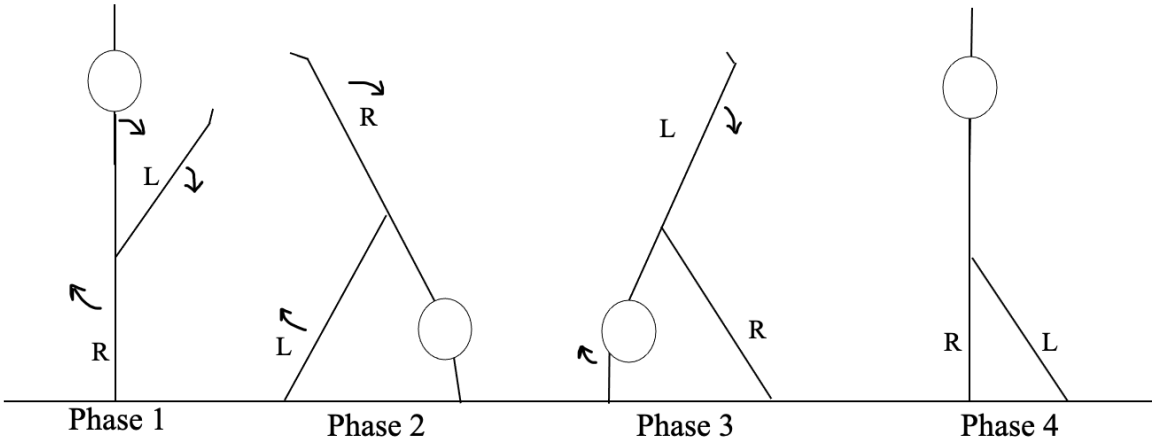

Figure 1: Various Phases of Forward Walkover on floor (Where, R = Right, L = Left and → represents direction of the movement)

For the recording of EMG during Forward Walkoveractivity on floor, the machine was set at a speed of 25 mm per sec. and the subject was given the instruction to start the activity. A supporter was asked to handle the wires and move with the gymnast to avoid the hinderance of wires during the EMG recording of Forward Walkover. The timer was set at the rate of 1 sec.

RESULTS

The results related to the involvement of muscles are expressed in the form ofpercentage of 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% to 40% of its MVC was said to be moderately active and whereas, a muscle exhibiting an activation of less than 20% of MVC was considered as slightly less active. 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.

Percent involvement of the musclesincluded in the study during Forward Walkover activity on Floor [Table1, Fig. 2]:

Among the muscles studied, Trapezius middle, Trapezius upper and Erector Spinaemuscles were observed to be highly active during the Forward Walkover activity on the floor. Rectus abdominis muscles showed moderate activation during this activity, however the activation level of the muscles,Latissimus dorsi and Pectoralis majorwere observed to be minimum (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 active as per the criteria laid down in the study during the first phase of the Forward Walkover activity on floor. The muscle Erector Spinae(left) got recruited during transitional phase 1-2 followed by Trapezius upper, Trapezius middle(right) during phase 2 of the activity. The muscles Trapezius middle(left) and Trapezius lower were the next to get activated during transitional phase 2-3. Erector Spinae(right) muscle started getting

actively involved during phase 3 followed by Rectus abdominis muscle during transitional phase 3- 4 of the Forward Walkover activity on floor.

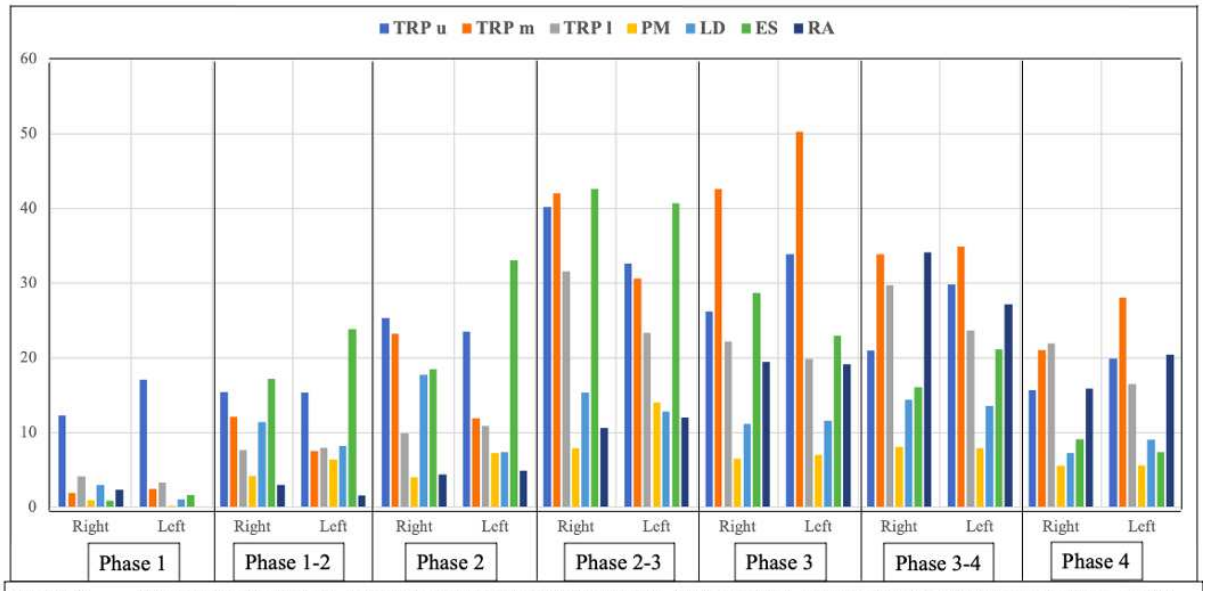

Figure 2: Magnitude of activation & recruitment pattern of trunk muscles during various phases of Forward Walkover activity on the floor (Where, TRP u=Trapezius upper, TRP m=Trapezius middle, TRP l=Trapezius lower, PM=Pectoralis major, LD=Latissimus dorsi, ES=Erector spinae, RA=Rectus abdominis)

Magnitude of muscle involvement during various phases of Forward Walkover activity on the floor

Phase 1

The involvement of all the muscles included in the study were found to range between 0.97% to 17.13% of their MVCs during phase 1 withTrapezius upper muscle showing maximum activity (12.26% for right and 17.13% for the left side). In general, small variations in the percent involvement of corresponding muscles of the two sides (i.e. right and left) were observed.

Phase 1-2

The activity of all the muscles under study increased during transitional phase 1-2 as compared to phase 1, except Trapezius upper left muscle, which showed a small decrease of 1.79% in transitional phase 1-2.Out of the seven muscles studied, the maximum percent involvement as well as maximum increase in the activity from phase 1 to transitional phase 1-2 was observed in case of Erector Spinae muscle, (percent involvement of 17.16% for rightside and 23.83% for the left side of the body). The involvement of Trapezius upper, Trapezius middle(right) and Latissimus dorsi(right) muscles ranged between 10% to 15% of their MVCs. However, rests of the muscles were involved to the maximum extent of 10% of their MVCs. During this phase, the involvement of Trapezius middle and Latissimus dorsi muscles were found to be more on the right side than on the left side of the body, that of Trapezius upper was almost equal on both the sides, and involvement of therest of the muscles (Trapezius lower, Pectoralis major, Erector Spinae and Rectus abdominis) were noticed to be more on the left side than on the right side of the body.

Phase 2

In 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, except for the Latissimus dorsi(left) muscle which showed a slight decrease of 0.84%. Out of the fourteen muscles (seven on both sides of the body) included in this study, the activation of Trapezius upper (right and left), Trapezius middle(right) and Erector Spinae(left)were found to be more than 20% with Erector Spinae(left) muscle showing maximum involvement of 33.06% of its MVC. The remaining muscles exhibited the activation of less than 20% of their respective MVCs [Fig.2]. The Rectus abdominis muscle, on the other hand, was minimally involved during this phase of Forward Walkover activity. Comparison of the activation patterns of certain trunk muscles on the right and left sides of the body indicated greater involvement of Trapezius middle, Trapezius lower and Latissimus dorsi muscles on the right side. Similarly, the activation of the Erector Spinae muscle was found to be greater on the left side as compared to the right side of the body.

Phase 2-3

Activity of all the muscles increased during transitional phase 2-3 exceptLatissimus dorsi(right) muscle. The muscle Erector Spinae showed the maximum involvement during this phase, which was of the order of 42.60% for right side and 40.71% for the left side of the body.Trapezius upper, Trapezius middle and Trapezius lower muscles showed the involvement of 40.15%, 42.01% and 31.59% for right side respectively and 32.59%, 30.65% and 23.20% for the left side of the body respectively.However, the activity of Latissimus dorsi, Pectoralis major and Rectus abdominis muscles were observed to be less than 20%. Activation of all of the muscles studied hereexcept Pectoralis major and Rectus abdominis muscles were found to be more on the right side than on the left side of the body.

Phase 3

Degree of involvement of Rectus abdominis, Trapezius upper(left) and Trapezius lower(right)muscles were found to increase during phase 3, whereas that of other muscles decreased during this phase as compared to the previous phase. Trapezius middlemuscle showed the maximum activation of 42.59% for the right side and 50.25% for the left side of the body during this phase of the activity. Involvement of the muscles,Trapezius upper, Trapezius lower (right) and Erector Spinae ranged between 20% to 40% and that of Trapezius lower (left), Pectoralis major, Latissimus dorsi and Rectus abdominis muscles were noticed to be less than 20% with Pectoralis major showing minimum activity of 6.45% for the right side and 7.03% for the left side of the body. Involvement of muscles Trapezius upper and Trapezius middlewere found to be more on the left side than the right side, whereas that of Trapezius lower and Erector Spinae muscles were noticed to be more on the right side than the left side of the body. Involvement of Rectus abdominis, Pectoralis major and Latissimus dorsiwere observed to be comparable on both sides of the body.

Phase 3 - 4

Activity of all of the muscles except Trapezius lower and Erector Spinae was observed to decrease during transitional phase 3-4 as compared to phase 3. Involvement of Trapezius upper, Trapezius middle, Trapezius lower, Erector Spinae(left) and Rectus abdominiswere found to be in the range between 20% and 40% with Trapezius middleshowing maximum activity of 33.86% for the right side

and 34.94% for the left side. Pectoralis major, Latissimus dorsi and Erector Spinae(right) muscles showed the involvement of less than 20% with minimum value of 8.04% for the right side and 7.85% for the left side of the body in case of Pectoralis major muscle. Degree of involvement of all the muscles were found to be more on the right side than the left side of the body except for Trapezius upper, Trapezius middle and Erector Spinae muscles.

Phase 4

As compared to transitional phase 3-4, the percent involvement in relation to the MVC of all the muscles studied decreased at phase 4. The percent involvement of Trapezius middle, Trapezius lower (right), Rectus abdominis(left) muscles was observed to range between 20% and 40%. However, the involvement of rest of the muscles were noticed to be less than 20% of their MVCs during the last phase of Forward Walkover activity on floor. Activities of Trapezius lower and Erector Spinaemuscles were observed to be of greater degree on the right side than the left side of the body. However, the remaining muscles showed relatively greater activity on the left than the right side of the body.

Table 1: Mean and Standard Deviation(SD) values of level of activation of trunk muscles studied expressed aspercentage of their respective MVCs values during various phases of ForwardWalkover activity on floor.

Muscles		**Percent involvement 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**
Trapezius upper	Mean	12.26	17.13	15.41	15.34	25.38	23.53	40.15	32.59	26.25	33.84	20.97	29.79	15.72	19.89
	SD	8.84	13.00	8.05	11.86	15.44	17.63	27.02	11.33	16.43	12.02	10.38	15.65	12.09	11.30
Trapezius middle	Mean	1.89	2.45	12.07	7.53	23.20	11.90	42.01	30.65	42.59	50.25	33.86	34.94	21.01	28.05
	SD	3.04	4.63	10.41	7.28	20.91	12.10	15.30	19.56	23.79	27.73	9.91	14.94	8.03	21.97
Trapezius lower	Mean	4.09	3.29	7.63	7.97	9.90	10.82	31.59	23.30	22.17	19.80	29.75	23.66	21.94	16.47
	SD	4.75	2.84	5.01	5.27	6.27	10.01	13.76	13.64	16.74	10.54	13.66	12.68	10.15	15.23
Pectoralis major	Mean	0.97	0.14	4.15	6.41	4.01	7.27	7.87	14.03	6.45	7.03	8.04	7.85	5.51	5.61
	SD	1.21	0.34	2.71	4.44	2.79	8.00	3.93	10.96	3.86	3.36	6.83	3.76	3.95	3.11
Latissimus dorsi	Mean	2.93	1.01	11.39	8.21	17.70	7.37	15.31	12.76	11.10	11.54	14.41	13.62	7.29	9.00
	SD	5.10	2.03	8.77	5.17	20.20	3.87	12.90	6.42	8.42	6.07	10.92	6.81	4.00	5.69
Erector Spinae	Mean	0.89	1.63	17.16	23.83	18.50	33.06	42.60	40.71	28.69	22.97	16.07	21.10	9.12	7.35
	SD	2.18	2.93	8.79	9.21	8.20	19.80	21.56	19.30	20.18	11.80	9.22	12.81	2.51	2.93
Rectus abdominis	Mean	2.38	0	2.97	1.57	4.33	4.87	10.59	11.97	19.44	19.15	34.11	27.14	15.82	20.43
	SD	5.82	0	5.76	2.60	5.46	4.96	9.90	5.84	33.77	13.71	21.72	16.42	12.96	24.95

DISCUSSION

A forward walkover is an acrobatic maneuver that involves lifting one's legs above one's torso in a back bridge position. The legs fully rotate in such a manner that the gymnast both starts and finishes in a standing upright position. It is the result of the successive impulsion developed by the lower limb and the upper limb with hip remaining extended and without flying phase.

Foidart-Dessalle et al. (2005) studied the action of some periscapular muscles during forward walkover activity of trained gymnasts and beginners. They found the restricted activity of these muscles in the confirmed gymnasts as compared to the beginners. They further observed the maximum involvement of Deltoid posterior, Trapezius superior and Latissimus dorsi muscles during the weight bearing phase of shoulder joints and a subsequent decrease during the next phases.

In the present study, both arms and left leg were flexedat the starting position of Forward Walkover activity on the floor(Phase 1). In this posture, the main movements were seen at shoulder, hip and ankle joints. At this posture, Trapezius upper muscle showed the involvement of more than 10% of MVC understandably due to the flexion at shoulder joints, as it assisted the movement by adjusting the scapula during the elevation of arms.

Theanalysis of the activity during transitional phase 1 to 2 revealed flexion of trunk at hip joint, extension of the flexed left leg and hyper extension of the right leg at hip joint with reference to left leg along with planter flexion of foot. The action, of course, required a fixed sequence of movements executed in a quick succession. The muscle response pattern during this phase revealed the moderate involvement (i.e. between 20% to 40% of MVC) of Erector spinae (left) muscle to keep the trunk rigid while its flexion at hip joint with reference to the left leg.

At the time of attainment of phase 2, the body weight was borne by the arms extended at the elbow joints and flexed at the shoulder joints. The muscular action identified through EMG analysis revealed the activation (>20% of MVC) of Trapezius upper and Erector spinae (left) muscles. At this phase of the Forward Walkover activity, the hands touchedthe floor with hyper extension at wrist joints while maintaining flexion at shoulder joints and extension at elbow joints.The left footwas ready to take-off and plantarflexionwas maintained at both feet.

The muscular action identified through EMG analysis during transitional phase 2-3 of the Forward walkover activity revealed the maximal activation (> 40% of MVC) of Trapezius upper and Erector spinae (left) muscles. The activity of these muscles depicted an increasing trend during this phase to support the rotation of the trunk at shoulder joint and legs at hip joint.

At phase 3 of the activity, when the right leg touched the floor, the body weight started shifting from the arms to the right leg. At this phase, Trapezius middlehad been observed to be the main contributory muscle to facilitate the subject to attain this dynamic posture.The transverse (middle) fibers of the Trapezius acted together with the rhomboids to produce a retraction of the scapula, by pulling it towards the

midline. The trapezius muscle was also responsible for upward rotation of the scapula.

After attaining the above phase, the gymnast pushed off the floor with her hands, keeping the head extended. Once the right foot was on the floor, she pulled her hips up over the leg to shift the center of gravity upwards. As the trunk moved up, the left leg completed the rotation and touched the floor. Progression of the activity to the last phase i.e. phase 4 indicated the shifting of body weight from hands to both the legs. The present EMG study of the muscles revealed the diminishing percent of muscle activation as compared to the earlier phases due to the shifting of weight bearing regions.The decrease in the activity of these muscles during these phases in the present study was in sync with the results of Foidart-Dessalle et al. (2005).

To sum up, Trapezius upper, Trapezius middle and Erector spinae muscles of the trunk were observed to be the main contributory muscles during Forward Walkover activity on floor. These muscles contributed by maintaining the posture of the gymnast by rotating the trunk and stabilizing the scapulae.The findings are likely to find utility for the sports scientists and coaches for designing specific training programs for the gymnasts.

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