Stability Ball Versus Office Chair: Comparison of Muscle Activation and Lumbar Spine Posture During Prolonged Sitting

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Objective: The objective of the study was to evaluate the differences between sitting on a stability ball and in an office chair in terms of trunk muscle activation and lumbar spine posture. **Background:** Stability balls have become increasingly popular as an alternative to office chairs to help reduce the prevalence of low back pain; however, little research has been conducted on their use as office chairs. **Methods:** The 14 participants (7 men, 7 women) were required to sit on both a stability ball and an office chair for 1 hour each while performing various computer workstation tasks throughout the sitting periods. The activation of eight muscles and lumbar spine posture were measured and analyzed. **Results:** Increased muscle activation in thoracic erector spinae ($p = .0352$), decreased pelvic tilt ($p = .0114$), and increased perceived discomfort ($p < .0001$) while sitting on the stability ball were observed. **Conclusions:** The small changes in biological responses when sitting on a stability ball as compared with an office chair, combined with the increased reported discomfort while on the ball, suggests its use for prolonged sitting may not be advantageous. **Application:** Prolonged sitting on a stability ball does not greatly alter the manner in which an individual sits, yet it appears to increase the level of discomfort. Therefore, it is important to fully explore a new chair design and consult scientific research before implementing its use.

INTRODUCTION

The stability ball is a popular piece of exercise equipment seen in many fitness centers, and in recent years it has become increasingly popular in the workplace as an alternative to the traditional office chair. Various suppliers of stability balls, such as BodyTrends.Com© (http://www.bodytrends.com/ballchar.htm), Ball Dynamics® (http://www.balldynamics.com/fitball.php), and Fitness Wholesale Online® (http://www.fitnesswholesale.com/tbs.htm) are promoting their use as office chairs. One claim for their use is to reduce and prevent low back pain (LBP) by increasing trunk muscle activity. The rationale provided for this claim is that increased muscle activity will subsequently increase core stability and strength, which is theorized to be beneficial for reducing the prevalence of LBP. Although this is a defendable rationale for strength and conditioning in an exercise program, in prolonged exposure, elevated activation levels with fewer rest periods have been shown to increase pain reporting (Jonsson, 1982; Veiersted, Westgaard, & Andersen, 1990). The main purpose of the study was to compare the trunk muscle activation levels and lumbar spine posture of individuals sitting on a stability ball and in an office chair for an extended period.

One common claim is that individuals with LBP tend to have lower trunk strength in the abdominal and back muscles (Ashmen, Swanik, & Lephart, 1996; J. H. Lee, Ooi, & Nakamura, 1995; McNeill, Warwick, Andersson, & Schultz, 1980). However, this lower trunk strength may be a result of LBP, rather than a risk factor (J. H. Lee et al., 1999). A cross-sectional study revealed no association between abdominal muscle strength and the causation of LBP; however, those suffering from

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LBP at the time of the study had lower abdominal strength than did those who were pain free (P. Lee, Helewa, Goldsmith, Smythe, & Stitt, 2001), suggesting lower abdominal strength was a result of LBP. Another theory is that an imbalance in trunk flexor and extensor muscle strength is a potential risk factor for developing LBP (J. H. Lee et al., 1999).

Increased trunk extensor strength and its association with reducing LBP in patients has also been a much-examined topic. A prospective study conducted by Bentsen, Lindgarde, and Manthorpe (1997) showed significant reduction in LBP after a back-strengthening exercise program. Similarly, Handa, Yamamoto, Tani, Kawakami, and Takemasa (2000) and Elnaggar, Nordin, Sheikhzadeh, Parnianpour, and Kahanovitz (1991) demonstrated that after exposure to a trunk-muscle-strengthening exercise regime, LBP was reduced in patients. In contrast, no correlation was found between pain levels in LBP patients and increased back strength following an endurance and coordination training program designed for the treatment of LBP (Johannsen et al., 1995).

Cholewicki, Polzhofer, and Radebold (2000) examined the effect of sitting on an unstable surface on trunk posture. It was observed that the displacement of both the mediolateral and anterior-posterior direction of the center of pressure increased with increased seat instability. This proposal of increased center of pressure displacement contributes substantially to the reasoning behind the prolonged use of a stability ball as a chair. The unstable nature of the ball induces motion, which is theorized to increase muscle activation and muscle strength. In theory, this motion would also provide rest periods for muscle groups not involved in each individual small motion. However, previous studies have also documented decreased postural control in individuals with LBP (Mientjes & Frank, 1999; Radebold, Cholewicki, Polzhofer, & Greene, 2001; Takala, Korhonen, & Viikari-Juntura, 1997), indicating that the use of stability balls with this population requires further examination.

Given the lack of literature regarding the use of stability balls for prolonged periods as an alternative to office chairs, the primary objective of this research was to evaluate differences between sitting on a stability ball and sitting on an office chair with respect to back and abdominal muscle activation levels and lumbar spine postures. The secondary objective was to determine whether there are differences in muscle activation levels and lumbar spine postures among four different computer workstation tasks. It was hypothesized that because of the unstable nature of the stability ball, significant muscular and postural differences between the sitting conditions would be observed. In addition, it was hypothesized that the type of task performed would influence both muscular and postural sitting responses.

METHODOLOGY

Participants

Seven women and 7 men were recruited from the university population (Table 1). All participants were free of LBP for at least the previous 12 months before taking part in the study. Each participant was required to review and sign a consent form outlining the experiment, approved by the University Office of Research.

Instrumentation

Muscle activation levels and 3-D lumbar spine motion were recorded while the participants sat for 1 hr each on the stability ball and in a standard office chair. Four controlled computer workstation tasks were performed in each sitting condition.

Eight pairs of disposable electromyographic (EMG) electrodes (Ag-AgCl) were affixed to the skin over the muscle belly of the left and right thoracic erector spinae (ES) approximately 5 cm bilateral to T9, left and right lumbar ES approximately 3 cm bilateral to L3, left and right rectus

TABLE 1: Average (±1 *SD*) of Participant Information

Gender	*n*	Age (years)	Mass (kg)	Height (m)
Male	7	25.4 (5.44)	79.45 (10.01)	1.81 (0.05)
Female	7	22.3 (0.95)	59.64 (5.82)	1.63 (0.04)

abdominis (RA) approximately 2 cm bilateral to umbilicus, and left and right external oblique (EO) approximately 15 cm bilateral to umbilicus (McGill, 1991). A reference electrode was placed over the left scapula. Raw EMG data were bandpass filtered from 10 to 1000 Hz and differentially amplified (common-mode rejection ratio >90 dB at 60 Hz, input impedance >10 Mohms) to generate a maximum amplification of approximately 2 V (Model AMT-8, Bortec, Calgary, AB, Canada). The EMG signal was A/D converted at 2048 samples/s using a 12-bit A/D card with a ±2.5-V range.

The ISOTRAK 3Space (Polhemus, VT) is a two-sensor system with a source that emits an electromagnetic field. The ISOTRAK source was placed approximately 0.75 m away from the participant on the right-hand side and mounted to a fixed stand, which was kept constant for each participant. Sensors 1 and 2 were attached over the bony spinous processes of L1 and the sacrum, respectively, and the 3-D position and rotation of the sensors were recorded. The ISOTRAK signal was A/D converted at 30 samples/s. The collection of EMG data and posture data was synchronized by sending a pulse through the A/D converter from the ISOTRAK computer to the EMG computer, initiating data collection.

Calibration

Each participant performed two maximum voluntary contractions (MVCs), one for the back extensor muscle group and one for the abdominal muscle group, in order to allow us to normalize the EMG data (McGill, 1991). Briefly, to perform a back extensor MVC, the participant extended against resistance while his or her torso was suspended over the edge of a bench. To carry out an abdominal MVC, the participant performed a modified sit-up against resistance while twisting about the waist to ensure maximal contraction of the abdominal muscles. EMG data were then collected for 10 s while the participant laid quietly on his or her back, arms at the sides, to represent muscle activation at rest. The participant was also asked to stand erect, and the degree of lumbar flexion assumed in this posture was defined as zero. A maximum voluntary flexion trial was performed by requesting the participant to bend forward to his or her full potential while maintaining extended knees. The maximum flexion trial was used to normalize the posture data.

Sitting Trials

An armless office chair and a stability ball were used for each of the two 1-hr sitting trials. The chair and ball (sitting conditions) were adjusted to promote a starting posture with 90° hip flexion and 90° knee flexion. Each 1-hr sitting trial was divided into four 15-min trials, during which the participant was required to perform different controlled computer workstation tasks. The four tasks were typing, computer-aided design, typing/mouse combined work, and reading. The sitting condition that was used for the first 1-hr sitting trial and the order of the computer workstation tasks were randomized for each participant. Both EMG and posture data were collected for each entire 15-min trial. The participant was required to keep both feet on the ground at all times. At the beginning of each sitting trial and after each 15-min interval, the participant rated his or her discomfort using a 100-mm visual analog scale. Maximum flexion trials were measured two additional times, once after each 1-hr sitting trial.

Data Processing

The EMG data were full wave rectified and passed through a Butterworth filter, which had a 2.5-Hz cutoff frequency (Brereton & McGill, 1998), to produce a linear envelope for each of the eight muscle groups. The filtered signals were normalized to the maximum muscle activation determined from the MVCs (expressed as % MVC). Amplitude probability distribution functions (APDFs) were generated to determine the probability of time spent at zero muscle activation (0% MVC), referred to as *probability of rest.* In addition, the average EMG level, total number of gaps (periods of time when EMG levels dropped below 0.5% MVC for longer than 0.2 s; Veiersted et al., 1990), and average number of gaps for each muscle were determined. Cocontraction between the abdominal muscles and the back extensors was also quantified. The abdominal muscle total activation consisted of summing the left and right RA with the left and right EO. The back extensor total activation was composed of the summation of left and right thoracic ES with the left and right lumbar ES. Both the abdominal signal and the back extensor signal were integrated, and the common area between the two signals was defined as *trunk muscle cocontraction* (Winter, 1990).

Lumbar flexion was determined by calculating the angle between the two sensors on the spine, and pelvic tilt was determined by calculating the angle between the source and the sensor attached to the skin over the sacrum. The range of flexion was determined by subtracting the percentage of maximum flexion observed at a probability of .1 from that at .9, which were determined from the APDFs generated for each sitting trial. Posture data were examined to determine whether each participant assumed a static or dynamic sitting preference. Salewytsch and Callaghan (1999) defined *static sitting* as maintaining a steady lumbar flexion position (within a 15% window of lumbar flexion) for a minimum of 85% of the total time of a trial. A participant who had varying lumbar flexion (i.e., not within the previous criteria) was considered to have assumed a dynamic sitting preference.

The completed visual analog scales of perceived discomfort were measured to the nearest millimeter for each body region on the scale (head/neck, shoulders, upper back, lower back, and overall).

Statistical Analysis

Three-way analyses of variance (ANOVAs) were used to test the effects of sitting condition and task (repeated measures) and gender (nested measure) on all EMG variables, posture variables, and perceived discomfort. In all statistical tests, the 95% level of confidence was used for rejection of the null hypothesis. Tukey's post hoc multiple comparisons were used to examine any significant findings.

RESULTS

Sitting Condition

No significant differences attributable to sitting condition were observed in the average number of gaps, total number of gaps, or probability at rest (Tables 2 and 3). In addition, there were no significant differences attributable to sitting condition in average EMG except in the left thoracic ES (p = .0352), with an average of 2.06% MVC muscle activation on the ball and 1.36% MVC muscle activation in the chair (Figure 1). Additionally, no significant differences in cocontraction (average cocontraction on ball was 47.8% and 44.4% on the chair) were observed in individuals between sitting conditions.

No significant differences were observed in the average percentage of flexion (43.4% on chair and 43.0% on ball), the range of flexion (Δ13.9% on chair and Δ14.0% on ball) or preference for static or dynamic sitting between the ball and the chair. However, greater pelvic tilt in the posterior direction was observed in individuals in the chair (23.3°) as compared with those on the ball (18.3°; p = .0114).

Significant differences in perceived discomfort were found in the lower back (p = .0010) and overall for the whole body (p < .0001) between the two sitting conditions. Increased discomfort in the lower back was observed as time elapsed (initial pain recorded before the hour-long sitting period as compared with pain recorded after the period) for both the chair and ball conditions. However, only the whole-body discomfort scores were significantly higher after 1 hr of sitting on the stability ball (pain score of 17.5 mm) versus in the office chair (9.1 mm).

Task

The type of task performed had a strong influence on the muscular and postural sitting responses (Figure 2). Typing resulted in the highest average EMG levels in both the left and right thoracic ES (p = .0476 and .0069, respectively), whereas reading showed the lowest average activation levels in these muscles. In addition, typing resulted in the lowest probability of rest as well as in the lowest number of gaps in both the left (p = .0076 and .0074, respectively) and right (p = .0157 and .0029, respectively) thoracic ES, whereas reading showed the highest probability of rest and the greatest number of gaps in these muscles. The left thoracic ES was the only muscle that showed significant differences in the average gap length. Typing showed the lowest average gap length, and reading showed the highest (p = .0454). Neither the lumbar ES muscles nor any abdominal muscle showed significant differences in any muscular activation variable across the four computer tasks.

It was observed that the average percentage flexion during sitting was significantly higher while reading than while typing (p = .0325). No

TABLE 2: Summary of Women's EMG Data (*n* = 7) for the Ball and Chair Sitting Conditions

	Probability at Rest				Average EMG (% MVC)				Total No. of Gaps				Average Gap Length(s)			
Muscle	REA	CAD	TYP/M	TYP	REA	CAD	TYP/M	TYP	REA	CAD	TYP/M	TYP	REA	CAD	TYP/M	TYP
								Ball								
LTES	.15	.17	.20	.18	3.10	2.80	2.40	2.21	209.43	281.86	323.57	285.57	0.32	0.33	0.39	0.42
SD	.26	.24	.23	.16	1.98	1.55	1.60	1.11	369.44	393.36	342.51	256.63	0.26	0.23	0.20	0.21
RTES	.16	.22	.35	.18	3.11	2.78	2.15	2.57	219.43	297.00	301.86	211.71	0.39	0.45	2.75	0.51
SD	.27	.26	.33	.18	1.73	1.96	1.71	1.31	371.23	328.30	282.46	179.34	0.21	0.23	6.06	0.33
LLES	.44	.47	.52	.51	0.70	1.03	0.97	1.27	323.57	330.29	384.86	257.71	1.94	3.90	1.70	2.35
SD	.40	.42	.41	.46	0.42	0.99	1.28	1.61	282.93	424.43	444.90	390.49	3.69	7.79	2.21	3.17
RLES	.36	.28	.30	.30	2.64	2.42	2.65	2.88	160.57	242.71	200.43	230.14	1.82	0.70	2.12	0.62
SD	.45	.39	.36	.39	2.53	1.94	2.31	2.52	206.04	424.26	272.62	319.96	3.46	0.90	4.57	0.80
LRA	.65	.66	.64	.65	0.64	0.64	0.66	0.67	720.14	750.00	736.57	745.43	2.27	3.50	2.31	1.16
SD	.37	.36	.35	.35	0.79	0.81	0.79	0.81	547.21	556.87	551.14	517.93	4.71	7.98	4.85	1.78
RRA	.71	.72	.70	.70	0.66	0.67	0.73	0.73	880.00	865.14	779.71	757.29	0.68	0.67	0.87	0.84
SD	.32	.33	.33	.32	1.06	1.11	1.09	1.15	460.63	431.15	464.69	445.80	0.44	0.37	0.75	0.66
LEO	.55	.60	.60	.58	0.57	0.48	0.50	0.58	647.57	592.29	552.57	509.86	2.89	1.46	3.96	6.92
SD	.30	.36	.34	.36	0.29	0.29	0.33	0.43	499.68	520.40	477.01	508.44	6.37	1.75	7.25	13.24
REO	.41	.42	.41	.43	1.52	1.11	0.82	1.04	503.86	463.00	474.00	524.57	0.63	0.61	0.83	0.89
SD	.36	.37	.33	.34	2.07	1.05	0.35	0.88	463.62	429.38	457.01	448.66	0.48	0.47	0.93	0.95
								Chair								
LTES	.36	.23	.32	.40	1.58	1.79	1.42	1.45	558.86	388.29	481.00	586.00	0.38	0.39	0.51	0.48
SD	.30	.14	.23	.28	1.17	1.42	0.82	0.92	464.11	243.37	320.29	401.81	0.27	0.18	0.12	0.24
RTES	.43	.25	.27	.37	1.71	1.91	1.69	1.64	531.86	376.86	308.57	463.86	0.51	0.43	0.64	0.60
SD	.35	.18	.29	.24	1.86	1.49	1.09	1.14	440.16	284.63	313.90	311.90	0.46	0.20	0.28	0.37
LLES	.54	.62	.59	.52	1.10	1.03	0.89	1.02	393.57	350.43	353.43	344.43	1.42	3.74	3.95	3.76
SD	.42	.44	.38	.41	1.48	1.41	1.35	1.46	339.59	460.13	348.47	375.83	2.10	5.34	5.49	6.63
RLES	.39	.47	.55	.47	1.23	1.26	0.94	1.27	250.14	399.29	283.14	197.71	8.87	2.45	6.72	5.68
SD	.48	.45	.47	.45	1.11	1.49	0.97	1.17	427.92	502.63	394.67	316.72	22.50	5.44	10.94	9.98
LRA	.67	.66	.62	.67	0.64	0.65	0.68	0.69	706.14	714.00	652.71	717.57	2.62	1.34	4.82	1.28
SD	.36	.36	.37	.36	0.84	0.82	0.85	0.95	513.22	495.28	498.75	500.36	5.57	2.20	11.45	2.02
RRA	.71	.72	.68	.71	0.69	0.67	0.70	0.73	771.57	743.43	601.71	694.71	0.96	0.97	1.45	1.45
SD	.32	.33	.38	.33	1.15	1.12	1.16	1.28	471.81	473.49	479.17	528.91	0.95	0.82	1.72	1.69
LEO	.50	.41	.41	.42	0.90	1.06	0.74	0.84	589.71	441.71	427.29	466.86	1.54	2.15	2.71	4.35
SD	.37	.38	.41	.38	1.06	1.22	0.53	0.66	536.52	477.52	530.97	526.10	3.04	4.62	6.12	10.46
REO	.45	.50	.44	.35	0.89	0.68	0.77	1.10	592.00	567.00	377.29	439.14	0.58	0.66	0.88	0.54
SD	.32	.27	.41	.34	0.55	0.30	0.61	0.80	438.27	298.00	351.92	412.14	0.31	0.43	0.92	0.37

Note. Tasks: REA = reading, CAD = computer-aided design, TYP/M = typing/mouse combination work, and TYP = typing. Muscles: LTES, RTES = left and right thoracic erector spinae, LLES, RLES = left and right lumbar erector spinae, LRA, RRA = left and right rectus abdominus, LEO, REO = left and right external oblique.

TABLE 3: Summary of Men's EMG Data (*n* = 7) for the Ball and Chair Sitting Conditions

	Probability at Rest				Average EMG (% MVC)				Total No. of Gaps				Average Gap Length(s)			
Muscle	REA	CAD	TYP/M	TYP	REA	CAD	TYP/M	TYP	REA	CAD	TYP/M	TYP	REA	CAD	TYP/M	TYP
								Ball								
LTES	.44	.41	.26	.22	1.23	1.19	1.84	1.87	501.14	373.43	348.14	328.57	0.65	0.59	0.53	0.54
SD	.31	.39	.31	.28	0.85	0.73	1.28	1.48	296.66	317.94	403.44	405.65	0.24	0.30	0.15	0.25
RTES	.34	.40	.14	.45	1.45	1.45	2.00	0.67	424.57	304.14	206.00	198.86	0.64	0.66	0.56	6.11
SD	.28	.34	.16	.40	0.86	1.08	1.05	0.62	348.14	237.56	271.55	236.48	0.18	0.33	0.13	11.25
LLES	.33	.48	.35	.33	1.02	1.01	0.98	0.85	96.86	259.86	167.29	471.71	3.64	14.95	2.62	0.40
SD	.42	.42	.36	.30	0.95	1.01	0.80	0.46	90.52	311.71	184.16	432.19	4.66	37.32	3.74	0.32
RLES	.45	.60	.31	.67	0.98	0.83	1.27	0.51	228.29	343.43	228.86	349.86	3.40	3.02	1.02	132.33
SD	.43	.41	.33	.38	0.84	0.82	0.66	0.42	302.89	334.00	260.68	355.12	5.19	4.32	1.44	338.60
LRA	.70	.71	.57	.60	0.36	0.57	0.69	0.56	322.43	302.14	329.14	250.14	12.42	66.34	44.91	132.01
SD	.40	.44	.50	.44	0.39	0.64	1.14	0.53	383.76	393.61	438.71	290.15	25.20	169.13	112.29	338.73
RRA	.57	.63	.57	.63	0.42	0.43	0.57	0.67	315.86	362.57	351.00	719.00	19.26	41.14	18.12	0.68
SD	.48	.42	.48	.27	0.39	0.43	0.65	0.51	445.40	438.23	427.71	341.35	29.59	83.73	41.51	0.27
LEO	.67	.77	.48	.65	0.59	0.40	0.66	0.84	730.29	756.29	657.71	607.14	0.87	0.99	0.80	0.84
SD	.26	.20	.36	.25	0.62	0.22	0.61	0.73	325.65	263.02	347.11	421.00	0.51	0.64	0.46	0.36
REO	.65	.74	.63	.59	0.84	0.48	0.72	0.55	607.14	401.71	510.71	498.14	0.84	4.79	3.73	5.23
SD	.25	.27	.27	.37	0.73	0.35	0.60	0.41	421.00	356.40	403.60	430.05	0.36	6.76	7.51	9.90
								Chair								
LTES	.51	.34	.47	.38	1.08	1.39	1.07	1.07	531.29	376.71	400.71	476.00	0.91	0.66	1.28	1.04
SD	.34	.34	.39	.31	1.01	1.03	0.98	0.59	352.41	375.19	344.47	368.41	0.62	0.49	1.40	1.12
RTES	.52	.40	.49	.36	1.15	2.00	1.30	1.56	401.71	255.71	342.14	366.29	1.00	0.84	1.47	0.80
SD	.38	.38	.38	.27	0.96	1.70	1.31	1.08	282.65	299.51	302.33	313.52	0.77	0.83	1.71	0.48
LLES	.49	.45	.52	.40	1.74	2.19	1.34	1.14	114.86	109.14	69.71	100.71	22.24	9.29	38.39	7.98
SD	.48	.46	.49	.43	1.95	2.16	1.72	1.06	209.14	198.01	155.25	117.44	47.46	15.12	65.96	14.20
RLES	.40	.39	.53	.40	2.12	2.23	1.78	2.01	35.29	16.00	142.00	68.71	17.82	36.41	12.11	4.99
SD	.48	.47	.46	.43	1.73	1.91	2.00	2.06	34.40	27.72	306.90	81.19	41.86	83.72	21.79	8.24
LRA	.70	.70	.71	.64	0.37	0.36	0.39	0.43	299.71	269.29	279.71	261.43	18.64	70.04	48.71	70.50
SD	.42	.42	.41	.41	0.43	0.42	0.42	0.43	364.87	357.58	325.84	329.54	30.17	121.00	111.36	167.86
RRA	.68	.68	.66	.63	0.43	0.39	0.48	0.40	350.71	306.71	344.71	401.14	7.81	15.76	3.05	9.50
SD	.42	.42	.40	.41	0.43	0.39	0.38	0.41	410.88	401.44	325.44	372.20	14.11	26.71	4.05	22.06
LEO	.71	.71	.76	.66	0.42	0.34	0.36	0.38	824.86	786.71	749.14	809.86	0.77	1.07	0.98	0.86
SD	.18	.21	.18	.27	0.24	0.21	0.23	0.22	170.95	248.88	209.09	157.64	0.25	0.93	0.46	0.33
REO	.76	.72	.86	.70	0.39	0.48	0.43	0.57	528.00	547.14	548.71	546.43	2.47	1.70	2.97	3.77
SD	.26	.26	.11	.27	0.22	0.24	0.36	0.43	379.79	403.93	446.42	399.10	2.72	1.55	3.79	7.11

Note. Tasks: REA = reading, CAD = computer-aided design, TYP/M = typing/mouse combination work, and TYP = typing. Muscles: LTES, RTES = left and right thoracic erector spinae, LLES, RLES = left and right lumbar erector spinae, LRA, RRA = left and right rectus abdominus, LEO, REO = left and right external oblique.

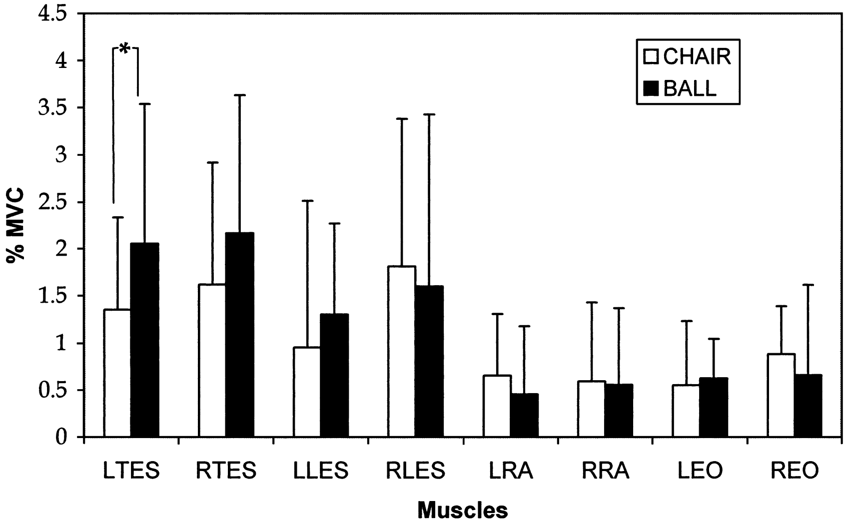

Figure 1. Average muscle activation levels (+1 *SD*) expressed as an average across all 14 participants for all eight muscles for the two sitting conditions (ball and chair). Asterisk (*) indicates statistical significance ($p < .05$). Muscles: LTES, RTES = left and right thoracic erector spinae, LLES, RLES = left and right lumbar erector spinae, LRA, RRA = left and right rectus abdominus, LEO, REO = left and right external oblique.

significant differences were observed in pelvic tilt between tasks ($p = .4358$) or in the percentage of cocontraction between tasks ($p = .3101$).

Gender

Significant differences were observed between genders in average percentage of lumbar flexion ($p = .0106$). Average lumbar flexion for women was 29.1% and 57.3% for men. A trend was observed toward a higher average percentage flexion for women in the chair than on the ball, whereas the average percentage flexion for men was lower in the chair than on the ball. Women tended to exhibit a static sitting posture over a dynamic sitting posture more than did the men ($p = .0479$). Probability at rest was only significantly different between genders in the right EO ($p = .0464$). The right EO probability at rest was 0.4261 for women and .7060 for men. Although percentage cocontraction was not observed to be significantly different between genders, a significant Gender × Sitting Condition interaction was observed ($p = .0139$; Figure 3). In men, trunk cocontraction was higher while in the chair than when on the ball, whereas in women, trunk cocontraction was lower for the chair than for the ball. No significant difference in pelvic tilt between genders was observed ($p = .5468$).

DISCUSSION

Individuals appear to sit on a stability ball similar to the way they sit in an office chair. With the exception of higher average EMG activation in the left thoracic ES on the stability ball, no significant muscular differences between the two sitting conditions were observed. The assessment of prolonged sitting on a stability ball and in an office chair revealed that the only postural difference observed between sitting conditions was the degree of pelvic tilt, which was significantly greater in the posterior direction while sitting in an office chair as compared with on a stability ball. However, it is interesting that a significant difference in pelvic tilt was observed but that no significant difference in lumbar flexion between sitting conditions was observed. This means that individuals, on average, maintained a similar lumbar posture in both sitting conditions but rotated their pelvis posteriorly in the chair. A plausible explanation is that the greater anterior pelvic tilt observed in individuals on the ball was compensated by increased extension of the thoracic spine or, conversely, by thoracic flexion when seated on the chair. Therefore, individuals could maintain a similar degree of lumbar flexion while increasing the anterior tilt of the pelvis on the ball, compared with the office chair. Because muscular activity of the back extensors

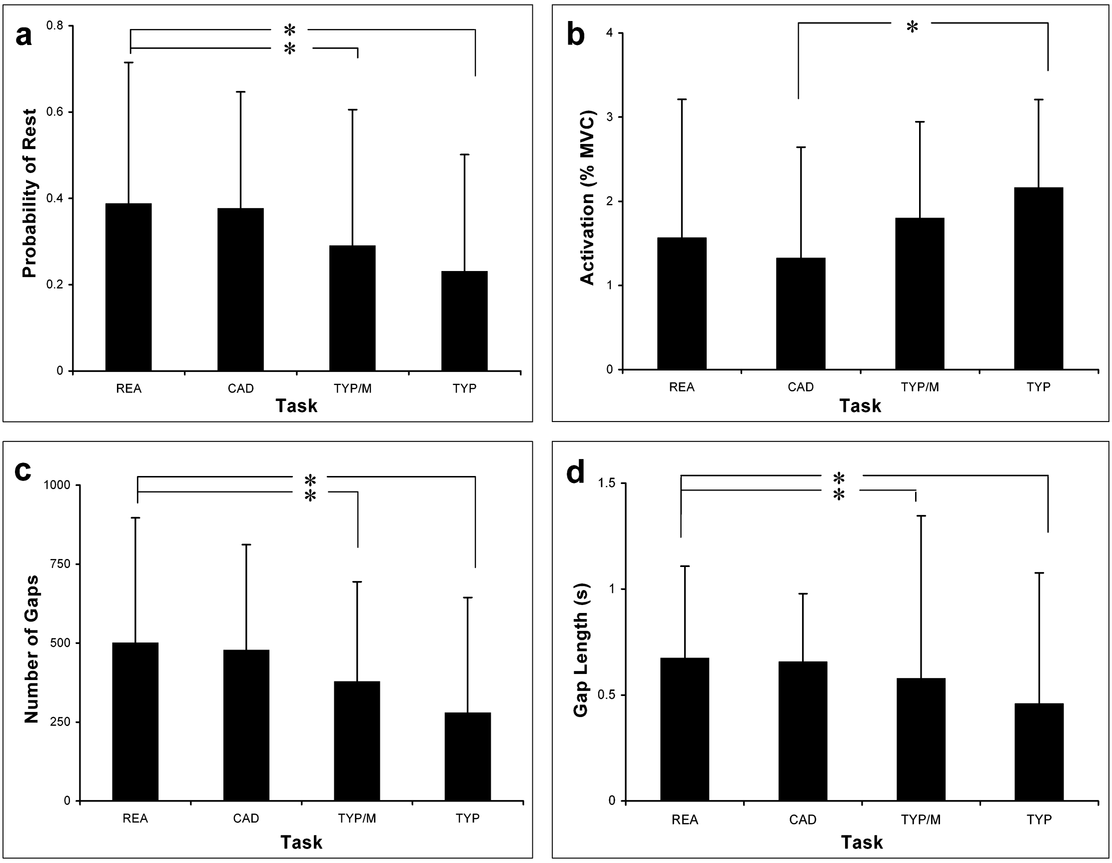

Figure 2. Averages (+1 *SD*) across all 14 participants for thoracic erector spinae showing the effect of task (REA = reading, CAD = computer aided design, TYP/M = typing/mouse combination work, TYP = typing) on (a) the probability of a resting level of muscle activation, (b) average muscle activation, (c) number of gaps observed, and (d) average gap length. Asterisks (*) indicate significance.

was not significantly different between the sitting conditions, it is likely that the differences observed in pelvic tilt were not attributable to a change in overall trunk flexion, as increased back extensor activity would be required for a greater degree of trunk flexion. Additionally, increased hip flexion while on the ball may result in an imbalance of the hip flexor and extensor muscles (lengthening of the hip extensors, shortening of the hip flexors), which may influence sitting and discomfort.

Another possible source of the increased discomfort observed in individuals on the ball versus the chair is pressure distribution between the user and the seating surface. Research examining the user-seat interface found an increased and more uniform contact area between the user and seating surface while sitting on a stability ball as compared with an office chair and a wooden stool, which resulted in increased levels of discomfort (Gregory, Kavcic, Dunk, McGill, & Callaghan, 2004). Although this seems counterintuitive, it is thought that the uniform pressure distribution resulted in a transfer of a portion of the high peak stresses under the ischial tuberosities, which have a higher pressure threshold, to the soft tissue of the gluteal region. Seats that have been described as "comfortable" had a mean pressure level of 2.9 kPa under these soft tissues, half the comfortable mean pressure under the ischial tuberosities of 5.8 kPa (Kamijo, Tsujimara, Obara, & Katsumata, 1982), demonstrating that discomfort can be linked to distributed pressures of lower magnitudes.

It has been shown that increased cocontraction of the trunk muscles increases spine stability (Pope & Panjabi, 1985) and, in turn, may also help prevent LBP (Cholewicki, Panjabi, & Khachatryan,

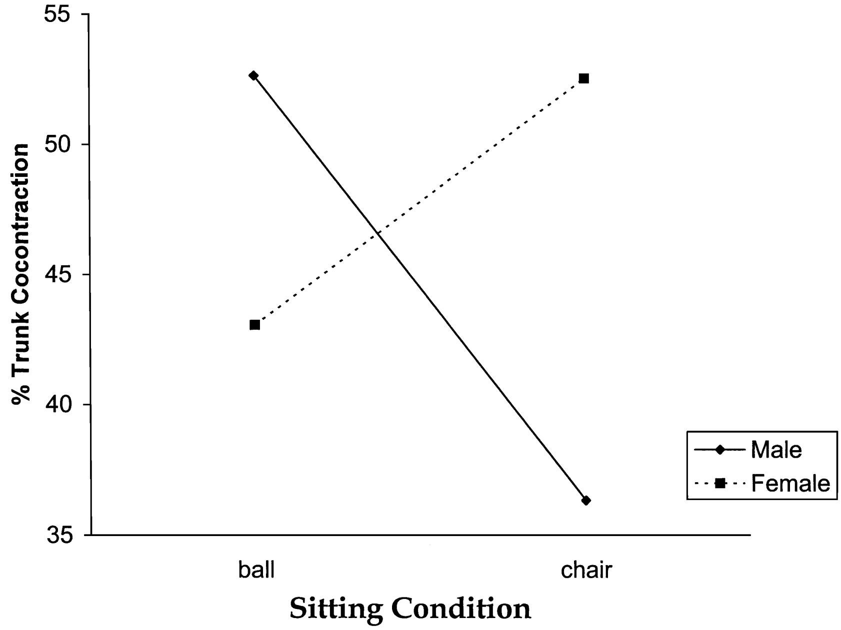

Figure 3. The observed Gender × Sitting Condition interaction (ball vs. chair), in which men ($n = 7$) showed higher trunk cocontraction on the ball than in the chair, whereas women ($n = 7$) showed the opposite trend ($p = .0139$).

1998; Gardner-Morse & Stokes, 1998). No significant differences were seen in trunk cocontraction, suggesting that increased spine stabilization and control was not needed or stimulated while sitting on the ball, despite its unstable nature. Interestingly, men tended to show the expected increase in cocontraction on the ball versus on the chair, whereas women showed the opposite. This coincides with the Gender × Sitting Condition interaction trend noted in average percentage flexion. The increased percentage flexion of men on the ball as compared with in the chair (opposite trend in women) may have induced a flexion relaxation response. The average lumbar flexion values of approximately 43% are in agreement with the flexion angles that resulted in seated flexion relaxation reported by Callaghan and Dunk (2002). Flexion relaxation would have resulted in decreased back extensor activity, which, based on the equation for calculating cocontraction, would result in increased trunk muscle cocontraction if abdominal levels remained unchanged.

Although this study sheds light on the biomechanical differences between prolonged sitting in an office chair and on a stability ball, it possesses several limitations. A 1-hr sitting period for each sitting condition (total 2 hr) was chosen to mimic a reasonable length of time an individual would remain seated without standing. Therefore, this study can comment on only short-term differences between the two sitting conditions. Long-term usage may reveal adaptation (postural or muscular) while on the ball as compared with in the chair, which was not tested in this study. The type of office chair that was used in the study was also chosen to mimic an office environment. Individuals generally choose a back-supported chair, and therefore we believed that a back-supported chair would better represent a workplace scenario. Given the absence of a back support on the ball, it is possible that spine stability was altered by the presence of a backrest on the chair and not by the unstable nature of the ball. However, it would have been beneficial to measure contact between the participant and the backrest to determine if the backrest was used on a regular basis.

An additional limitation of this study was failing to measure muscles that may also play a role in stabilizing the lumbar spine, such as the multifidus and transverse abdominus. Biomechanical differences between the two sitting conditions may be observed in deep muscles (e.g., psoas); however, such muscles tend to be associated with recording errors attributable to crosstalk from adjacent muscles when using surface EMG (McGill, Juker, & Kropf, 1996; Stokes, Henry, & Single, 2003) and are therefore more difficult to accurately measure. Biomechanical differences may have also been observed in muscles inferior to the trunk (leg muscles) between the sitting conditions; however, these muscles were also not measured in the current study.

It is also important to note that the participants in this study were from a healthy population who had not experienced LBP in the previous 12 months. Had an LBP population been used, differences in trunk muscle activity and lumbar postures may have been observed. Additionally, knowledge of trunk flexion may have provided insight into the reason pelvic tilt was different but lumbar flexion remained the same, and it therefore would have been beneficial to measure. Finally, the preferred hand of the participants (i.e., the hand used for writing and mouse work) was not documented and could have altered the results. This failure to screen for hand preference may be the reason a difference in muscle activation in the left thoracic ES was observed between the sitting conditions, whereas no other muscular differences were observed. The dominant hand for the majority of the population is the right hand, which could potentially alter EMG activation on one particular side of the body – in this case, the left side of the thoracic ES. A similar effect was observed in work conducted by van Dieen, de Looze, and Hermans (2001).

Previous studies on prolonged sitting (chair with backrest) have shown that the ES muscles are activated, on average, less than 2% MVC (Beach, Mooney, & Callaghan, 2003; van Dieen et al., 2001), which mimicked activation levels while sitting on the chair in the current study. Callaghan and Dunk (2002) and Arokoski, Valta, Kanaanpaa, and Airaksinen (2002) examined unsupported (no backrest) short-duration sitting and documented higher muscle activation levels in both the thoracic and lumbar ES muscles. The ball (not possessing a back support) was expected to mimic conditions in previous studies that used an unsupported chair, yet no significant differences in muscle activation were observed between the ball and the chair, and therefore higher muscle activation attributable to the absence of a backrest was not observed. Arokoski et al. (2002) also measured abdominal muscle activation levels and documented levels between 1.2% and 5.3% MVC in the rectus abdominis and between 3.0% and 5.6% MVC in the external oblique muscles. The current study revealed substantially lower abdominal muscle activation levels than those of Arokoski et al. (2002). However, the higher abdominal EMG levels observed in Arokoski et al. (2002) may have arisen because the unsupported sitting condition was used as exercise in a rehabilitation program. Beach et al. (2003) observed that individuals sit, on average, at 60% of their maximum lumbar flexion during back-supported sitting, whereas Callaghan and McGill (2001) observed individuals to sit between 30% and 80% flexion during unsupported sitting. Average flexion was 43.0% on the stability ball and 43.4% on the chair, which correspond with previous findings.

Significant differences in muscle activity and lumbar spine posture were observed according to the type of computer workstation task performed. Similar to the current study, van Dieen et al. (2001) examined the effects of computer workstation tasks on back extensor muscle activation and trunk posture. They observed that the probability of rest was affected by the task performed ($p < .001$; tasks were reading, computer-aided design, and word processing), with reading having the largest time spent at resting muscle activation levels. It was also observed that the amount of trunk posture movement while sitting was the greatest while reading (van Dieen et al., 2001). Similar to van Dieen et al. (2001), the current study showed reading had the lowest average EMG activity, the longest and most frequent number of gaps, and the highest probability of rest in the thoracic ES.

It is interesting to note that reading also showed the highest average flexion posture, which may have induced flexion relaxation, supporting the previously stated findings regarding muscular responses. Callaghan and Dunk (2002) observed an average decrease of approximately 3% MVC in the thoracic erector spinae muscles from upright sitting to a slumped position and approximately 1% to 2% MVC in the lumbar erector spinae muscles. It is hypothesized that when an individual is in such a flexed position, the passive tissues contribute to maintaining the posture, rather than the thoracic ES (Floyd & Silver, 1955). These passive tissues are richly innervated with pain sensors (Rhalmi, Yahia, Newman, & Isler, 1993) and are therefore a potential source of LBP (Callaghan &

Dunk, 2002). However, even though reading resulted in the highest degree of flexion and lowest muscle activation in the thoracic ES muscles, the other three tasks showed different responses, and therefore the implementation of job rotation would appear to provide sufficient postural changes and muscular responses.

CONCLUSION

There does not appear to be any advantage to using a stability ball as an office chair. No postural or muscular activation differences were observed between the ball and the chair, with the exception of reduced pelvic tilt while sitting on the ball. However, the increased reported discomfort and potential safety issues associated with sitting on an unstable surface question the use of a stability ball as an office chair.

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