"An Electromyographic analysis of upper extremity muscles interaction during Forward Walkover activity on floor"

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Abstract

In spite of the complex nature of the sports skills, there is an improvement on the performance of all of the sports events since their beginning. The application of the research findings had paved the way to the designing of training program for the athletes and had given heartening results by improving the performance. Still certain important areas, like analysis of the muscle involvement pattern in various sports skills have not been paid due attention. The skills involved in gymnastics are very complex in nature. So, it is a very difficult task to analyze the movements involved in various gymnastic activities and to find out which muscle is acting at a particular instant and to what extent. The present endeavor had been undertaken with the aim to analyze the upper extremity muscles interactions during Forward Walkover activity on floor using electromyographic (EMG) techniques and kinesiological concepts. Electromyographic (EMG) 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 Triceps brachii lateral, Deltoid anterior, Deltoid middle and Triceps brachii long were observed to be highly involved during the Forward Walkover activity on floor. The Deltoid posterior, Flexor carpi radialis muscles showed moderate activation during this activity, however the activation level of Brachioradialis and Biceps brachii were observed to be much lower (i.e. of the order of 10%-20% of their respective MVCs). The sequential recruitment pattern of the muscles was discussed. The findings likely to find utility in the scientific orientation of the training schedules for the gymnasts.

KEYWORDS: Gymnastics, Muscle Recruitment, Electromyography, Forward Walkover on Floor, Upper Extremity Muscles

INTRODUCTION

Sports activities offer the greatest variety of motion ranges in human body. In sports activities, the movements occur in all planes and axis and a number of joints are involved in a single activity. Each sports activity involves a variety of movement skills which are the result of coordinated actions of a large number of muscles. The performance of an athlete in a particular sports event depends largely upon the development and learning of these skills. Studies have shown that there is a continuous improvement in the performance of all of the sports in the Olympic games, which are the oldest and the biggest sports competition on the earth. The improvement in the weight lifting event (middle weight category) is observed to be as high as 97.95% from the first Olympic games held in 1986 to the year 1972 (Sachdeva, 1993; Sachdeva and Verma, 1995).

The application of the research findings had paved the way for the designing of training program forathletes and had given heartening results by improving the performance. Still certain important areas, like analysis of the muscle involvement pattern in various sports skills have not been paid due attention. It is very important to establish the role of major muscles required in various sports skills so that the training can be imparted to improve the efficiency of these muscles. Some attempts have been made to analyze the muscle involvement pattern in various games [Stater-Hammel, 1949; Herman, 1962; Kamon and Gormlay,1968; 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; Mohan et al., 1995; Koukoubis et al., 1995, Dyson et al., 1996; Hancock and Hawkins, 1996; Handel et al., 1997; Rokite et al., 1998; Bernasconi et al., 2009]

Competitive gymnastics is a technical sport, which involves very complex body movements in all the planes like rolling, turning, springing, twisting, bending, and tucking etc. on floor, in air 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, precise co-ordinations, sense of balance and rhythm in space and time on various apparatuses. In addition, the gymnastic performance is also known to be strongly linked with the vestibular control of skill. A gymnast must be able to perform a wide array of athletic maneuvers, including rolls, walkovers, cartwheels, handspring, somersaults, saltos, back tucks etc.

One basic maneuver in a gymnast’s pallet is Forward Walkover, which can be seen at all levels of competitive gymnastics from state level to Olympic Games. The Forward Walkover is performed on the floor as well as balancing beam. It is a unique elemental maneuver, that draws upon a wide set of gymnastic skills.

Therefore, there is a need of a systematic study to analyze the role of major muscles in gymnastic activities and their interaction in FWO on floor. The relative intensity and duration of muscle involvement to a specific gymnastic skill or a set of skills would enable the coaches and sports scientists to know about the major muscles required for that skill, so that the training can be imparted to develop the muscle groups in right proportion.

Variety of methods are used to study the action of muscles. But all these methods can explain the muscle action during simple movements 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.

The electromyography (EMG) studies were able to analyze the exact muscle involvement pattern even in complex and fast sports actions. Using EMG techniques, the activity of 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) said 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'. The present study was undertaken with the aim to analyze the various upper extremity muscles interaction during Forward Walkover activity on floor 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 eight upper extremity muscles involvement pattern during Forward Walkover 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:
The non-invasive technique of recording muscles potential from the surface of the body was employed in the present investigation. Following eightmuscles of upper extremity (both right and left sides of the body) were selected for pursuing the investigation of this study.

Brachioradialis
Flexor Capri radials
Biceps brachii
Triceps-brachii long
Triceps brachii lateral
Deltoid anterior
Deltoid middle
Deltoid posterior

Instrumentation:
Electromyographic (EMG) activities for different muscles during the activity had been obtained using a multichannel recorder (Sensormedics, R612, Netherlands). 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 of the upper extremity of both sides of the body were palpated using their anatomical attachments and kinesiological concepts. It was difficult to standardize the electrode positions due to wide variations in the muscles size and length. In an attempt to standardize the electrode placement position, Thorstensson et al., 1982 had described the use of lead line length and subsidiary line length. 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 in the anatomical axis. The electrodes were sealed in their respective positions 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 hinderance 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 Forward Walkover on floor activity 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 did not indicate sudden peaks of the EMG signal, nevertheless the calculations and measurements of the amplitude became easier (Dainty 1987). The gain of amplification was selected according to the level of activity of the selected eight muscles of the upper extremity. 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 procedure 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 on the subject. Chart speed was fixed at 10 mm per second for the recordings of MVC.

Recordings during Forward Walkover on the floor:

For the process of execution of Forward Walkover on the 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.

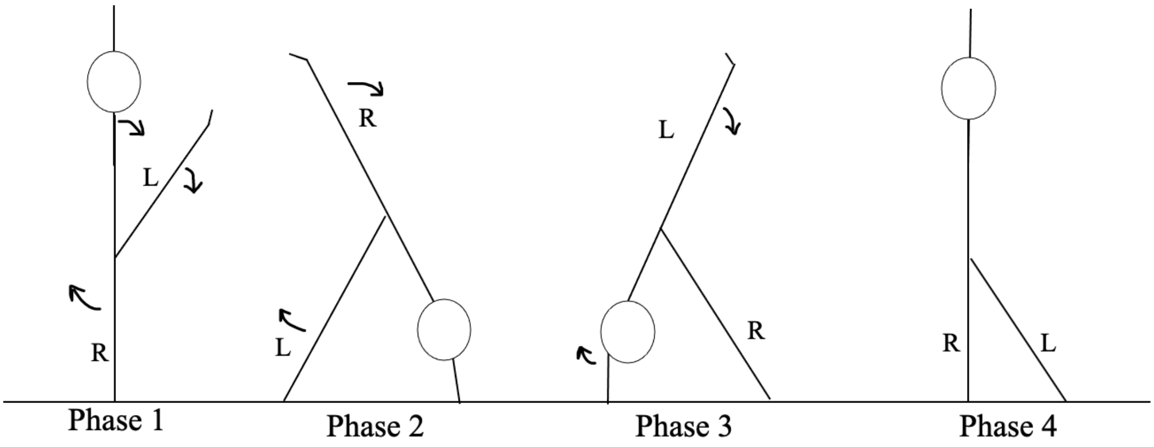

Figure 1: Various Phases of Forward Walkover on floor (Where, R = Right, L = Left and ⟶ represents direction of the movement)

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 to move with the gymnast to avoid the hinderance of wires in the execution of the activity. The timer was set at the rate of 1 sec.

RESULTS [Table 1, Fig. 2]

The results related to the involvement of selected upper extremity muscles were expressed as the 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.

The muscles Triceps brachiilateral, Deltoid anterior, Deltoid middle and Triceps brachial long were observed to be highly involved during the Forward Walkover Activity on Floor. The Deltoid posterior, and Flexor carpi radialis, muscles showed moderate activation during this activity. However, the activation level of rest of the muscles, namely, Brachioradialis and Biceps brachii were observed to be low (i.e. of the order of 10%-20% of their respective MVCs).

Sequential Recruitment of the muscles of upper extremity:

None of the muscles included 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 muscles Triceps brachiilateral (left), Deltoid anterior, Deltoid middle(right) got recruited during transitional phase 1-2 followed by Triceps brachiilateral (right), Deltoid middle(left), Deltoid posterior(right) during phase 2 of the activity. The muscles Flexor carpi radialis, Triceps brachiilong, Deltoid posterior(left) were the next to get activated during transitional phase 2-3.

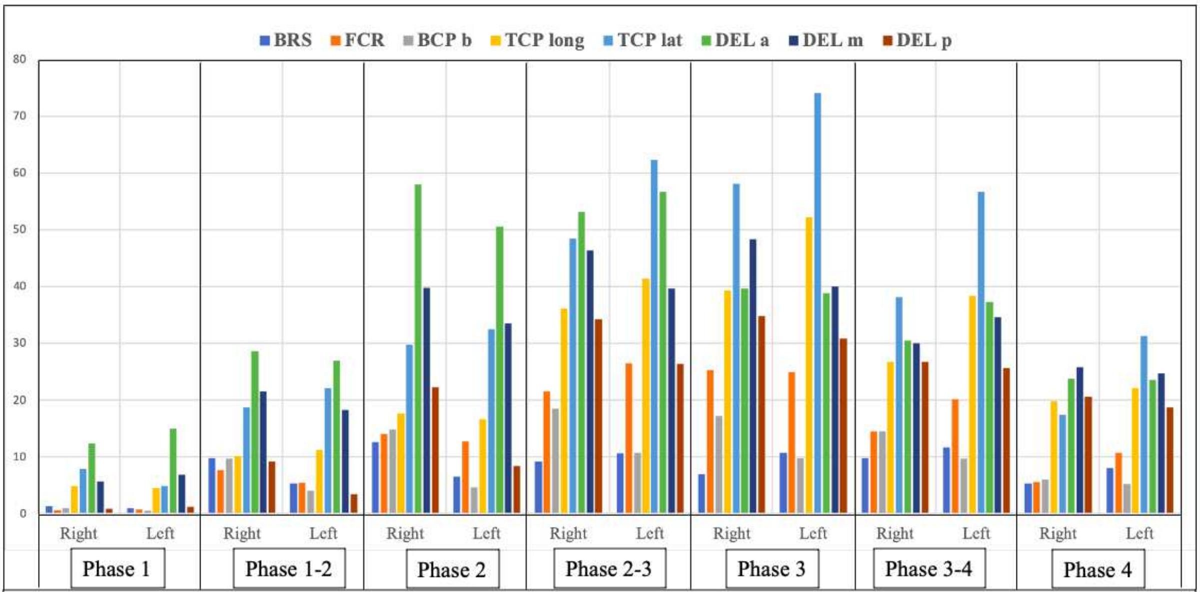

Figure 2: Magnitude of activation of the muscles during various phases of Forward Walkover activity on floor
(Where, BRS=Brachioradialis, FCR=Flexor carpi radialis, BCP b=Biceps brachii, TCP long=Long head of Triceps brachii, TCP lat=lateral head of Triceps brachii, DEL a=Deltoid anterior, DEL m=Deltoid middle, DEL p=Deltoid posterior)

Magnitude of upper extremity muscles involvement during various phases of Forward Walkover activity on floor

Phase 1

The involvement of all the muscles included in the study was found to range between 0.63% to 17.13% of their MVCs during phase 1.Out of the eight muscles of the upper extremity included, Deltoid anterior demonstrated the maximum involvement of 12.42% for the right side and 15.01% for the left side of the body. 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 activities of all the muscles of the upper extremity under study increased during transitional phase 1-2 as compared to phase 1.During this phase, Deltoid anterior, Deltoid middle, Triceps brachii lateral and Triceps brachii long muscles showed the involvement of 28.61%,21.59%, 18.79% and 10.03%respectively on right side, and 26.93%, 18.32%, 22.18% and 11.19% respectively on left side of the body. Involvement of other muscles of the upper extremity i.e. Brachioradialis, Flexor carpi radialis, Biceps brachii and Deltoid posterior was found to be less than 10% of their respective MVCs. Activities of the studied muscles were observed to be slightly more on the right side than the left, except for Triceps brachii long and Triceps brachii lateral muscles.

Phase 2

At phase 2, the activities of all the muscles of upper extremity in terms of their involvement as percent of MVC increased as compared to transitional phase 1-2.The activity of Deltoid anterior muscle was found to be maximum (58.02% for the right side and 50.57% for the left side) followed by Deltoid middle and Triceps brachii lateral showing the involvement of 39.74% and 29.98% respectively for the right, and 33.53% and 32.45% for the left side respectively. Another muscle namely Deltoid posterior (right) showed an involvement of the order of 22.24% of its MVC while rest of the muscles of upper extremity included in the study demonstrated the involvement of less than 20% of their MVCs. In general, the magnitude of involvement of all the muscles of right side of upper extremity was observed to be more than the muscles of the left side with the exception of Triceps brachii lateral.

Phase 2-3

Magnitude of involvement of all the eight muscles included in the study except Brachioradialis(right) and Deltoid anterior(right) were noticed to increase during transitional phase 2-3 as compared to phase 2. Percent involvement with respect to their MVCs of Triceps brachii long(left), Triceps brachii lateral, Deltoid anterior and Deltoid middle(right)were found to be more than 40% with a maximum value attained by Triceps brachii lateral(left) muscle (62.29%), whereas the involvement of Flexor carpi radialis, Deltoid posterior,Triceps brachii long(right) and Deltoid middle(left) ranged between 20% and 40% of their MVCs. Brachioradialis and Biceps brachii muscles showed the involvement of less than 20%. Activities of all of the muscle in terms of percentage of their MVCs were found to be more on the left side than the right side of the body except Biceps brachii, Deltoid middle and Deltoid posterior muscles.

Phase 3

The activities of Triceps brachiilong, Triceps brachiilateral, Brachioradialis(left) and Flexor carpi radialis(right) muscles expressed as percentage of their respective MVC were observed to be more at phase 3 as compared to transitional phase 2-3, whereas involvement of other muscles of the upper extremity i.e. Biceps brachii, Deltoid anterior, Deltoid middle, Deltoid posterior, Brachioradialis(right) and Flexor carpi radialis(left)were observed to decrease at phase 3. At this phase, Triceps brachiilong(left), Triceps brachiilateral and Deltoid middle muscles showed the involvement of more than 40% with Triceps brachii lateral showing maximum involvement of 58.08% for the right and 74.04% for the left side. The muscles Flexor carpi radialis, Triceps brachii long (right), Deltoid anterior and Deltoid posterior showed their contribution ranging between 20% to 40% of their maximum whereas, the involvement of Brachioradialis and Biceps brachii muscle were found to be less than 20% of MVC.

Phase 3 - 4

As compared to phase 3, involvement of selected upper extremity muscles exceptBrachioradialis and Biceps brachii(right)were observed to decrease duringtransitional phase 3-4. The maximum involvement of 38.09% for the right and 56.74% for the left side was shown by Triceps brachii lateral muscle. Involvement of Flexor carpi radialis(left), Triceps brachii long, Triceps brachii lateral (right), Deltoid anterior, Deltoid middle, and Deltoid posterior ranged between 20% and40% and that of Brachioradialis, Flexor carpi radialis(right) and Biceps brachii was found to be less than 20% of their MVCs. The involvement of all the muscles studied was noticed to be more on left side as compared to right side of the body during this phase of the activity.

Phase 4

As compared to transitional phase 3-4, the percent involvement with respect to the MVC of all the muscles of upper extremity studied decreased at phase 4. The percent involvement of Triceps brachii long(left), Triceps brachii lateral(left), Deltoid anterior, Deltoid middle, Deltoid posterior(right) muscles were observed to range between 20% and 40% with maximum value of 31.26% shown by Triceps brachii lateral (left). However, the activities 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 Biceps brachii, Deltoid anterior, Deltoid middle, Deltoid posterior muscles were observed to be of greater degree on the right side than on the left side of the body. However, the remaining upper extremity muscles 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 the muscles of the upper extremity studied, expressed as percentage of their respective MVCs 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**
Brachioradialis	Mean	1.29	1.01	9.84	5.33	12.57	6.54	9.20	10.58	7.03	10.73	9.75	11.66	5.29	8.07
	SD	3.18	1.62	5.13	3.15	7.35	3.52	3.70	5.57	1.95	6.63	7.33	6.25	4.16	4.90
Flexor carpi radialis	Mean	0.63	0.81	7.73	5.41	14.05	12.70	21.51	26.53	25.30	24.94	14.52	20.17	5.57	10.72
	SD	1.00	1.99	3.18	3.41	6.90	8.99	9.73	13.05	15.82	12.99	8.07	13.46	3.80	8.20
Biceps brachii	Mean	1.01	0.53	9.65	4.02	14.84	4.66	18.45	10.71	17.22	9.77	14.50	9.66	6.02	5.18
	SD	1.36	0.94	7.05	2.39	12.00	2.12	8.63	4.93	16.18	5.22	14.87	7.54	3.02	2.45
Triceps brachii long	Mean	4.89	4.48	10.13	11.19	17.71	16.64	36.17	41.45	39.25	52.18	26.75	38.33	19.78	22.16
	SD	3.46	4.74	6.94	5.05	12.43	9.56	19.84	19.03	20.12	25.40	14.34	16.83	24.15	16.94
Triceps brachii lateral	Mean	7.91	4.87	18.79	22.18	29.78	32.45	48.43	62.29	58.12	74.04	38.09	56.74	17.39	31.26
	SD	6.13	4.28	5.70	11.82	15.21	16.95	13.86	22.86	16.77	29.86	10.49	18.41	9.62	18.88
Deltoid anterior	Mean	12.42	15.01	28.61	26.93	58.02	50.57	53.21	56.68	39.63	38.86	30.44	37.32	23.84	23.60
	SD	9.33	7.65	11.36	9.54	20.98	33.17	11.07	13.33	19.89	13.41	17.23	20.41	15.40	22.44
Deltoid middle	Mean	5.65	6.87	21.59	18.32	39.74	33.53	46.34	39.68	48.38	40.02	30.00	34.66	25.82	24.75
	SD	4.18	6.67	14.30	10.26	25.05	17.10	19.70	17.43	26.22	13.76	8.79	8.72	13.75	15.87
Deltoid posterior	Mean	0.88	1.19	9.22	3.47	22.24	8.40	34.24	26.43	34.87	30.90	26.73	25.73	20.65	18.68
	SD	1.40	1.72	9.39	2.53	26.40	9.89	19.90	14.79	19.94	18.89	8.63	6.55	10.90	12.26

DISCUSSION

The Forward Walkover activity on floor started with stretching the arms and kicking the left leg into the air(Phase 1). The muscle, which had been observed to contribute though slightly (between 10% and 20% of MVC) during this phase, was Deltoid anterior, understandably due to the flexion at shoulder joints.The Deltoid anterior muscle was considered as the prime mover in the flexion of arms at shoulder joint.

The transition from phase 1 to phase 2 involved the stepping on the left foot and pushing the knee forward into a lunge with the shoulder over the hips in alignment. The rear leg (right) in the lunge was lifted up and over as the hands touched the mat shoulder width apart with fingers pointed straight ahead. The underlined objective of this transitional phase was to travel from one point to another with optimum speed, power and force. The action, of course, required a fixed sequence of movements executed in a quick succession. The muscle response pattern during this phase involved the integrated action of many muscles. The present EMG study revealed the moderate involvement (i.e. between 20% and 40% of MVC) of Triceps lateral (left), Deltoid anterior, and Deltoid middle (right) muscles.The activity of Deltoid group of muscles was meant for maintaining the flexion at shoulder joint. The attainment of phase 2 of the Forward Walkover activity on floorwascharacterized 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 withplantarflexion at both feet. The Deltoid anteriormuscle wasfound to be highly active (i.e. more than 40% of MVC) at this stage.

Progression of Forward Walkover activity from phase 2 to phase 3 involved the pushing of second leg (left leg) off the mat, when the legs were completely split, stretched and straight and approaching of the first leg (i.e. right leg) on the floor. It was accomplished by the rotation of trunk at shoulder joints and that of legs at hip joint. During this phase, the body weight was borne by the arms extended at the elbow joints and flexed at the shoulder joints. As the body weight fell on the hands during this phase, the muscles which were meant for keeping the elbows extended along with the muscles responsible for maintaining body weight and causing flexion at the shoulder joints to allow the subject to change its position from phase 2 to phase 3. The muscular action identified through EMG analysis revealed maximal activation (> 40% of MVC) of Triceps lateral, Triceps long (left), Deltoid anterior and Deltoid middle (right) muscles. At phase 3 of the activity, the right leg touched the floor and the body weight started shifting from the arms to the right leg. At this phase, the musclesTriceps long (left), Triceps lateral and Deltoid middlehad been observed to be maximally active to facilitate the subject to attain this dynamic posture.

After attaining the above phase, 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 attempted to pull her hips up over this leg to shift the center of gravity upwards. As the trunk moved up, the second leg (left) completed the rotation and touched the floor. Progressions of the activity to the last phase i.e.,phase 4 of the Forward Walkover on floor, indicated the shifting of body weight from hands to both the legs. The present EMG study of the upper extremity muscles revealed the diminishing role of muscle activation during this phase as compared to the earlier phases. This agreed with the shifting of weight bearing regions as discussed above.

To sum up, the Triceps and Deltoid group of muscles were observed to be the main contributory muscles during Forward Walkover activity on floor. These musclesexhibited the maximum contribution (i.e.> 40% of MVC) from phase 2 to phase 3, when the body weight was borne by the shoulder joints.

The results of the study in general identified the specific group of muscles of the upper extremityduring the forward walkover activity along with their degrees of involvement. The findings likely to find utility in the scientific orientation of the training schedules for the gymnasts. A strong interaction between the gymnast's coaches and the sports scientists can pave the way forindividualization of the training schedules.

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