"A study of the trunk muscles interactions during Forward Walkover Activity on Balancing Beam using Electromyographic techniques"

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Abstract

The gymnastic performance is known to be strongly linked with the vestibular control of skills. 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 the major muscles required along with their duration and extent. The present endeavor had been undertaken with the aim to analyze the contribution of selected seven muscles of the trunk region during Forward Walkover activity on balancing beam using electromyographic (EMG) techniques and kinesiological concepts. A multichannel recorder (Sensormedics, R612, Netherlands) was used to record the EMG activities for different trunkmuscles. The signal conditioning was made through a coupler (Direct/Average EMG type 9852A), preamplifier (type820), and amplifier (type 412). Trapezius middle, Trapezius upper, Trapezius lower and Erector Spinae muscles were observed to be highly involved during the Forward Walkoveractivity on balancing beam. However, the activation levels of the rest of the trunk muscles, namely, Latissimus dorsi,Pectoralis major and Rectus abdominis were observed to be moderate during this activity. The findings are likely to find utility for the sports scientistsand coaches for designing training schedules for the gymnasts.

KEYWORDS: Gymnastics, Trunk muscles, Trapezius upper, Trapezius middle, Trapezius lower, Pectoralis major, Latissimus dorsi, Erector Spinae, Rectus abdominis, Muscle recruitment, Electromyography, Forward Walkover, Balancing beam

INTRODUCTION

The successful performance of a gymnast depends upon the execution of complex 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 the floor. A well-rounded gymnast must be able to perform a wide array of athletic maneuvers, including walkovers, cartwheels, handspring, leaps, somersaults,etc. Forward walkover is performed on both floor and balancing beam in competitive gymnastics. This is the base of learning a wide set of complex gymnastic skills.

Analysis of the recruitment of major muscles in various gymnastic activities and their levels of interaction would enable the sports scientists and coaches to know about the major muscles required for that specific skill. It will be helpful in imparting advance training to sportspersons to develop the specific muscle groups in the right proportions.

The electromyographic (EMG) techniqueis able to analyze the exact muscle involvement patterns even in complex and fast sports activities, like gymnastics. Basmajian (1985)suggested that EMG technique surpassed all the older methods of studying muscular action as that revealed what the individual muscles were actually doing, not just what they 'can do' or 'probably do'. Some attempts had been made by various researchers to analyze the muscle involvement patterns in various sports [Stater-Hammel, 1949; Helga, 1975; Eriksson et. al., 1978; Anderson, 1974; Dyhre Poulson, 1987; 1990; Anderson, 1991; Goswami et. al., 1993; Nummela et. al., 1994; Koukoubis et. al., 1995; Dyson et. al., 1996; Hancock and Hawkins, 1996; Handel et. al., 1997; Rokite et. al., 1998; Koh et. al. 2011; Bressel, et. al., 2011; Chengliang et. al., 2019; Andrzej et. al., 2019].

The present study was undertaken with the aim to analyze thesequence and degree of involvementsof seven selected musclesof trunk region duringForward Walkover activity on balancing beam using kinesiological concepts and Electromyographic (EMG) techniques.

METHODOLOGY

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

Following seven muscles of the 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 individually 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 and subsidiary line length, as described by Thorstenssonet 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 trunk 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 on balancing beam.

EMG Recordings:

EMG signals were recorded during maximum voluntary contraction (MVC) of various trunk muscles of both left and right sides of the body forForward Walkover activity on balancing beam on a continuous chart paper. The EMG's were recorded in the average mode, which gave 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). 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 Contractions of chosen seven trunk muscles were 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.

Recordings during Forward Walkover Activity on Balancing Beam:

For the process of execution of Forward Walkover on the balancing beam,four phases had been marked on the graph during the activity as shown in Fig. 1. It was done to analyze the involvement levelsof the selected trunk musclesinteraction patterns during the execution of the said activity.

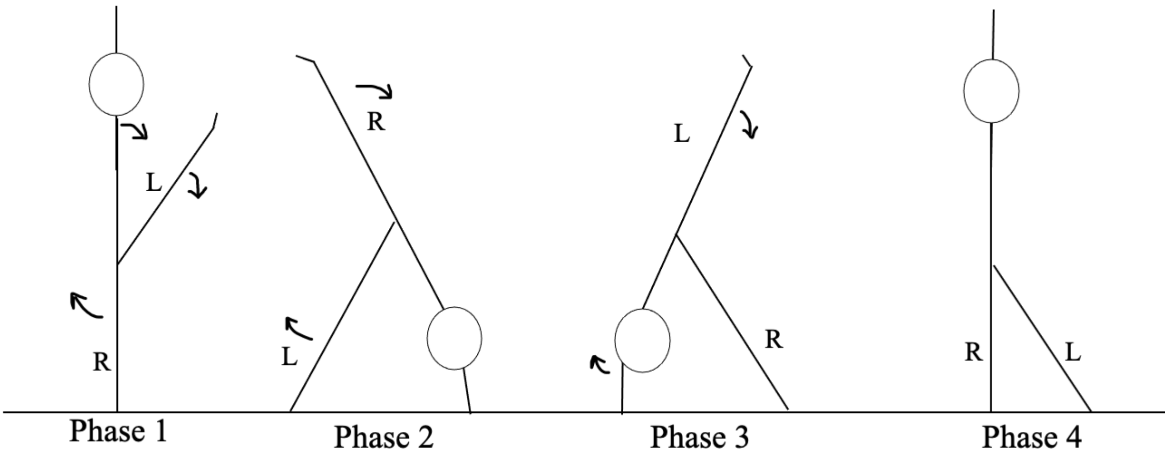

Figure 1: Various Phases of Forward Walkover (Where, R = Right, L = Left and → represents direction of the movement)

For the recording of EMG during Forward Walkover activity on the balancing beam, 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. A supporter was asked to handle the wires and move with the gymnast to avoid the hindrances of wires during the EMG recording of Forward Walkover.

RESULTS

The results related to the involvements of selected seven trunk muscles were expressed in the form of percentage of MVC. A muscle showing an involvement of more than 40% of its MVC was considered as highly active (main contributory muscle), that between 20% to 40% of its MVC was said to be moderately active, and 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 level of more than 20% of its MVC.Percent involvement of the muscles included in the study during Forward Walkover activity on the Balancing Beam was discussed and represented in Table1 and Fig. 2.

Out of the seven trunkmuscles studied, the contribution levels of the three muscles, namely,Trapezius upper, Trapezius middle and Erector spinae were noticed to be the highest. The remaining four muscles, namely, Trapezius lower, Pectoralis major, Latissimus dorsi, and Rectus abdominis exhibited moderate participation levelsduring the Forward Walkover activity on balancing beam.

Sequential Recruitment of the trunk muscles

Out of all the trunk muscles studied, only Trapezius upper (right and left) muscle was observed to be active at Phase 1 of the Forward Walkover activity on balancing beam. The muscles, namely, Trapezius middle (right and left), Trapezius lower (right and left), Pectoralis major (right and left) and Erector spinaesprang into action during the transitional phase 1-2, followed by Latissimus dorsi (right) during Phase 2 of the activity.

The muscles Latissimus dorsi (left) and Rectus abdominis (right and left) started their activities during the transitional phase 2-3 of the Forward Walkover activity on balancing beam.

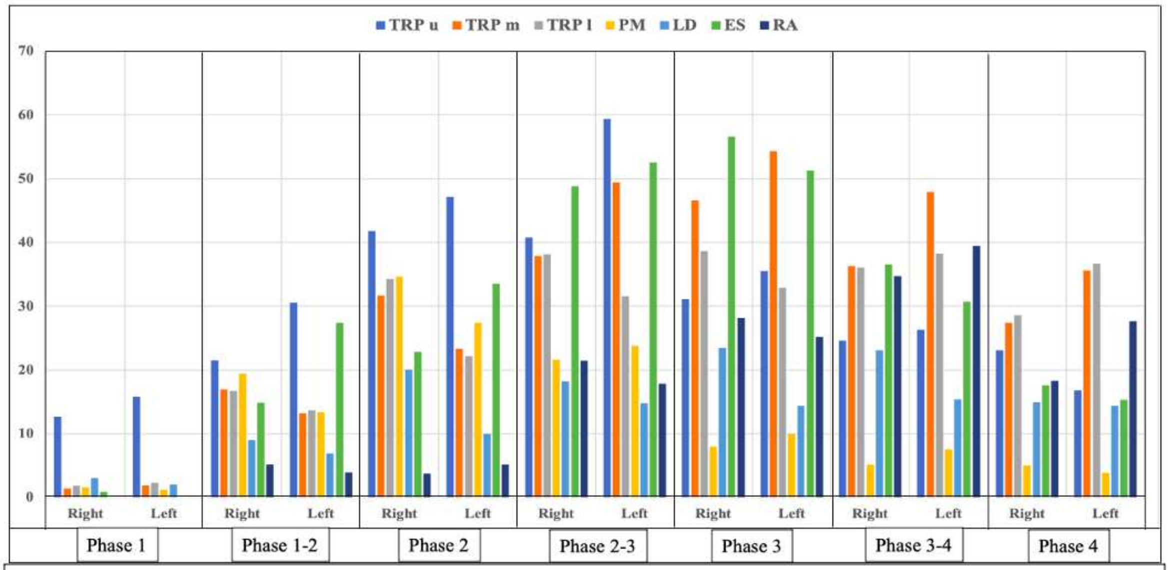

Figure 2: Magnitude of activation & recruitment pattern of trunk muscles during various phases of Forward Walkover activity on Balancing Beam (Where, TRP u=Trapezius upper, TRP m=Trapezius middle, TRP l=Trapezius lower, PM=Pectoralis major, LD=Latissimus dorsi, ES=Erector spinae, RA=Rectus abdominis)

Magnitude of muscle involvement during various phases of Forward Walkover activity on the balancing beam :

Phase 1

Among all the trunk muscles studied, the involvement of Trapezius upper muscle was found to be maximum, which was of the order of 12.73% for right and 15.89% for the left side of the body at the starting position of the Forward Walkover activity on balancing beam.Rest of the muscles included in this study showed the involvement of less than 5% of their MVC values. Some variations in the percentage involvement of the muscles between the right and left sides were noticed**.**

Phase 1-2

The activities of all the seven trunk muscles under study increased during transitional phase 1-2 as compared to phase 1 during Forward Walkover Activity on Balancing Beam. Percent involvementsof Trapezius upper and Erector spinae muscles were of the order of 21.56% and 14.94% respectively on the right side, and 30.54% and 27.40% respectively on the left side of the body. The other two trunk muscles, namely,Latissimus dorsi and Rectus abdominis showed the involvement levels of less than 10%. However, the involvements of rest of the muscles of trunk, namelyTrapezius middle, Trapezius lower and Pectoralis majorwere found to range between 10% and 20% of their MVCs. Activity levels of Trapezius upper and Erector spinae muscles were observed to be more on the left side, whereas the activities of the rest of the muscles of trunk region were more on the right side than on the left.

Phase 2

The activity levels of all the trunk muscles included here, except for Rectus abdominis, were found to increase at phase 2 as compared to transitional phase 1-2. The maximum involvement level during this phase was found in case of Trapezius upper muscle (41.81% for right side and 47.14% for left side of the body).Involvement levels of other five trunk muscles, namely, Trapezius lower (right and left), Trapezius middle (right and left), Pectoralis major (right and left), Erector spinae(right and left) and Latissimus dorsi(right)ranged between 20% and 40%, and the activity levels of other muscles of trunk region were noticed to be less than 20% with minimum involvement of 3.80% for right side and 5.21% for left side of the body of Rectus abdominis muscle. Except Trapezius upper and Erector spinae muscles, the involvement levels of all the chosen muscles of trunk were found to be more on the right side than the left side of the body.

Phase 2-3

Degrees of involvement of all the selected trunk muscles included in the present study were found to exceed 15% of their MVCs during transitional phase 2-3 of Forward Walkover on balancing beam. Activity levels of the muscles of trunk except Trapezius upper(right), Pectoralis major (right and left) and Latissimus dorsi(left)were observed to be higher during this phase as compared to phase 2. Three muscles, namely,Trapezius upper, Trapezius middle(left) and Erector spinae demonstrated their respective activation levels exceeding 40% of their MVCs, with maximum degree of involvement of 59.39% was of Trapezius upper (left) muscle. Involvements of Latissimus dorsi and Rectus abdominis(left)were noticed to range between 15% and 20% while that of rest of the muscles oftrunk region ranged between 20% and 40%. Corresponding activities of the muscles of trunk, except Trapezius lower, Latissimus dorsi and Rectus abdominiswere found to be greater on the left side than on the right side of the body.

Phase 3

The activity levels of five out of seven selected trunk muscles, namely,Trapezius middle (right and left), Trapezius lower (right and left), Latissimus dorsi(right), Erector spinae(right) andRectus abdominis (right and left)were found to be greater at phase 3 as compared to transitional phase 2-3, whereas that of Trapezius upper (right and left), Pectoralis major (right and left), andErector spinae(left)decreased during phase 3 of the Forward Walkover Activity on Balancing Beam. The maximum involvement of the order of 56.63%was shown by Erector spinae (right) muscle, whereas,Pectoralis major muscles showed the minimum involvement of 7.89% for the right side and 10% for the left side of the body. Involvement levels of two muscles, namely, Trapezius middle (right and left) and Erector spinae(right and left) were found to be more than 40%, and that of Pectoralis major (right and left), andLatissimus dorsi(left)were noticed to be less than 20%. Rest of the muscles included in this study showed their involvement levels ranging between 20% and 40% of their respective MVCs. Activities of chosen four muscles, namely,Trapezius lower, Latissimus dorsi, Erector spinae, andRectus abdominiswere observed to be more on the right side, whereas other selected trunk muscles were involved more on the left side during this phase of the Forward Walkover activity on balancing beam.

Phase 3 - 4

During thistransitional phase, percent involvement levels of all the trunk muscles except Trapezius lower(left), Latissimus dorsi (left), andRectus abdominis(right and left) were observed to decrease as compared to phase 3.Trapezius middle(left) muscles showed the maximum involvement of the order of 47.98%. The activation levels of other two muscles, namely,Pectoralis major(right and left) and Latissimus dorsi(left) were found to be less than 20%, with minimum involvement of 5.22% by Pectoralis majorright muscle. However, the involvements of rest of the selected trunk muscles included here ranged between 20% and 40% of their respective MVCs. Five out of seventrunk muscles exhibited greater degrees of activation on left side than the right, except for Latissimus dorsi and Erector spinae muscles.

Phase 4

During phase 4, the involvements of all the muscles included in the study were observed to decrease as compared to transitional phase 3-4 of Forward Walkover activity on balancing beam. Four muscles, namely,Trapezius upper(right), Trapezius middle (right and left), Trapezius lower (right and left), andRectus abdominis(left)showed the involvement levels between the range of 20% and 40%of their respective MVCs, with Trapezius middle (left) muscle showing the maximum involvement of the order of 35.64%. Involvements of rest of the muscles were found to be less than 20% of their respective MVCs, with minimum value of 3.46% for the right side and 3.89% for left side of the body in case of Pectoralis major muscle. The involvements of all six trunk muscles were found to be more on the left side than the right, exceptTrapezius uppermuscle.

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 balancing beam.

Muscles	Percent involvement during various phases of Forward Walkover activity on Balancing Beam.													
	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
TRP u Mean	12.73	15.89	21.56	30.54	41.81	47.14	40.80	59.39	31.15	35.57	24.64	26.38	23.16	16.80
SD	9.76	15.09	10.15	17.32	21.26	30.68	15.01	23.49	13.00	15.57	14.44	10.64	20.32	8.74
TRP m Mean	1.46	1.99	17.01	13.20	31.71	23.37	37.95	49.49	46.69	54.35	36.29	47.98	27.42	35.64
SD	1.84	2.77	5.82	7.77	17.63	11.07	10.30	19.46	20.82	31.91	9.65	25.45	9.90	23.22
TRP l Mean	1.89	2.29	16.76	13.65	34.32	22.14	38.14	31.64	38.67	32.92	36.07	38.30	28.66	36.72
SD														

	3.08	4.93	9.81	7.99	22.66	11.76	15.56	11.27	28.71	18.32	30.47	23.69	13.03	23.11
PM Mean	1.61	1.23	19.49	13.43	34.68	27.37	21.65	23.79	7.98	10.00	5.22	7.59	4.99	3.89
SD	2.13	1.73	13.66	7.15	24.35	21.22	10.55	15.90	2.56	6.65	2.62	5.53	4.55	2.11
LD Mean	3.06	2.03	9.02	6.94	20.03	10.00	18.23	14.82	23.45	14.34	23.12	15.41	15.00	14.38
SD	7.49	4.00	6.44	3.27	21.65	6.29	11.54	4.43	16.70	6.13	12.94	8.78	6.82	10.88
ES Mean	0.89	0	14.94	27.40	22.88	33.55	48.82	52.58	56.63	51.30	36.58	30.72	17.58	15.37
SD	2.18	0	7.94	15.28	12.08	18.36	13.15	15.68	28.89	24.66	19.75	24.04	14.45	14.69
RA Mean	0	0	5.23	3.99	3.80	5.21	21.46	17.87	28.17	25.18	34.79	39.48	18.28	27.67
SD	0	0	4.57	3.42	4.42	4.08	11.69	15.62	18.81	23.62	10.09	13.38	12.32	26.43

DISCUSSION

During forward walkover activity, the legs fully rotate in such a manner that the gymnast both starts and finishes in a standing upright position.

Foidart-Dessalle, et. al. (2005) compared some periscapular muscle activity in confirmed and beginner gymnastics. They foundthat the activitiesof some periscapular muscleswere restricted in confirmed gymnasts as compared to the beginners during forward walkover activity on floor. 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 phase when body weight shifted back to the legs.

In the present study, Trapezius upper, Trapezius middle, Trapezius lower and Erector spinae muscles of the trunk were observed to be the main contributory muscles during Forward Walkover activity on balancing beam. These muscles might have contributed by stabilizing the scapulae, keeping the neck extended and assisting in the smooth rotation of trunk by adjusting the center of gravity during the dynamic posture.

The contributions of Trapezius group of muscles (Trapezius upper, Trapezius middle, Trapezius lower), and Pectoralis major musclewere noticed to be maximum during the phases, when the body weight was majorly borne by the shoulder joints. While the clavicular end of Pectoralis assisted in the flexion of arms atglenohumeral joint, the trapezius group played a major role in stabilizing the scapulae during the dynamic posture and to assist the smooth execution of the activity. The increased activation of these muscles might also be attributed in maintaining equilibrium and balance on the narrow balancing beam. Andrzej et. al. (2019) identified the Pectoralis major, Latissimus dorsi and Trapezius group of muscles from the trunk region as main contributory muscles during Handstand performance on parallel bars and still rings in both adult and young male gymnasts.

As the activity progressed to the final phase, the body weight started shifting back to the legs from the shoulders. 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).

Some differences in the muscles' activities on right and left side of the body were observed so as to adjust the center of gravity during the execution of activity. Themuscle Erector Spinae exhibited more activity level on the left side of the body during transitional phases 1-2, phase 2 and transitional phase 2-3 i.e., during the rotation phase of the right leg. On the other hand, its activity was noticed to be more on the right side of the body during the rotation of left leg (during phase 3 and transitional phase 3-4). This might be attributed forthe posture maintenanceof the spine, while supporting the rotation of the leg of opposite side of the body.

The findings of the present study likely to find utility for the sports scientists and coaches for identifying the major muscles groups involved in the gymnastic skill, hence designing the scientific oriented training schedules for the gymnasts.

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