

A Biomechanical Analysis of the Spine during Two Types of Lifting

Tamer Husain Mohamed Al-Shetehy¹

Abstract:

Studying the mechanical aspects of spinal injuries is the base for preventing these injuries and protecting this most moving vital part of the body. While lifting, athletes make hypotheses about weight and load distribution and, accordingly, plan the lift. It is well-documented that there is a strong correlation between lifting and low back pain. The current research aims at identifying the differences in trunk movements and trunk extensor muscles during two positions of lifting (squat – leaning). The researcher used the descriptive approach on sample of (30) athletes. Data collection tools included EMG, Motion Analysis System and Bar and weights. The researcher concluded that there are major differences in EMG measurements of the Erector Spinae Muscle and trunk movements between the two types of lifting. The researcher recommended that wearing supporters while lifting and its effects on the variables under investigation should be studied.

Key words: the spine – EMG - Erector Spinae Muscle

Background and Problem:

Motor stability of the spine should be secured during lifting as lose of stability may increase risks of injuries in unexpected situations. Although the resulting trunk movement is minimal, insufficient stability may induce over spin on the cross-sectional level. This type of spin, accompanied with increased pressure, may lead to injuries of the ligaments and inter-vertebral disks (Van der Burg et al 2003) (12)

Previous studies indicated strong evidence on the casual relation between lifting and low back pain. While lifting, lifters make some estimation about weight and load distribution and this leads to planning the lift. If load inertia characteristics are not evaluated correctly, compensative control needed at the beginning of the lift takes place. This type of control increases injury risks as acute muscle contractions happen when sudden or erroneous lifts take place, especially if weight is heavier than expected. In these cases, sliding or temporary lose of balance may happen causing an over reaction of the neuromuscular system. In turn, this may damage the sensory receptors surrounding tissues. (Roshdy & Berequa 1997) (8)

Therefore, it is clear that there is an established relation between lifting and low back pain. This led the researcher to investigate this relation.

Identifying and studying trunk and erector spinae muscles movements may help coaches, athletes and injury specialist to understand the mechanisms of back injuries induced by lifting imbalanced weights to minimize risk factors of these injuries.

Aim:

The current research aims at identifying trunk and erector spinae muscles movements in different locations of weight's center of mass during two types of lifting (squat – leaning).

Research Question:

Are their any differences in trunk and erector spinae muscles movements in different locations of weight's center of mass during two types of lifting (squat – leaning)?

¹ Assistant Professor, Sports Training And Kinesiology Department – Faculty of Physical Education for Men – Benha University

Methods:

Approach:

The researcher used the descriptive approach.

Subjects:

Sample included (30) athletes (15 Greco-Roman wrestlers and 15 weight lifters). Sample was chosen according to the following criteria:

1. All athletes are first class
2. All athletes are free of low back pain and back injuries
3. All athletes are free of postural abnormalities.

Table (1) shows the sample's descriptive data.

Table (1): Sample data on weight, height and age

Variable	Number	Mean	Median	SD	Squewness
Age (years)	30	20.33	20	1.66	0.145
Weight (kg)	30	70.10	70.50	3.82	0.766
Height (cm)	30	172.90	172	6.71	0.301

Data collection tools and equipments:

EMG unit – electrodes – 3D motion analysis system – reflective markers – PC with motion analysis software – a wooden box – dummy – cotton and ethylene to clean skin – data recording forms – a restameter for measuring weights and heights.

Main Experiment:

After taking sample measurements, the researcher prepared the EMG and motion analysis systems. In addition, the researcher expected the lifting positions as follows:

- ❖ Preliminary position
- ❖ Leaning position: bending hips and trunk with knees extended (dummy)
- ❖ Squat position: bending hips and knees with back extended (box)
- ❖ Final position: the athlete ends up standing through extending knees, hips and trunk.

Sample was divided into four groups:

1. Group (1): leaning lift with unexpected location of center of mass for the dummy (Center – anterior right – anterior left – posterior right – posterior left) (wrestlers)
2. Group (2): leaning lift with expected location of center of mass for the dummy (wrestlers)
3. Group (3): lift with unexpected location of center of mass for the box (Center – anterior right – anterior left – posterior right – posterior left) (weight lifters)
4. Group (4): lift with expected location of center of mass for the box (weight lifters)

The researcher followed the following protocol:

- Each athlete starts and ends the lift with a verbal order from the researcher
- Each athlete has three trials and means of these three trials are calculated
- Location of center of mass are randomly indicated
- A rest interval of (1) minute between each two consecutive lifts

Statistical Treatment:

The researcher used SPSS software to calculate the following: mean – SD – ANOVA – LSD – t-test – percentage of EMG data. Motion analysis data was analyzed using motion analysis system.

Results:

Table (2): Description of EMG range for erector spinae muscles EMG (Stoop lift)

location of center of mass	Unexpected				Expected			
	Right erector spinae		Left erector spinae		Right erector spinae		Left erector spinae	
	Mean	SD±	Mean	SD±	Mean	SD±	Mean	SD±
Center	68.8	11	66.5	10	59.4	16	60.3	16
Anterior right	63.8	11	74	9	56.4	14	70.2	18
Anterior left	75.2	7.2	58.6	9	69.3	15	58.1	16
Posterior right	59.5	10	63.4	1	52.9	13	59.4	18
Posterior left	64.8	9	55	13	58.1	14	53.1	15

Table (2) shows that the minimum value of EMG for right erector spinae was at the posterior right for the expected location while it was at the anterior left for the unexpected location. The same table shows that the minimum value of EMG for left erector spinae was at the posterior left for the expected location while it was at the anterior right for the unexpected location.

Table (3): T-test for the load expectation effect 0 on erector spinae muscles EMG (Stoop Lift)

location of center of mass	Right erector spinae				T	Left erector spinae				T
	Unexpected location of center of mass		Expected location of center of mass			Unexpected location of center of mass		Expected location of center of mass		
	Mean	SD±	Mean	SD±		Mean	SD±	Mean	SD±	
Center	68.8	11	59.4	16	2.9	66.5	10	60.3	16	0.9
Ant right	63.8	11	56.4	14	3.4	74	9	70.2	18	1.1
Ant left	75.2	7.2	69.3	15	2.1	58.6	9	58.1	16	0.1
Post right	59.5	10	52.9	13	3.3	63.4	1	59.4	18	1.2
Post left	64.8	9	58.1	14	3	55	13	53.1	15	0.6

(T) Table value on $P \leq 0.05 = 2.04$

Table (3) shows (t) values for the load effect on right and left erector spinae muscles during stoop lift. (t) Values indicate statistically significant differences for all the five locations of right erector spinae but not for the left erector spinae.

Table (4): LSD test for normalized maximum EMG amplitudes for erector spinae muscles during stoop lift with expected and unexpected load locations

Location		Expected				Unexpected			
Location		Right erector spinae		Left erector spinae		Right erector spinae		Left erector spinae	
Location	Location	Mean difference	P	Mean difference	P	Mean difference	P	Mean difference	P
Center	Ant right	5.023	0.073	-7.486	0.000	3.052	0.162	-9.867	0.000
	Ant left	-6.419	0.001	7.909	0.000	-9.888	0.000	2.19	0.305
	Postright	9.315	0.000	3.064	0.008	6.491	0.000	0.891	0.514
	Post left	4	0.081	11.494	0.000	1.35	0.375	7.21	0.006
Anterior right	Center	-5.023	0.073	7.486	0.000	-3.052	0.162	9.867	0.000
	Ant left	-11.442	0.000	15.395	0.000	-12.94	0.000	12.058	0.000
	Postright	4.291	0.006	10.55	0.000	3.439	0.119	10.758	0.000
	Post left	-1.023	0.624	18.981	0.000	-1.703	0.483	17.078	0.000
Anterior left	Center	6.419	0.001	-7.909	0.000	9.888	0.000	-2.19	0.305
	Ant right	11.442	0.000	-15.395	0.000	12.94	0.000	-12.058	0.000
	Postright	15.734	0.000	-4.845	0.000	16.379	0.000	-1.299	0.526
	Post left	10.419	0.000	3.386	0.007	11.238	0.000	5.02	0.001
Posterior right	Center	-9.315	0.000	-3.064	0.008	-6.491	0.000	-0.891	0.514
	Ant right	-4.291	0.006	-10.55	0.000	-3.439	0.119	-10.758	0.000
	Ant left	-15.734	0.000	4.845	0.000	-16.379	0.000	1.299	0.526
	Post left	-5.314	0.000	8.43	0.000	-5.141	0.000	6.319	0.003
Posterior left	Center	-4	0.081	-11.494	0.000	-1.35	0.375	-7.21	0.006
	Ant right	1.023	0.624	-18.981	0.000	1.703	0.483	-17.078	0.000
	Ant left	-10.419	0.000	-3.586	0.007	-11.238	0.000	-5.02	0.001
	Post right	5.314	0.000	-8.43	0.000	5.141	0.000	-6.319	0.003

Table (4) shows LSD values. According to these values, locations can be ordered from the most to the least important as follows: anterior left – posterior right – posterior left - anterior right – center.

Table (5): Description of EMG range for erector spinae muscles EMG (Squat lift)

location of center of mass	Unexpected				Expected			
	erector spinae		erector spinae		erector spinae		erector spinae	
	Mean	SD±	Mean	SD±	Mean	SD±	Mean	SD±
Center	58.7	13	57.6	15	57.6	15	56	14
Anterior right	52.5	15	66	14	51.3	8.5	62.2	15
Anterior left	66.3	12.9	53.1	16	61.7	11	52.7	14
Posterior right	48	15.2	55.8	15	47.6	11	54.2	12
Posterior left	54.7	15	50.2	10	53.3	10	46.4	13

Table (5) shows the maximum and minimum values of EMG for left and right erector spinae for the expected and unexpected locations.

Table (6): T-test for the load expectation effect on erector spinae muscles EMG (Squat Lift)

location of center of mass	Right erector spinae				T	Left erector spinae				
	Unexpected location of center of mass		Expected location of center of mass			Unexpected location of center of mass		Expected location of center of mass		
	Mean	SD±	Mean	SD±		Mean	SD±	Mean	SD±	
Center	58.7	13	57.6	15	0.7	57.6	15	56	14	0.9
Ant right	52.5	15	51.3	8.5	0.5	66	14	62.2	15	3.2
Ant left	66.3	12.9	61.7	11	4.1	53.1	16	52.7	14	0.1
Post right	48	15.2	47.6	11	0.2	55.8	15	54.2	12	0.9
Post left	54.7	15	53.3	10	0.5	50.2	10	46.4	13	1.9

(T) Table value on $P \leq 0.05 = 2.04$

Table (6) shows (t) values for the load effect on right and left erector spinae muscles during squat lift. (t) Values indicate statistically significant differences for all the five locations of right and left erector spinae as the anterior locations were more important.

Table (7): LSD test for normalized maximum EMG amplitudes for erector spinae muscles during Squat lift with expected and unexpected load locations

Location		Expected				Unexpected			
		Right erector spinae		Left erector spinae		Right erector spinae		Left erector spinae	
Location	Location	Mean difference	P	Mean difference	P	Mean difference	P	Mean difference	P
Center	Ant right	6.264	0.003	-8.383	0.000	5.944	0.000	-6.204	0.000
	Ant left	-7.589	0.000	4.467	0.002	-4.452	0.009	3.3	0.091
	Post right	10.696	0.000	1.8	0.157	9.68	0.000	1.529	0.161
	Post left	4.011	0.008	6.985	0.004	3.963	0.002	9.537	0.000
Anterior right	Center	-6.264	0.003	8.383	0.000	-5.944	0.000	6.204	0.000
	Ant left	-13.853	0.000	12.85	0.000	-10.396	0.000	9.505	0.000
	Post right	4.432	0.002	10.183	0.000	3.736	0.000	7.733	0.000
	Post left	-2.253	0.139	15.368	0.000	-1.981	0.210	15.742	0.000
Anterior left	Center	7.589	0.000	-4.467	0.002	4.452	0.009	-3.3	0.091
	Ant right	13.853	0.000	-12.85	0.000	10.396	0.000	-9.505	0.000
	Post right	18.286	0.000	-2.666	0.041	14.132	0.000	-1.772	0.436
	Post left	11.601	0.000	12.518	0.000	8.415	0.000	6.237	0.001
Posterior right	Center	-10.696	0.000	-1.8	0.157	-9.68	0.000	-1.529	0.161
	Ant right	-4.432	0.002	-10.183	0.000	-3.736	0.000	-7.733	0.000
	Ant left	-18.286	0.000	2.666	0.041	-14.132	0.000	1.771	0.436
	Post left	-6.685	0.002	5.184	0.017	-5.717	0.003	8.008	0.000
Posterior left	Center	-4.011	0.008	-6.985	0.004	-3.963	0.002	-9.537	0.000
	Ant right	2.253	0.139	-15.368	0.000	1.981	0.210	-15.742	0.000

Location		Expected				Unexpected			
		Right erector spinae		Left erector spinae		Right erector spinae		Left erector spinae	
Location	Location	Mean difference	P	Mean difference	P	Mean difference	P	Mean difference	P
	Ant left	-11.601	0.000	-2.518	0.170	-8.415	0.000	-6.237	0.001
	Post right	6.685	0.002	-5.184	0.017	5.717	0.003	-8.008	0.000

Table (7) shows LSD values. According to these values, anterior locations (right and left) have the same importance.

Table: (8): Descriptive Statistics for the trunk range of motion during Stoop Lift with expected and unexpected locations of center of mass.

location of center of mass	Flexion				Side Bending				Rotation			
	Unexpected		Expected		Unexpected		Expected		Unexpected		Expected	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Center	70.7	6.7	70.3	4.5	5.1	1.6	4.4	1.7	2.8	1.1	2.5	0.8
Anterior right	73.3	6.9	72.7	5.3	7.9	2.7	7.5	3.3	4.1	1.2	3.8	0.8
Anterior left	76.3	6.6	75.9	4.8	9.1	3.5	7.8	2.4	5	1.3	4.8	1
Posterior right	69.7	6.7	68.3	6.2	7.4	2	6.8	2.2	3.5	1	3.4	0.7
Posterior left	67.9	6.7	67.5	5.6	7.2	1.5	6.5	1.8	3.3	1	3	0.6

Table (8) shows that minimum values of the means for trunk tang of motion at flexion, side bending and rotation were recorded at posterior left, center and center locations respectively for the unexpected location, while their minimum values for the expected locations were recorded at posterior left, center and center respectively.

Table: (9): (T) tests for location expectation effects on the trunk range of motion during Stoop Lift with expected and unexpected locations of center of mass.

location of center of mass	Flexion					Side Bending					Rotation				
	Unexpected		Expected		T	Unexpected		Expected		T	Unexpected		Expected		T
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Center	70.7	6.7	70.3	4.5	0.35	5.1	1.6	4.4	1.7	1.4	2.8	1.1	2.5	0.8	1.07
Ant right	73.3	6.9	72.7	5.3	0.47	7.9	2.7	7.5	3.3	0.4	4.1	1.2	3.8	0.8	1.4
Ant left	76.3	6.6	75.9	4.8	0.49	9.1	3.5	7.8	2.4	2.2	5	1.3	4.8	1	0.8
Post right	69.7	6.7	68.3	6.2	1.4	7.4	2	6.8	2.2	1.3	3.5	1	3.4	0.7	0.00
Post left	67.9	6.7	67.5	5.6	0.44	7.2	1.5	6.5	1.8	2.7	3.3	1	3	0.6	1.2

Table (9) shows that there are no statistically significant differences for most results of the five locations except for the left side locations for the side bending direction.

Table (10): LSD test for trunk range of motion during Stoop Lift with expected and unexpected locations of center of mass

Location		Unexpected						Expected					
		Flexion		Side Bending		Rotation		Flexion		Side Bending		Rotation	
Location	Location	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P
Center	Antright	-2.56	0.000	-0.53	0.187	-1.35	0.000	-2.40	0.000	-3.03	0.000	-1.33	0.000
	Ant left	-5.60	0.000	-3.95	0.000	-2.10	0.000	-5.50	0.000	-3.23	0.000	-2.18	0.000
	Postright	1.000	0.136	-2.25	0.000	-0.66	0.000	2.067	0.007	-2.30	0.000	-0.93	0.000
	Post left	2.800	0.001	-0.76	0.118	-0.53	0.000	2.900	0.000	-1.93	0.000	-0.55	0.000
Ant right	Center	2.567	0.000	0.533	0.187	1.350	0.000	2.400	0.000	3.033	0.000	1.333	0.000
	Ant left	-3.03	0.000	-1.16	0.053	-0.75	0.000	-3.10	0.000	-0.20	0.682	-0.85	0.000
	Postright	3.567	0.000	2.783	0.000	0.683	0.000	4.467	0.000	0.733	0.201	0.400	0.003
	Post left	5.367	0.000	-2.01	0.000	0.817	0.000	5.300	0.000	1.100	0.075	0.783	0.000
Ant left	Center	5.600	0.000	3.950	0.000	2.100	0.000	5.500	0.000	3.233	0.000	2.183	0.000
	Antright	3.033	0.000	1.167	0.053	0.750	0.000	3.100	0.000	0.200	0.682	0.850	0.000
	Postright	6.600	0.000	1.700	0.001	1.433	0.000	7.567	0.000	0.933	0.008	1.250	0.000
	Post left	8.400	0.000	1.933	0.002	1.567	0.000	8.400	0.000	1.300	0.014	1.63	0.000
Post right	Center	-1.00	0.136	2.250	0.000	0.667	0.000	-2.06	0.007	2.300	0.000	0.933	0.000
	Antright	-3.56	0.000	-2.78	0.000	-0.68	0.000	-4.46	0.000	-0.73	0.201	-0.40	0.003
	Ant left	-6.60	0.000	-1.70	0.001	-1.43	0.000	-7.56	0.000	-0.93	0.008	-1.25	0.000
	Post left	1.800	0.000	0.233	0.428	0.133	0.340	0.833	0.001	0.367	0.363	0.383	0.002
Post left	Center	-2.80	0.001	0.767	0.118	0.533	0.000	-2.90	0.000	1.933	0.000	0.550	0.000
	Antright	-5.36	0.000	-2.01	0.000	-0.81	0.000	-5.30	0.000	-1.10	0.075	-0.78	0.000

Location		Unexpected						Expected					
		Flexion		Side Bending		Rotation		Flexion		Side Bending		Rotation	
Location	Location	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P
	Ant left	-8.40	0.000	-1.93	0.002	-1.56	0.000	-8.40	0.000	-1.30	0.014	-1.63	0.000
	Postright	-1.80	0.000	-0.23	0.428	-0.13	0.340	-0.83	0.001	0.36	0.363	-0.38	0.002

Table (10) shows that all locations nearly had the same significance expect for the anterior left location that had a higher significance degree compared to the other four locations. This indicates that anterior left location has the most significant effect on trunk range of motion.

Table: (11): Descriptive Statistics for the trunk range of motion during Squat Lift with expected and unexpected locations of center of mass.

location of center of mass	Flexion				Side Bending				Rotation			
	Unexpected		Expected		Unexpected		Expected		Unexpected		Expected	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Center	45.8	9	42.9	7.6	3.8	1.6	3	0.8	2.3	0.9	2.2	0.6
Ant right	47.9	8.6	44.1	6.4	5.2	2.5	4.7	2	4	1.5	3.5	1.1
Ant left	51.6	7.9	45.8	5.9	6.2	3.9	6	2.2	4.5	1.5	4.2	1.2
Post right	44.5	10	40	6.2	4.7	2.2	4.3	1.1	3.7	1.2	3.1	0.9
Post left	43.1	9.9	39	7	4.4	1.9	3.7	1.2	3	0.7	2.6	0.8

Table (11) shows that minimum values of the means for trunk tang of motion at flexion, side bending and rotation were recorded at posterior left, center and center locations respectively for the unexpected location, while their minimum values for the expected locations were recorded at posterior left, center and center respectively.

Table: (12): (T) tests for location expectation effects on the trunk range of motion during Squat Lift with expected and unexpected locations of center of mass.

location of center of mass	Flexion					Side Bending					Rotation				
	Unexpected		Expected		T	Unexpected		Expected		T	Unexpected		Expected		T
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Center	45.8	9	42.9	7.6	1.3	3.8	1.6	3	0.8	2.6	2.3	0.9	2.2	0.6	0.7
Ant right	47.9	8.6	44.1	6.4	1.9	5.2	2.5	4.7	2	1.5	4	1.5	3.5	1.1	1.5
Ant left	51.6	7.9	45.8	5.9	3.5	6.2	3.9	6	2.2	0.4	4.5	1.5	4.2	1.2	1.2
Post right	44.5	10	40	6.2	1.9	4.7	2.2	4.3	1.1	0.9	3.7	1.2	3.1	0.9	1.6
Post left	43.1	9.9	39	7	1.5	4.4	1.9	3.7	1.2	2.5	3	0.7	2.6	0.8	2.3

Table (12) shows that there are no statistically significant differences for most results of the five locations except for the posterior left for the side bending and rotation directions and anterior left for flexion.

Table (13): LSD test for trunk range of motion during Squat Lift with expected and unexpected locations of center of mass

Location		Unexpected						Expected					
		Flexion		Side Bending		Rotation		Flexion		Side Bending		Rotation	
Location	Location	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P
Center	Antright	-2.16	0.029	-1.36	0.000	-1.65	0.000	-1.20	0.117	-1.55	0.000	-1.23	0.000
	Ant left	-5.66	0.000	-2.38	0.000	-2.16	0.000	-3.00	0.000	-2.90	0.000	-2.05	0.000
	Postright	1.333	0.093	-0.83	0.009	-0.30	0.127	2.900	0.001	-1.23	0.000	-0.93	0.000
	Post left	2.767	0.013	-0.61	0.031	-0.78	0.000	3.867	0.001	-0.71	0.000	-0.41	0.004
Ant right	Center	2.167	0.029	1.367	0.000	1.650	0.000	1.200	0.117	1.550	0.000	1.233	0.000
	Ant left	-3.50	0.000	-1.01	0.068	-0.51	0.010	-1.80	0.016	-1.35	0.000	-0.81	0.000
	Postright	3.500	0.002	0.533	0.037	-1.35	0.000	4.100	0.000	0.317	0.252	0.300	0.006
	Post left	4.933	0.000	0.750	0.022	0.867	0.000	5.067	0.000	0.833	0.041	0.817	0.000
Ant left	Center	5.667	0.000	2.383	0.000	2.167	0.000	3.000	0.000	2.900	0.000	2.050	0.000
	Antright	3.500	0.000	1.017	0.068	0.517	0.010	1.800	0.016	1.350	0.000	0.817	0.000
	Postright	7.000	0.000	1.550	0.018	0.817	0.001	5.900	0.000	1.667	0.000	1.117	0.000
	Post left	8.433	0.000	1.767	0.016	1.383	0.000	6.867	0.000	2.183	0.000	1.633	0.000
Post right	Center	-1.33	0.093	0.833	0.009	-0.30	0.127	-2.90	0.001	1.233	0.000	0.933	0.000
	Antright	-3.50	0.002	-0.53	0.037	-1.35	0.000	-4.10	0.000	-0.31	0.252	-0.30	0.006
	Ant left	-7.00	0.000	-1.55	0.018	-0.81	0.001	-5.90	0.000	-1.66	0.000	-1.11	0.000
	Post left	1.433	0.043	0.217	0.472	0.567	0.006	0.967	0.015	0.517	0.070	0.517	0.002
Post left	Center	-2.76	0.013	0.617	0.031	0.783	0.000	-3.86	0.001	0.717	0.000	0.417	0.004

Location		Unexpected						Expected					
		Flexion		Side Bending		Rotation		Flexion		Side Bending		Rotation	
Location	Location	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P
	Antright	-4.93	0.000	-0.75	0.022	-0.86	0.000	-5.06	0.000	-0.83	0.041	0.817	0.000
	Ant left	-8.43	0.000	-1.76	0.016	-1.38	0.000	-6.86	0.000	-2.18	0.000	-1.63	0.000
	Postright	-1.43	0.043	-0.21	0.472	0.567	0.006	-0.96	0.105	-0.51	0.070	-0.51	0.002

Table (13) shows that all locations nearly had the same significance expect for the anterior left location that had a higher significance degree compared to the other four locations. This indicates that anterior left location has the most significant effect on trunk range of motion

Table: (14): Descriptive Statistics for the trunk velocity during Stoop Lift with expected and unexpected locations of center of mass.

location of center of mass	Flexion				Side Bending				Rotation			
	Unexpected		Expected		Unexpected		Expected		Unexpected		Expected	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Center	77.6	9.3	73.2	7.5	25.6	5.3	24.4	8.6	16.6	5.4	16.2	3.1
Anterior right	78.9	9.4	75.8	7	34.8	7	33.6	7.6	23.3	4.9	22.9	4.1
Anterior left	83.5	8.1	79.5	6.6	37.6	8	35.4	7.5	29.1	7.2	28.9	5.2
Posterior right	76.1	8.8	70.6	7.7	31.2	7.2	30.7	8.3	20.9	5.3	20.6	3.8
Posterior left	74.5	8.2	69.5	5.6	30.8	6	28.5	8.1	18.1	5	17	3.7

Table (14) shows that minimum values of the means for trunk velocity at flexion, side bending and rotation were recorded at posterior left, center and center locations respectively for the unexpected location, while their minimum values for the expected locations were recorded at posterior left, center and center respectively.

Table: (15): (T) tests for location expectation effects on the trunk velocity during Stoop Lift with expected and unexpected locations of center of mass.

location of center of mass	Flexion					Side Bending					Rotation				
	Unexpected		Expected		T	Unexpected		Expected		T	Unexpected		Expected		T
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Center	77.6	9.3	73.2	7.5	2.2	25.6	5.3	24.4	8.6	0.6	16.6	5.4	16.2	3.1	0.5
Ant right	78.9	9.4	75.8	7	1.7	34.8	7	33.6	7.6	0.5	23.3	4.9	22.9	4.1	0.6
Ant left	83.5	8.1	79.5	6.6	2.4	37.6	8	35.4	7.5	1.3	29.1	7.2	28.9	5.2	0.2
Post right	76.1	8.8	70.6	7.7	3.1	31.2	7.2	30.7	8.3	0.3	20.9	5.3	20.6	3.8	0.3
Post left	74.5	8.2	69.5	5.6	2.6	30.8	6	28.5	8.1	1.2	18.1	5	17	3.7	1

Table (15) shows that there are no statistically significant differences for all locations except in side bending and rotation directions while there were statistically significant differences for flexion direction. This indicates that expecting load location affects trunk velocity in flexion direction during stoop lift.

Table (16): LSD test for trunk velocity during Stoop Lift with expected and unexpected locations of center of mass

Location		Unexpected						Expected					
		Flexion		Side Bending		Rotation		Flexion		Side Bending		Rotation	
Location	Location	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P
Center	Antright	-1.40	0.115	-9.13	0.000	-6.83	0.000	-2.66	0.000	-9.30	0.000	-6.86	0.000
	Ant left	-5.90	0.000	-11.9	0.000	-12.5	0.000	-6.40	0.000	-11.0	0.000	-12.7	0.000
	Postright	1.467	0.033	-5.70	0.002	-4.36	0.000	2.600	0.000	-6.26	0.006	-4.53	0.000
	Post left	3.100	0.002	-5.20	0.002	-1.50	0.012	3.633	0.000	-4.13	0.005	-0.93	0.061
Ant right	Center	1.400	0.115	9.133	0.000	6.833	0.000	2.667	0.000	9.300	0.000	6.867	0.000
	Ant left	-4.50	0.000	-2.80	0.109	-5.66	0.000	-3.73	0.000	-1.73	0.300	-5.86	0.000
	Postright	2.867	0.001	3.433	0.051	2.467	0.001	5.267	0.000	3.033	0.023	2.333	0.000
	Post left	4.500	0.000	3.933	0.017	5.333	0.000	6.300	0.000	5.167	0.000	5.933	0.000
Ant left	Center	5.900	0.000	11.93	0.000	12.50	0.000	6.400	0.000	1.03	0.000	12.73	0.000
	Antright	4.500	0.000	2.800	0.109	5.667	0.000	3.733	0.000	1.733	0.300	5.867	0.000
	Postright	7.367	0.000	6.233	0.000	8.133	0.000	9.000	0.000	4.767	0.008	8.200	0.000
	Post left	9.000	0.000	6.733	0.000	11.00	0.000	10.03	0.000	6.900	0.002	11.80	0.000
Post right	Center	-1.46	0.033	5.700	0.002	4.36	0.000	-2.60	0.000	6.267	0.006	4.533	0.000
	Antright	-2.86	0.001	-3.43	0.051	-2.46	0.001	-5.26	0.000	-3.03	0.023	-2.33	0.000
	Ant left	-7.36	0.000	-6.23	0.000	-8.31	0.000	-9.00	0.000	-4.76	0.008	-8.20	0.000
	Post left	1.633	0.011	0.500	0.650	2.867	0.000	1.033	0.188	2.133	0.107	3.600	0.000

Location		Unexpected						Expected					
		Flexion		Side Bending		Rotation		Flexion		Side Bending		Rotation	
Location	Location	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P
Post left	Center	-3.10	0.02	5.200	0.002	1.500	0.012	-3.63	0.000	4.133	0.005	0.933	0.061
	Antright	-4.50	0.000	-3.93	0.007	-5.33	0.000	-6.30	0.000	-5.16	0.000	-5.93	0.000
	Ant left	-9.00	0.000	-6.73	0.000	-11.0	0.000	-10.0	0.000	-6.90	0.002	-11.8	0.000
	Postright	-1.63	0.011	-0.50	0.651	-2.86	0.000	-1.03	0.188	-2.13	0.107	-3.60	0.000

Table (16) shows that all locations nearly had the same significance expect for the anterior left and center locations that had a higher significance degree compared to the other locations. This indicates that rotation direction is more affected by location changes compared to side bending and flexion.

Table: (17): Descriptive Statistics for the trunk velocity during Squat Lift with expected and unexpected locations of center of mass.

location of center of mass	Flexion				Side Bending				Rotation			
	Unexpected		Expected		Unexpected		Expected		Unexpected		Expected	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Center	63.9	9.4	59.7	7.6	20.5	7.6	17.7	3.5	14.8	4.5	15.1	4.1
Anterior right	66.4	10.5	61.2	7.2	27.5	9.5	26.6	5.7	22.5	4.4	21.1	3.5
Anterior left	69.1	8.8	66.9	7.3	31.2	10.2	28.9	7.9	27.2	5	26.6	5.2
Post right	61.7	11.4	56.6	6.5	23.9	8.6	23.4	5.3	20.1	4.7	19.4	3.5
Posterior left	59.9	13.3	55	9.1	22.7	8.8	20.3	4.6	17.5	4	17.3	3.1

Table (17) shows that minimum values of the means for trunk velocity at flexion, side bending and rotation were recorded at posterior left, center and center locations respectively for the unexpected location, while their minimum values for the expected locations were recorded at anterior left.

Table: (18): (T) tests for location expectation effects on the trunk velocity during Squat Lift with expected and unexpected locations of center of mass.

location of center mass	Flexion					Side Bending					Rotation				
	Unexpected		Expected		T	Unexpected		Expected		T	Unexpected		Expected		T
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Center	63.9	9.4	59.7	7.6	2	20.5	7.6	17.7	3.5	1.9	14.8	4.5	15.1	4.1	0.6
Ant right	66.4	10.5	61.2	7.2	2.5	27.5	9.5	26.6	5.7	0.6	22.5	4.4	21.1	3.5	1.6
Ant left	69.1	8.8	66.9	7.3	1.6	31.2	10.2	28.9	7.9	1.5	27.2	5	26.6	5.2	0.6
Post right	61.7	11.4	56.6	6.5	2.2	23.9	8.6	23.4	5.3	0.3	20.1	4.7	19.4	3.5	1.1
Post left	59.9	13.3	55	9.1	1.6	22.7	8.8	20.3	4.6	1.9	17.5	4	17.3	3.1	0.4

Table (18) shows that there are no statistically significant differences for all results of the five locations with side bending and rotation directions while there were moderate significance for flexion direction.

Table (19): LSD test for trunk velocity during Squat Lift with expected and unexpected locations of center of mass

Location		Unexpected						Expected					
		Flexion		Side Bending		Rotation		Flexion		Side Bending		Rotation	
Location	Location	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P
Center	Antright	-2.43	0.007	-6.83	0.000	-7.73	0.000	-1.63	0.117	-8.86	0.000	-5.96	0.000
	Ant left	-5.13	0.000	-10.5	0.000	-12.4	0.000	-7.20	0.000	-11.0	0.000	-11.4	0.000
	Postright	2.200	0.063	-3.36	0.000	-5.36	0.000	3.033	0.000	-5.80	0.000	-4.23	0.000
	Post left	4.033	0.001	-2.20	0.006	-2.80	0.000	4.600	0.000	-2.56	0.001	-2.10	0.001
Ant right	Center	2.433	0.007	6.833	0.000	7.733	0.000	1.633	0.117	8.867	0.000	5.967	0.000
	Ant left	-2.70	0.059	-3.70	0.002	-4.70	0.000	-5.56	0.000	-2.20	0.035	-5.43	0.000
	Postright	4.633	0.000	3.467	0.000	2.367	0.000	4.667	0.000	3.067	0.001	1.733	0.000
	Post left	6.467	0.000	4.633	0.002	4.933	0.000	6.233	0.000	6.300	0.000	3.867	0.000
Ant left	Center	5.133	0.000	10.53	0.000	12.43	0.000	7.200	0.000	11.06	0.000	11.40	0.000
	Antright	2.700	0.059	3.700	0.002	4.700	0.000	5.567	0.000	2.200	0.035	5.433	0.000
	Postright	7.333	0.000	7.167	0.000	7.067	0.000	10.23	0.000	5.267	0.000	7.167	0.000
	Post left	9.167	0.000	8.333	0.000	9.633	0.000	11.80	0.000	8.500	0.000	9.300	0.000
Post right	Center	-2.20	0.063	3.367	0.000	5.367	0.000	-3.03	0.000	5.800	0.000	4.233	0.000
	Antright	-4.63	0.000	-3.46	0.000	-2.36	0.000	-4.66	0.000	-3.06	0.001	-1.73	0.000
	Ant left	-7.33	0.000	-7.16	0.000	-7.06	0.000	-10.2	0.000	-5.26	0.000	-7.16	0.000

Location		Unexpected						Expected					
		Flexion		Side Bending		Rotation		Flexion		Side Bending		Rotation	
Location	Location	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P	Mean	P
	Post left	1.833	0.038	1.167	0.295	2.567	0.000	1.567	0.171	3.233	0.000	2.133	0.000
Post left	Center	-4.03	0.001	2.200	0.006	2.800	0.000	-4.60	0.000	2.567	0.001	2.100	0.001
	Antright	-6.46	0.000	-4.63	0.002	-4.93	0.000	-6.23	0.000	-6.30	0.000	-3.86	0.000
	Ant left	-9.16	0.000	-8.33	0.000	-9.63	0.000	-11.8	0.000	-8.50	0.000	-9.30	0.000
	Postright	-1.83	0.038	-1.16	0.295	-2.56	0.000	-1.56	0.171	-3.23	0.000	-2.13	0.000

Table (19) shows that all locations nearly had the same significance expect for the anterior left location that had a higher significance degree compared to the other four locations. This indicates that rotation direction is more affected by location changes compared to side bending and flexion.

Discussion:

Results indicated that there were statistically significant differences among the five locations of load center of mass for both right and left erector spinae muscles on both expected and unexpected conditions. These differences appeared in both stoop and squat lifts. Comparing expected and unexpected conditions indicated a significant effect for location on the right, but not left erector spinae. Load expectation affects the dominant side of the muscle in stoop lifts. As for squat lifts, there were no statistically significant differences for all locations expect for anterior left and right. This indicates that expecting load had a little effect on erector spinae during squat lift. This is in agreement with Serossi & Pope (1987), Arjmand et al (2009), Marras & Mirka (1992), Norkin & Levangie (1992) and Rutowska et al (2009). (10) (1) (6) (7) (9)

In addition, result indicated that there were statistically significant differences among the five locations for the trunk range of motion. There were no statistically significant differences for most locations expect for left side locations at the side bending direction. This indicates that load expectation had almost no effect on trunk range of motion during stoop lifts. Also, there were no statistically significant differences for most locations expect for left posterior locations at the side bending and rotation directions and anterior left for flexion. This indicates that load expectation had almost no effect on trunk range of motion during squat lifts. This is in agreement with Kingma et al (2004), Van Dieen & De Looze (1999) and Van Der Berg et al (2003). (4) (11) (12)

Furthermore, result indicated that there were statistically significant differences among the five locations for the trunk velocity. There were no statistically significant differences for all locations in side bending and rotation directions while there were statistically significant differences for flexion direction. This indicates the effect of load expectation on trunk velocity during stoop lifts. As for squat lifts, there were no statistically significant differences for most locations in side bending and rotation directions while there were statistically significant moderate differences for flexion direction. This indicates the effect of load expectation on trunk velocity during squat lifts. This is in agreement with Lavander et al (2003), Bernard et al (1999) & Heiss et al (2002). (5) (2) (3)

Conclusions:

The researcher concluded the following:

1. There are major differences in EMG measurements of the Erector Spinae Muscle and trunk movements between the two types of lifting
2. A weight that is lifted without estimating the location of its center of mass may cause injuries
3. Injury risks can be minimized by shifting the weight's center of mass towards the dominant side

Recommendations:

1. Replicating this study with dynamic models for measuring pressure on lumbar vertebrae
2. Investigating the effects of lumbar supporters on the variables under investigation
3. Replicating this study with various weights and other lifting techniques
4. Replicating this study with female samples to identify gender differences

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