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To investigate low back posture and trunk muscle activation while exercising on an unstable chair (Flexchair®) in a healthy population.

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AUTHORS DECLARATION

Please include the following statement (signed) on a separate page after the title page with your manuscript.

I, the undersigned, declare that this project, which I am submitting, is all my own work and that the data presented is authentic.

__________________________ (Printed Name)

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Date / /

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Abstract

Background: Low back pain (LBP) is one of the most common and costly musculoskeletal pain syndromes of modern society (Dankaerts *et al* 2009). The Flexchair® is a novel dynamic sitting device that is equipped with a sensor measuring movement of the chair. It has been hypothesised that it may be helpful in providing feedback and eliciting the contraction/relaxation phenomenon. This may be achieved while performing trunk muscle exercises on it which may aid in improving trunk stability.

Objectives: To assess if there is a difference in trunk muscle activation between different exercises and conclude if the Flexchair® could possible provide adequate feedback and production of a contraction/relaxation phenomenon.

Methods: 10 healthy subjects (6M, 4F mean age 23± 3 years) performed 6 specific exercises on a Flexchair®. Data was recorded using EMG and SPMD software. Analysis was performed using a repeated-measures analysis of variance (ANOVA) with post-hoc least significant difference (LSD) applied (Ekstrom, Donatelli and Soderberg 2003).

Results: The activation of IO (p= 0.037) and LM (p=0.036) were significantly greater in exercise 6 (21% of MVIC) and exercise 5 (19% of MVIC). The contraction/relaxation of TES (p=0.030), ICLT (p=0.080) and LM (p=0.019.) were significantly greater in exercise 2 (9% of MVIC) and in exercise 6 for both ICLT (12% of MVIC) and LM (13% of MVIC).

Conclusions: The findings in this study may be useful in selecting specific exercises to enhance a motor control/endurance training programme for individuals who may be appropriate for biofeedback and encouragement of contraction/relaxation of their back muscles.

Keywords: Low Back Pain, Flexchair®., EMG, Feedback, Contraction/Relaxation phenomenon, Posture.

1.0 Introduction

Low Back Pain (LBP) is one of the most common and costly musculoskeletal problems in today's physiotherapy outpatient clinics with up to 80% of the population having it at some stage in their lives (Dankaerts et al 2009). Many reasons have been given for the cause of LBP, with prolonged sitting being thought to be an aggravating factor (Callaghan and Dunk 2002). For instance, the position of a person whilst sitting, highly influences patterns of trunk muscle activity. O'Sullivan et al (2006) reported that 'lumbo-pelvic" upright sitting posture resulted in tonic activity in the transverse portion of the Internal Oblique, superficial Lumbar Multifidus, and in some cases, activation of the Thoracic Erector Spinae. This highlights the variability of trunk muscle activation and the dependence it has on the sitting posture adopted.

Posture, however, is only one area to consider. Often posture depends on the performance of voluntary trunk movements and in addition, the maintenance of trunk stability. Trunk stability is thought to play an important role in the prevention and rehabilitation of lumbar spine injury (Comerford et al 2001, Nuzzo et al 2008). Trunk muscles are classified as global or local muscles based on their functional anatomy (Hubley-Kosey 2002). The global muscles, such as the Rectus Abdominus (RA) and the External Oblique's (EO), produce torque, and transfer the load directly between the thoracic cage and the pelvis (Stevens *et al* 2007). The local muscles, such as the Transverse Abdominus (TrA) and the Lumbar Multifidus (LM), have more direct or indirect attachments to the lumbar vertebrae. They therefore play a role in segmental stability of the lumbar spine when performing gross-body movements and postural adjustments (Behm et al 2002, Cholewicki et al 1997). From this, we can assume that the function of local muscles is necessary to provide segmental spinal stability (Lima et al 2003).

Trunk stability is seen as the coactivation of global and local muscles, therefore training that deals specifically with these muscles is needed to achieve coactivation (Granata and Wilson 2001). It has now become a popular training method to exercise these muscles for coactivation through the use of lumbar/core stabilisation exercises (Zazulak et al 2008). The main aims of lumbar stabilisation exercises are to improve neuromuscular control and endurance of muscles that are central to maintaining dynamic stability of both the spine and trunk (Hodges et al 2009). Many approaches have been used to achieve this. One approach that has come into focus recently is the use of training spinal stability on an unstable surface (Reeves et al 2005, Anderson et al 2005, Gill et al 2001). It has been proposed that the advantage of using this method of training is that it may have the potential to increase muscle recruitment that would help in maintaining spinal stability (Lehman et al 2005).

The literature to date, however, has mainly focused around the area of static sitting or the use of unstable sitting devices such as gym balls. Only recently has dynamic sitting been studied using different devices such as a stability ball (Gregory et al 2006, McGIll et al 2006), saddle chair (Gadge & Innes 2007) and Sitfit® (O' Sullivan et al 2006). The authors propose that they allow adjustments and stimulate a more dynamic way of sitting. It has been hypothesised that the unstable surface creates activation of spinal stabilising muscles around a neutral spine position by the degree of fine movements it produces (Farell et al 2000).

There has been limited research to date regarding the use of biofeedback while sitting on an unstable surface (Magnusson et al 2008). It has been noted that patients who present with poor sitting lack stability around their core area (O' Sullivan et al 2003). This has been associated with a lack of proprioceptive control in LBP populations (Gill & Callaghan 1998, Koumantakis et al 2002, O'Sullivan et al 2003). O'Sullivan et al (2003) highlighted that LBP patients have a decreased repositioning sense compared to no-LBP populations. Therefore, one can assume that patients' of this type would benefit from biofeedback. Biofeedback provides patients that have sensorimotor impairments with a tool to regain the ability to better assess different physiologic responses and to relearn control of these responses (Magnusson et al 2008). However, the literature thus far has mainly focused on proprioceptive activities in the stroke and paediatric populations (Dursan et al 1996, Bolek 2006). Research has only begun to focus on cervical spine activities (Kristjansson and Oddsdottir 2010). Evidence is now emerging to support the use of postural biofeedback with promising results (Donatell et al 2005, Magnusson et al 2008).

Since biofeedback has become an important aspect of treating LBP patients, a focus has also turned to the importance of the contraction/relaxation phenomenon and its proposed absence in the LBP population (Shirado et al 1995). The contraction/relaxation phenomenon refers to a sudden onset of myoelectric silence in the Erector Spinae (ES) muscles of the back during standing to full forward flexion (Callaghan and Dunk 2002). However few studies have focused on this in sitting (Anderson et al 1996). Recently O'Sullivan et al (2006) researched sitting posture in greater detail and found that the contraction/relaxation phenomenon differs from standing. Their findings suggest that sustaining mid to end-range flexed sitting postures result in relaxation of spinal stabilising muscles. Therefore it may be beneficial to have a device that could promote the occurrence of relaxation in these muscles. This device could then be transferred to a patient population. It has been proposed that dynamic sitting could possibly achieve this, however, there has still been no general consensus regarding the specific requirements of an ideal dynamic chair (Gadge & Innes 2007, McGIll et al 2006). In addition, there continues to be a lack of evidence surrounding dynamic sitting in general.

The Flexchair® (Flexchair® movement, BA Nootdrop, the Netherlands) is a novel dynamic sitting device that is equipped with a sensor measuring movement of the chair. The manufacturers state that it allows full range of motion of the lumbo-pelvic region and gives feedback about the lumbar spine posture during sitting. This is achieved by use of an accelerometer that registers the movement of the chair on a screen. If the movement of the chair could match the movement of the lumbo-pelvic region, it would allow users indirect feedback as to the position of their spine. As a result, one could hypothesise that it could give a feedback system to correct maladaptive sitting posture. However, it seems at present that no current studies have looked at this in a healthy population nor looked at the degree of muscle activation these positions achieve, or whether it can aid in producing the contraction/relaxation phenomenon. This device could be used as a feedback system to allow EMG activity to be monitored while performing exercises on it. Therefore the purpose of this study was to investigate trunk muscle activation while performing exercises on the Flexchair®. The first aim of this study was to assess if there is a difference in trunk muscle activation between different exercises. The second aim of the study was to assess to what degree the muscles are activated by particular exercises. The third aim was to assess if the Flexchair® can provide adequate biofeedback and produce a contraction/relaxation phenomenon. The final aim is to query which exercises may be more appropriate for targeting specific stabilising muscles and whether the device may be appropriate for use in promoting motor control and endurance in a clinical setting.

2.0 Methods

2.1Participants

Ten participants in total (6 males, 4 females) were recruited within the university campus. These participants had a mean (±SD) age of 23 (±3) years, height of 174 (±9) cm, mass of 70.4 (±11.57) kg and body mass index of 23.3 (±4) kg/m^2. Ethical approval from the local university research ethics committee was obtained prior to the study. All participants provided written informed consent prior to participation.

2.2 Inclusion and Exclusion criteria

Participants were excluded if they were pregnant, aged less than 18 years (Dolan and Green 2006), had current LBP (O' Sullivan et al. 2003), had previous LBP for greater than 3 months (Newcomer et al. 2001), were currently on pain medication for LBP, had previous back surgery, or had a known skin allergic reaction to tape.

2.3 Instrumentation

2.3.1 Spinal Posture Monitor Device (SPMD)

All posture measurements were performed with the SPMD (http://www.sels-instruments.be/) software. The SPMD uses a strain gauge which provides information about the relative distance between anatomical landmarks. It also estimates the amount of flexion/extension by the degree of strain on the gauge itself. Postural data was recorded in real-time at 20Hz. The percentage range of motion (ROM) is based on the elongation of the strain gauge and the lower lumbar spine saggital plane posture. Therefore, the degree of spinal flexion/extension is expressed relative to a referenced ROM, for instance total lumbar flexion ROM, rather than being expressed in degrees. This reflects the clinical assessment of patients where sitting posture is often considered relative to individual ROM. Electromyography normalisation of muscle activity relative to maximal or sub-maximal voluntary contraction is also similar to the above procedure (Dankaerts et al 2006). SPMD has been shown to be a reliable measure of sitting posture in spinal analysis with intraclass correlation coefficients for inter-rater and intra-rater reproducibility ranging from 0.837 to 0.940 (O'Sullivan et al. 2010)

2.3.2 Electromyogram (EMG)

A motion Lab Systems, (USA, Inc Baton Rouge, Louisiana) was used to collect EMG data using an electrode contact surface area of $1cm^2$ which was placed unilaterally 2.5 cm apart on the muscles (Ng et al. 1998). Surface EMG (sEMG) signals were recorded at a sampling frequency of 1000 Hz. The EMG system bandwidth was 10 – 500 Hz, and the common mode rejection ratio was more than 115 dB at 60 Hz. All raw myoelectric signals were amplified with a gain of 2000.

2.3.3 Flexchair®

The Flexchair® is a dynamic sitting device with a three-dimensional cant mechanism. The seat itself is shaped as a saddle, which helps to promote neutral spine sitting and lumbar movement while also maximising lumbar spine movement. The chair is attached to a wooden plate and consists of two hinges. The device can fully rotate and can move in all directions.

Flexchair®

Accelerometer

The set up normally consists of a three dimensional accelerometer (sensor) which is placed under the seat. The wireless sensor registers the movement of the chair. The movement is then displayed on a screen (Figure 1). This allows the seated person to receive direct feedback (Groenen and Flamaing 2008)

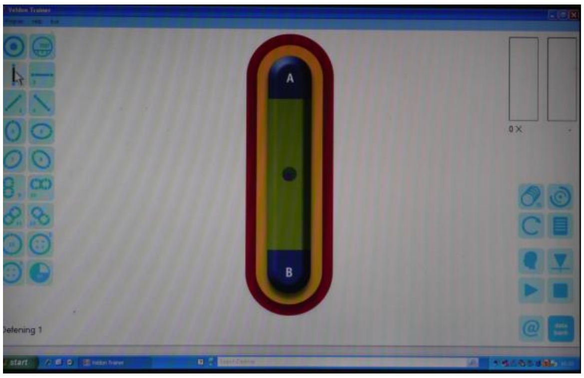


Figure 1. Visual feedback given by Flexchair®

2.3.4 Flexchair® Veldon® Software

This is a software package which accompanies the Flexchair® and allows the subject to get a visual display on how well they performed the exercises. This data was saved after each exercise for each subject.

2.4 Study Design

All participants were tested on a single test design.

2.5 Experimental Protocol

2.6 Participant preparation

2.6.1 Participant preparation EMG

The skin was prepared for electrode placement by abrading it with fine sandpaper, shaving any hair and cleansing it with isopropyl alcohol solution to reduce skin impedance. This preparation process is suggested by the literature before EMG measurement (Herman et al 2000, Seniam). Placement of electrodes followed a previous study by Dankaerts et al (2006). Electrode placement was as follows:

- RA, 1cm above the umbillicus and 2cm lateral to midline.
- EO, Just below ribcage and along a line connecting the most inferior point of the costal margin and the contralateral pubic tubercle.

- Transverse fibers of internal oblique (TrIO), 1cm medial to the ASIS (Anterior Superior Iliac Spine) and beneath a line joining both ASISs.

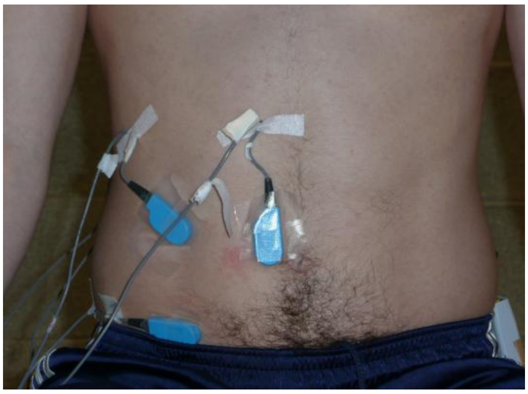
- Superficial fibres of LM (SLM), at L5 and aligned parallel to the line between PSIS (Posterior Superior Iliac Spine) and the L1-L2 interspinous space.

- Illicostalis lumborum par thoracis (ICLT), above and below the level of L1 spinous process midway between the midline and lateral aspect of the body. Thoracic Erector Spinae (TES), 5cm lateral to T9 spinous process (Figure 2) (Dankaerts et al 2006).

- A common earth electrode was placed over the Ulnar Styloid (Herman et al 2000, Seniam). Electrodes were taped securely to avoid excessive movement of the leads.

Both the abdominal and back muscles were normalised to maximal voluntary isometric contraction (MVIC) (refers to peak force produced by a muscle while contracting in a sustained position). To generate MVIC, 4 standardised tests were used (Dankaerts et al 2006). During Abdominal test 1, the subject was positioned supine with their legs straight and strapped down with a belt. A resisted curl-up with maximal manual isometric resistance was applied in a symmetrical manner through the shoulders of the subject by the investigator, at the head of the plinth. During Abdominal Test 2, a resisted crossed curl-up, with the right shoulder moving toward the left and maximal manual isometric resistance was applied through the right shoulder, by the investigator (standing at the left side). During Abdominal Test 3, the same procedure was repeated on the opposite side. In regards to the Extensor Test, the subject was positioned prone, legs straight, and strapped with a belt. The subject put their hands on their neck and were asked to lift the head, shoulders and elbows just off the plinth. Symmetrical maximal manual resistance was provided to the scapular region by the investigator (standing at the head of the subject) (Farfan 1973, O'Sullivan et al 2006). The highest contraction generated on any of the 3 abdominal and extensor tests was used as MVIC. Each trial lasted a total of 5 seconds in duration (Fitts and Posner 1995) with a 3-minute rest period given between trials performed to avoid the cumulative effect of fatigue. The mean MVIC value from the 3 trials was used as the measurement for each subject. These procedures have shown high levels of reliability (Dankaerts et al 2006). The middle 3 seconds of amplitude normalised

EMG data, from the 5-second testing period, was analysed. EMG data from the right side of the body was analysed for all participants.



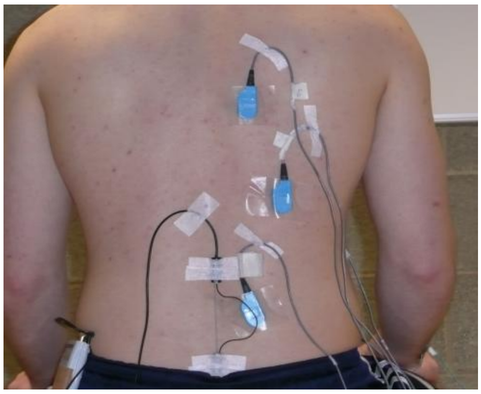


Figure 2.
Abdominal Electrode placement *Back Electrode placement*

2.6.2 Participant preparation SPMD

Participants removed their shoes and wore shorts during testing which prevented cutaneous sensory input (Lam et al 1999). The skin was cleaned with alcohol wipes prior to testing. The SPMD was positioned directly over the spine at the spinal levels of L3 and S1, as determined by palpation. The locations of these landmarks were marked with a non-permanent skin marker (Mannion and Troke 1999). These spinal levels were chosen, as the lower lumbar spine is the most common area for subjects to report LBP (Dankaerts et al 2006). In addition, recent research suggests that the upper and lower lumbar spine regions demonstrate functional independence (Dankaerts et al 2006, Mitchell et al 2008). The SPMD was applied with participants sitting in a slouched position. Application of the strain gauge in this position minimised displacement resulting from skin traction in the fully flexed position (Swinkels and Dolan 2000). Based on preliminary pilot testing, a 6cm strain gauge was used for all participants, and was secured with tape (Figure 3). Once the SPMD was positioned, participants stood up and performed repeated maximal flexion movements in standing. This ensured that the device was securely attached, and that its available length would not be exceeded during testing. Further, the SPMD was calibrated to full lumbar flexion ROM during sitting flexion. To do this, each subject was asked to slouch their lumbar spine as much as possible (when sitting on a standard stool) and were given the command to “sit up as tall as you can from you lower spine” which was set as 0% of their lumbar flexion ROM. They were then required to perform full flexion of the spine *(“slouch your lower spine as much as possible without moving your head or upper body ”).* This flexed position was set as 100% of their lumbar flexion ROM. Once this calibration procedure was completed, participants were asked to complete 3 repetitions of maximum ROM into full lumbar flexion in sitting to ensure that comfort and consistency of movement was possible while wearing the SPMD. Participants then reassumed a seated position and were instructed regarding the tasks to be performed.

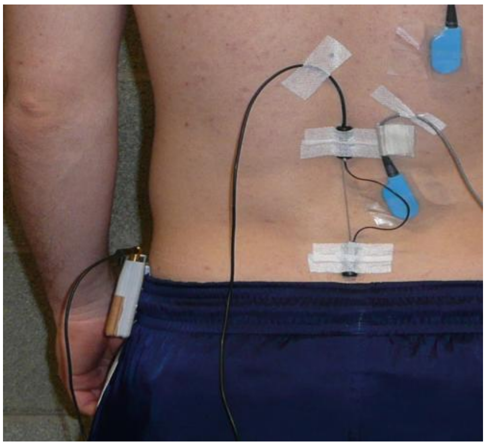


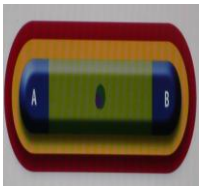
Figure 3.
SPMD placement

2.7 Testing Procedure

Participants were assessed after attachment of EMG and SPMD to record baseline measures. Measures were taken for usual sitting, where the subject was instructed to ”sit as you normally do” on a standard stool and this was recorded for 1 minute using the SPMD software. The middle 15 seconds was recorded using the EMG software. Measurements were also taken for “usual standing” and side lying using the above procedure for recording (Hubley-Kozey & Vezina 2002). During side lying, all subjects flexed their hips and knees to 90^0 to ensure reliability. Subjects then sat on the Flexchair® where the height was adjusted to ensure that the angle between the upper and lower legs of the patient was 120°. The angle was measured using a goniometer. The lower legs of the patient were kept vertical (line through Femoral lateral Epicondyle and lateral Malleolus). The order in which the subjects performed the exercises was randomised as subjects picked from unmarked envelopes. A total of six exercises were performed (Figure 4). Each exercise was performed for 1 minute with a 2-minute break between each exercise. The SPMD was set to record continuously for the duration of the exercise. The EMG was set to record the middle 15 seconds of the exercise, to ensure reliability and consistency between testing.

Figure 4. *Example of the 6 exercises performed*

(1)



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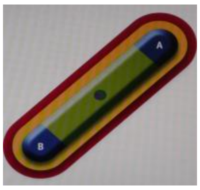

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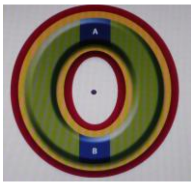

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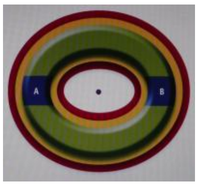

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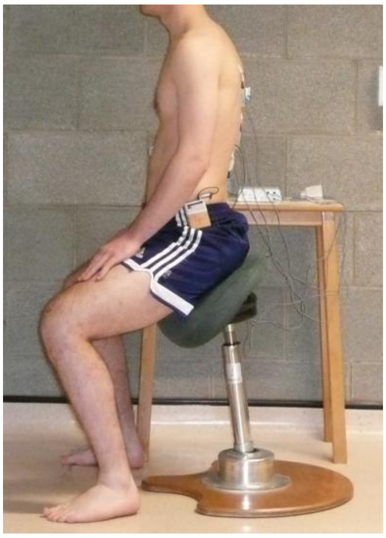
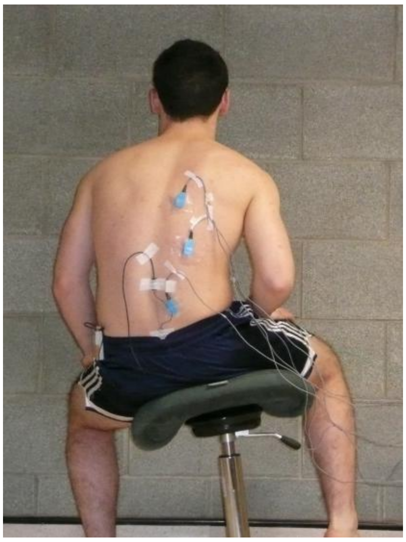




Example of a subject performing Exercise 1 & 2

2.8. Exercise performance

Each participant performed each exercise to an accuracy of over 90% (Mean and SD, 92.73, ±2.7).

2.9 Qualitative Questions

Prior to finishing, each participant was asked to fill out a questionnaire. This consisted of a total of five questions pertaining to the Flexchairs® comfort, ease of use, usefulness as a tool, enjoyment using the product and other comments.

2.10 Data analysis

Data was uploaded for SPMD automatically via wireless communication to a Microsoft Excel file. EMG data was saved and converted to RMS data for analysis. Flexchair® Veldon software was also saved and data was then analysed using SPSS 18.0. Analysis of EMG was performed for both the "ON" (period in which the muscle was activated) and the "Difference" (period in which the muscle was contracting/relaxing).

A repeated-measures analysis of variance (ANOVA) was applied when analysing the data, to determine if there were significant differences in EMG activity for specific muscles during the exercises. A separate ANOVA was performed for each of the 6 muscles, with the independent variable being exercises with 6 levels of comparison. A least significant difference (LSD) pair wise multiple comparison analysis was performed to determine the significance of the differences among pairs of means. An alpha level of 0.05 was applied to all the data in determining significant differences (Ekstrom, Donatelli and Soderberg 2003).

3.0 Results

3.1 Baseline Measures

Baseline Measures are shown for both EMG and SPMD recordings in the appendices (Table Ia and Figure Ib).

3.2 SPMD Data

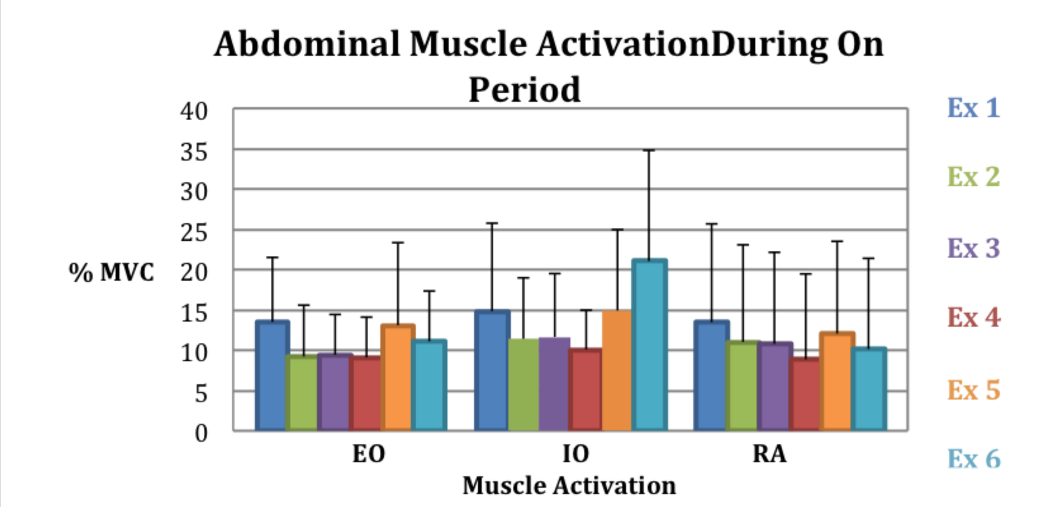
All data was recorded and average ranges for each exercise are displayed in the appendices (Figure IIa).

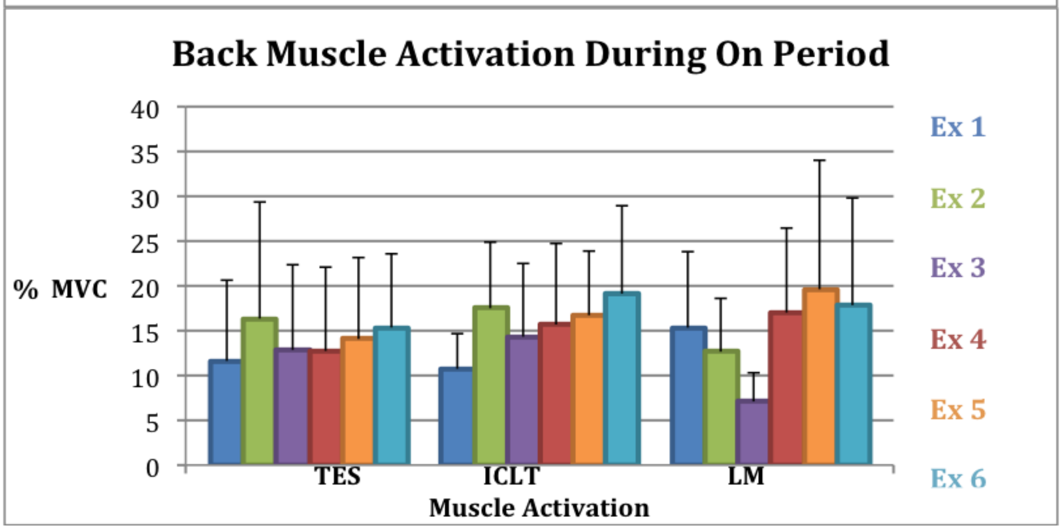
3.3 EMG Exercise Data

The EMG activity of each muscle during each exercise, as well as the significant differences between exercises, is displayed in Table 1 and Graphs 1 and 2. An example of a raw EMG recording is also displayed in the appendices (Figure IIIa), along with a further graph which illustrates the significant differences between muscles visually (Figure IVa and IVb). The activation of IO ($F=2.620$, $p=0.037$, $\eta p^2=0.225$) and LM ($F=3.403$, $p=0.036$, $\eta p^2=0.298$) were significantly greater in exercise 6 (21% of MVIC) and exercise 5 (19% of MVIC). The contraction/relaxation (difference) of TES ($F=2.779$, $p=0.030$, $\eta p^2=0.258$), ICLT ($F=3.619$, $p=0.080$, $\eta p^2=0.287$) and LM ($F=3.092$, $p=0.019$, $\eta p^2=0.279$) were significantly greater in exercise 2 (9% of MVIC) and in exercise 6 for both ICLT (12% of MVIC) and LM (13% of MVIC). Please refer to table and graphs for further significant results.

3.4 Qualitative Questions

Overall subjects found the Flexchair® comfortable with two subjects complaining that the seat was too hard. The majority of subjects found the feedback from the Flexchair® very useful, with three subjects complaining that exercise 5/6 were difficult to perform. All subjects reported that it was an enjoyable experience performing the exercises on the Flexchair®. For further detail please refer to appendices (Figure. Va)





Graphs 1 and 2 *Mean and Standard Deviations of muscle activity for each abdominal and back muscle during the "On" (period in which the muscle is contracting) activation period during each exercise. Abbreviations: EO, external oblique; IO, Internal Oblique; RA, Rectus Abdominus; TES, Thoracic Erector Spinae; ICLT, Intercostalis Lumborum Thoracic; LM, Lumbar Multifidus; MVC, Maximum voluntary contraction.*

	Ex1	Ex2	Ex3
Muscles	%MVC (SD±)	%MVC (SD±)	%MVC (SD±)
EO	9.13(7.88)	5.36(4.41)	4.03(4.677)
IO	14.85♍(10.91)	11.42(7.56)	11.65(7.85)
RA	13.48(12.19)	11.02(12.05)	10.79(11.36)
TES	2.35♌(2.72)	8.97(7.57)	4.89♌(4.28)
ICLT	3.48⊜♋♌♍(2.65)	10.18(4.19)	6.26⊜♍(4.38)
LM	8.32(5.06)	7.15♍(4.61)	2.19⊖⊜♋♌♍ (1.92)

	Ex4	Ex5	Ex6
Muscles	%MVC (SD±)	%MVC (SD±)	%MVC (SD±)
EO	5.26(3.93)	4.83(4.07)	5.58(4.48)
IO	10.09♍(4.89)	14.93♍(10.04)	21.06(13.73)
RA	8.87(10.59)	12.06(11.44)	10.15(11.24)
TES	6.92(6.98)	8.96(7.09)	6.61(6.69)
ICLT	10.22(8.14)	7.93(5.48)	11.63(8.80)
LM	12.45(9.00)	12.40(13.40)	12.68(8.82)

Table 1 *Mean and Standard Deviations of muscle activity for each abdominal and back muscle during the contraction/relaxation period of each exercise. Abbreviations: EO, external oblique; IO, Internal Oblique; RA, Rectus Abdominus; TES, Thoracic Erector Spinae; ICLT, Intercostalis Lumborum Thoracic; LM, Lumbar Multifidus; MVC, Maximum voluntary contraction; Ex, Exercise.*

All values outlined with a symbol above are statistically significant it was decided to focus on exercises which produced the higher value as it was felt that it may show more significance than focusing on lower values.

Legend

⊖ *Exercise 1 is higher* ⊜ *Exercise 2 is higher*

⊛ *Exercise 3 is higher* ♋ *Exercise 4 is higher*

♌ *Exercise 5 is higher* ♍ Exercise 6 is higher

4.0 Discussion

The Core muscles are essential for normal movement of the trunk (Cholewicki, Panjabi and Khachatryan 1997). The ability to activate these muscles in the appropriate manner is a particular issue for the LBP population (O'Sullivan et al 1997). This discussion will focus on specific key areas notably: exercising on the Flexchair®; Dynamic sitting vs. "Normal sitting"; Contraction/Relaxation phenomenon; feedback given by the Flexchair®; limitations to the study and finally, the conclusion. The discussion may assist physiotherapists to decide the areas of practice in which the Flexchair® may be a useful tool.

Exercising on the Flexchair®

A large number of articles focus on lumbar stabilisation exercises. Many of these promote the use of stability balls or unstable surfaces to try and promote greater trunk muscle activation (Marshall and Murphy 2005, Imai et al 2010, Lehman et al 2005). They tend to focus on much higher-level percentages of MVIC than that which is achieved by the Flexchair® making comparison difficult. Consequently, the use of the Flexchair® as a tool for encouraging correct trunk muscle activation may be more useful in an alternative group. In general, most of the exercises performed achieved a low load (20% MVIC or less). Therefore, it would seem fair to conclude that it would be more appropriate for a population where the primary concern is to improve the endurance in their trunk muscles or when beginning a motor control training programme as opposed to strength training (Ekstrom, Donatelli & Carp 2007).

Dynamic sitting vs. "Normal sitting"

Significant differences were noted in two muscles during exercises during the "ON" period, notably IO ($F=2.620$, $p=0.037$, $\eta p^2=0.225$) and LM ($F=3.403$, $p=0.036$, $\eta p^2=0.298$). Exercise 6 produced the greatest amount of muscle activation in IO (21% of MVIC), while exercise 5 also resulted in producing the highest muscle activation in LM (19% of MVIC). In a study by O' Sullivan et al (2006), which compared different sitting postures on trunk muscle activation, it is possible to compare the results of their study to the results obtained in the current study. The position of "Slump" and "Thoracic" upright sitting had muscle activation levels, which were below levels obtained in this study. This shows that the Flexchair® device challenges these specific muscles to a higher degree than “normal sitting” would. Hence, we could hypothesise that it could be an appropriate device to promote dynamic sitting and generate muscle activation to a greater degree than that which can be achieved by using static sitting postures alone.

Contraction/Relaxation phenomenon

The percentage difference in muscle activation from the “on” period to the “off” period of muscle activation also demonstrated notable results. Significant differences were noted in all three back muscles, TES (F=2.779, P=0.030, ηp^2=0.258), ICLT (F=3.619, P=0.008, ηp^2=0.287), LM (F= 3.092, P=0.019, ηp^2=0.279). Exercise 2 produced the greatest amount of difference in the “on/off” for TES (9% MVIC), while exercise 6 produced the greatest difference in the “on/off” for both ICLT (12% MVIC) and LM (13%). These results show that the Flexchair® could possible be useful in promoting a contraction/relaxation in trunk muscle activation. In a study by Callaghan and Dunk (2002), they examined the contraction/relaxation phenomenon in short slumped sitting. Their results tend to correlate to this study. They found that slumped sitting yielded a contraction/relaxation of the TES muscles, which was also achieved by the Flexchair®. They also showed that TES silence occurred at a smaller angle of lumbar flexion during sitting. This compares nicely to this study as exercise 2 has the least amount of range produced for lumbar range (28% of full ROM). However, there are differences in the contraction/relaxation of back muscles when compared to a LBP population. Shirado et al (1995) completed a study that compared healthy subjects to LBP patients in which they found that none of the subjects could demonstrate contraction/relaxation. Instead, it was found that they all exhibited significant differences in muscles activities and were unable to produce the “on/off” activation of back muscles. Thus, we could hypothesise that the Flexchair® may have a future role in promoting the contraction/relaxation of back muscles in LBP patients. The Flexchair® may promote this by retraining neuromuscular coordination, which in previous studies has been shown to improve through an exercise intervention (Marshell and Murphy 2006).

Feedback

The use of biofeedback is becoming increasingly popular with studies generally focusing on different methods of achieving it (Chow et al 2007, Donatell et al 2005). An advantage of the Flexchair® is its provision of instant feedback to the participant performing the exercises. By using a visual display, each participant can aim to improve on how well they perform the exercises. This allows the learning of appropriate muscle activity and postural control during dynamic conditions. Magnusson et al (2008) study reviewed the literature around the area of motor control relearning using biofeedback. They found that a physiotherapy intervention, along with postural feedback was advantageous to recovery. Their participants had a markedly improved status when biofeedback was applied. The authors strongly suggested that postural feedback is a useful adjunct to conventional physiotherapy alone. Thus, we could suggest that the Flexchair® may possibly be useful to a LBP population because of its use of real time feedback. Often it is found that LBP patients tend to under use their back muscles because they avoid or cannot use their muscles correctly (Hydes et al 1994). The Flexchair® could provide patients with a tool to regain the ability to better assess different physiological responses, and to relearn control of these responses (Donatell et al 2005). However, this can only be speculated at present as this study only looked at the use of the Flexchair® in a healthy population.

4.1 Limitations

One of the main limitations of this study was the use of a small sample group. Consequently, the results cannot be generalised to a wider population, such as other healthy groups or a LBP population (Beckerman et al 1993). The present study recruited physiotherapy students as participants, a group who may have a higher degree of body awareness and co-ordination skills than sedentary men and women (Storheim et al 2002). Potentially they may have found the exercises easier to perform.

Another area of concern in the study was the examiner's lack of clinical palpation experience which could result in incorrect positioning of the electrodes. The literature has shown that the level of skill of the examiner in palpation can have an affect on the degree of accuracy (Moir et al 1990). However, to limit this variability it was decided to use a second marker to agree on the area to reduce error.

The use of surface EMG may also have been a limiting factor in the study. Most authors feel that surface EMG is appropriate for superficial muscles (De Luca 1997). Surface EMG is deemed a good representation of the activity of the whole muscle. In previous studies, it has been shown that the reliability of the surface EMG is better than when analysing activity with intramuscular fine-wire electrodes (Giroux et al 1990). However, cross-talk (wherein a EMG signal is detected over a non-active muscle and instead is generated by a nearby muscle) may be a limitation when using surface electrodes during EMG recordings especially when analysing smaller muscles (Fuglevand et al 1992). However, it was felt that cross talk was not a significant problem in this study because of the large superficial muscles analysed.

Finally, because these results were obtained by using subjects without pathology, caution is warranted in extrapolating these findings to a patient population.

4.2 Conclusion

In summary, when we interpret the data we can see clear differences between the exercises and the specific muscles during the exercises. Interestingly, as stated above, all muscles were worked at a relatively low load (20% MVIC or less), which shows that it may be more suitable as a tool for motor control re-learning as opposed to strength training the specific muscles. The main findings in this study show that greatest activation of the abdominal muscles is seen in IO in exercise 6. LM also shows the greatest activation of the back muscles, with exercise 5 producing the highest output. Comparing the degree of contraction/relaxation of the muscles we see no statistical significance in the abdominal muscles, whereas all 3 back muscles show statistical significance. Exercise 4, 5 and 6 all produced a similar amount of contraction/relaxation in LM, while exercise 6 produced the greatest difference in ICLT and TES. The findings also show that the Flexchair® could have a future role as a tool in biofeedback and in encouraging the contraction/relaxation phenomenon in a patient population. The promising conclusions in this study suggest future work to ensure validity and reliability of the Flexchair® in real-world settings would be worthwhile, and might enhance the rigor of future Flexchair® trials. Similarly, more robust experimental designs, such as a fully powered randomised controlled trial, would help determine whether changes in muscle activation and posture can be attributed directly to the Flexchair® device. The findings in this study may be useful in selecting specific exercises to enhance a motor control/endurance training programme for individuals who may be appropriate for biofeedback and encouragement of contraction/relaxation of their back muscles. This may be achieved by varying the programme according to the demands needed for the individual.

5.0 References

Anderson, K. and Behm, D. (2005) ‘Maintenance of EMG activity and loss of force output with instability’ *Journal of Strength and Conditioning*, 18(3), 637-640

Andersson, E. A., Oddsson, L., Grundstrom, H., Nilsson, J. and Thorstensson, A. (1996) ‘EMG activities of the Quadratus Lumborum and Erector Spinae muscles during flexion-relaxation and other motor tasks’ *Clinical Biomechanics,* 11(7), 392-400.

Axler, C.T. and McGill, S.M. (1997) ‘Low back loads over a variety of abdominal exercises: searching for the safest abdominal challenge.’ *Medical Science Sports Exercise*. 29, 804-811

Beckermn, H., Bouter, L., van der Heijden, G., Bie, R. and Koes, B. (1993) ‘Efficacy of physiotherapy for musculoskeletal disorders: what can we learn from research?’ *British Journal of General Practice,* 43, 73-77

Behm, D. G., Anderson, K. and Curnew, R.S. (2002) ‘Muscle force and activation under stable and unstable conditions’ *Journal Strength Conditioning Research*, 16(3), 416-22

Bolek, J.E. (2006) ‘Use of multiple-site performance-contingent sEMG reward programming in pediatric rehabilitation: a retrospective review.’ *Applied Psychophysiology and Biofeedback*, 31(3), 263-72.

Callaghan, J.P. and Dunk, N.M. (2002) ‘Examination of the flexion relaxation phenomenon in the Erector Spinae muscles during short duration slumped sitting’ *Clinical Biomechanics,* 17, 353-360

Cholewicki, J., Panjabi, M.M. and Khachatryan, A. (1997) ‘Stabilising function of trunk flexor-extensor muscles around a neutral spine posture.’ *Spine,* 22, 2207-2212

Chow, J., Choe, Y.S., Noss, M.J., Robinson, K.J., Dugle, J.E., Acosta, S.H. and Garleb, K.A. (2007) ‘Effect of a viscouse fiber containing nutrition bar on satiety of patients with type 2 diabetes, *Diabetes Research Clinical Practice,* 76(3), 335-340

Comerford, M. J. and Mottram, S.L. (2001) 'Functional stability re-training: principles and strategies for managing mechanical dysfunction.' *Manual Therapy*, 6, 3-14

Dankaerts, W., O'Sullivan, P., Burnett, A. and Straker, L. (2006) 'Differences in sitting postures are associated with non-specific chronic low back pain disorders when sub-classified.' *Spine,* 31, 698-704.

Dankaerts, W., et al., O'Sullivan, P., Burnett, A. and Straker, L. (2006) 'Altered Patterns of Superficial Trunk Muscle Activation During Sitting in Nonspecific Chronic Low Back Pain Patients: Importance of Subclassification.' Spine, 31, 2017-2023.

Dankaerts, W., O'Sullivan, P., Burnett, A., Straker, L., Davey, P. and Gupta, R. (2009) 'Discriminating Healthy Controls and Two Clinical Subgroups of Nonspecific Chronic Low Back Pain Patients Using Trunk Muscle Activation and Lumbosacral Kinematics of Postures and Movements', *Spine*, 34(15), 1-9.

Dean, A. Y. and Dean, S. G., (2006) 'A pilot study investigating the use of the Orthosense Posture Monitor during a real-world moving and handling task', *Journal of Bodywork & Movement Therapies,* 10, 220.

De Luca, C.J. (1997) 'The use of surface electromyography in biomechanics.' *Journal Applied Biomechanics*, 13, 135–163.

Donatell, G.J., Meister, D.W., O'Brien J.R., Thurlow , J.S., Webster, J.G., Fellow, L and Salvi, F.J. (2005) 'A simple device to monitor flexion and lateral bending of the lumbar spine.' *IEEE Trans Neural Syst Rehabil Eng*, 13, 18 –23.

Dursun, E., Hamamci, N., Dönmez, S., Tüzünalp, O. and Cakci, A. (1996) 'Angular biofeedback device for sitting balance of stroke patients.' *Stroke*, 27(8), 1354-7

Ekstrom, R., Donatelli, R. and Soderbeg, G. (2003) 'Surface Electromyography Analysis of Exercises for the Trapezius and Serratus Anterior Muscles', *Journal of Orthopaedic and Sports Physical Therapy*, 33, 247-258

Ekstrom, R. A., Donatelli, R. A. and Carp, K.C. (2007) ‘Electromyography Analysis of Core Trunk, Hip, and Thigh Muscles During 9 Rehabilitation Exercises’ *Journal of Orthopaedic and Sports Physical Therapy*, 37(12), 754-762

Fuglevand, A.J., Winter, D.A., Patla, A.E. and Stashuk, D. (1992) ‘Detection of motor unit action potentials with surface electrodes: influence of electrode size and spacing.’ *Biology Cybern*, 67(2), 143–153**.**

Gadge, K. Innes, E. (2007) ‘An investigation into the immediate effects on comfort, productivity and posture of the Bambach saddle seat and a standard office chair.’ *Work*, 29(3), 189- 203

Giroux, B. and Lamontagne, M. (1990) ‘Comparisons between surface electrodes and intramuscular wire electrodes in isometric and dynamic conditions.’ *Electromyography Clinical Neurophysiology,* 30(7), 397–405.

Gilbert, C. and Moss, D. (2003) ‘Basic tools: Biofeedback and biological monitoring. In: D Moss, A McGrady, T. Davies, I. Wickramaskera. eds. Handbook of mind-body medicine in primary care: Behavioral and physiological tools.’ *Thousand Oaks, CA: Sage*, 109-122.

Gill, K.P. and Callaghan, M.J. (1998) ‘The measurement of lumbar proprioception in individuals with and without low back pain.’ *Spine*, 23(3), 371–7.

Gill, J., Allum, J., Carpenter, M., Ziolkowska, M., Adkin, A., Honeger, F. and Pierchala, K. (2001) ‘Trunk Sway Measures of Postural Stability During Clinical Balance Tests: Effects of Age’ Journal of Gerontology, 56(7), 438-447

Granata, K. P. and Wilson, S. E. (2001) ‘Trunk posture and spinal stability’ *Clinical Biomechanics*, 16, 650-659

Gregory, D.E., Dunk, N.M. and Callaghan, J.P. (2006) ‘Stability ball versus office chair: comparison of muscle activation and lumbar spine posture during prolonged sitting.’ *Human factors*, 48(1), 142-53.

Groenan, E. and Flamaing, P. (2008) ‘Assessment of lumber spine posture during sitting on a dynamic sitting device (Flexchair®)’ *Ergonomics*, 44, 1-26

Hermens H, Freriks B, Disselhorst-Klug C, Rau G. (2000) ‘Development of recommendations for sEMG sensors and sensor placement procedures.’ *Journal of Electromyography Kinesiology,* 10, 361-74.

Hides, J.A., Richardson, C.A. and Jull, G.A. (1996) ‘Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain.’ *Spine*, 21, 2763–9.

Hodges, P., van den Hoorn, W., Dawson, A. and Cholewicki, J. ‘Changes in the mechanical properties of the trunk in low back pain may be associated with recurrences’ *Journal of Biomechanics,* 42, 61-66

Hubley-Kozey, C. L. and Vezina, M. J. (2002) ‘Muscle Activation During Exercises to Improve Trunk Stability in Men With Low Back Pain’ *Archive Physical Medical Rehabilitation*, 83, 1100-8

Imai, A., Kaneoka, K., Okubo, Y., Shina, I., Tatsumura, M., Izumi, S. and Shiraki H. (2010) ‘Trunk Muscle Activity During Lumbar Stabilisation Exercises on both a Stable and Unstable Surface’ *Journal of Orthopaedic & Sports Physical Therapy*, 40(6), 369-375

Koumantakis, G.A., Winstanley, J. and Oldham, J.A. (2002) ‘Thoracolumbar proprioception in individuals with and without low back pain: intratester reliability, clinical applicability, and validity.’ *Journal of Orthopaedic and Sports Physical Therapy*, 32(7), 327–35.

Kristjansson, E. and Oddsdottir G. (2010) ‘”The Fly”: A new clinical assessment and treatment method for deficits of movement control in the cervical spine’ Spine, 35(23), 1298-1305

Lam, S. S., Jull, G. and Treleaven, J. (1999) 'Lumbar spine kinesthesia in patients with low back pain', *Journal of Orthopaedic and Sports Physical Therapy,* 29(5), 294-299.

Lehman, G., Gordon, T., Langley, J., Pemrose, P. and Tregaskis, S. (2005) ‘Replacing a Swiss ball for an exercise bench causes variable changes in trunk muscle activity during upper limb strength exercises’ *Dynamic Medicine*, 4(6), 1-7

Lima, L. M., Reynolds, K., Winter, C., Paolone, V. and Jones, M. (2003) 'Effects of Physioball and Conventional Floor Exercises on Early Phase Adaptations in Back and Abdominal Core Stability and Balance in Women' *Journal Strength Conditioning Research*, 17(4), 721-725

Magnusson, M.L., Chow, D., Diamandopoulos, Z. and Pope, M.H. (2008) 'Motor Control Learning in Chronic Low Back Pain' *Spine*, 33(16), 532-538.

Mannion, A. and Troke, M. (1999) 'A comparison of two motion analysis devices used in the measurement of lumbar spine mobility' *Clinical Biomechanics*, 14, 612-619.

Marshall, P. W. and Murphy, B. A. (2005) 'Core Stability Exercises On and Off a Swiss Ball' *Archive Physical Medical Rehabilitation*, 86, 242-249

Marshall, P. and Murphy, B. (2006) 'Changes in the Flexion Relaxation Response Following an Exercise Intervention' *Spine*, 31(23), 877-883

McGill, S.M., Kavcic, N.S. and Harvey, E. (2006) 'Sitting on a chair or an exercise ball: various perspectives to guide decision-making.' *Clinical biomechanics*, 21(4), 353-60.

Mitchell, T., O'Sullivan, P., Burnett, A. F., Straker, L. and Smith, A. (2008) 'Regional differences in lumbar spinal posture and the influence of low back pain', *BMC Musculoskeletal Disorders*, 9, 152.

Moir, S.A., McGregor, M. and Schut, B. (1990) 'The role of experience in clinical accuracy.' *Journal of Manipulative Physiological Therapies*, 13, 68-71

Newcomer, K., Laskowski, E., Yu, B., Johnson, J. and An, K.N. (2001) 'The effects of a lumber support on repositioning error in subjects with low back pain', *Archive Physical Medical Rehabilitation*, 82, 906-910

Ng, J., Kippers, V., Richardson, C. and Parnianpour (2001) 'Range of Motion and Lordosis of the Lumbar Spine: Reliability of Measurement and Normative Values.' *Spine*, 26, 53-60.

Nuzzo, J.L., McCaulley, G.O., Cormie, P., Cavill, M.J. and McBride, J.M. (2008) 'Trunk muscle activity during stability ball and free weight exercises.' *Journal Strength Conditioning Research*, 22, 95-102.

O’Sullivan, K., O’Dea, P., O’Sullivan, P., Clifford, A. and O’Sullivan, L. (2010) ‘Neutral lumber spine sitting posture in pain-free subjects’, *Manual Therapy*, 15, 557-561

O’Sullivan, P B., Twomey, L. T. and Allison, G. T. (1997) ‘Evaluation of Specific Stabilizing Exercise in the Treatment of Chronic Low Back Pain With Radiologic Diagnosis of Spondylolsis or Spondylolisthesis’, *Spine*, 22(24) 2959-2967.

O‟Sullivan, P.B., Burnett, A., Floyd, A.N., Gadson, K., Logiudice, J., Miller, D. and Quike, H. (2003) ‘Lumbar repositioning deficit in a specific low back pain population.’ *Spine*, 28(10), 1074– 9

O'Sullivan, P., Dankaerts, W., Burnett, A., Straker, L., Bargon, G., Moloney, N., Perry, M. and Tsang, S. (2006) ‘Lumbopelvic kinematics and trunk muscle activity during sitting on stable and unstable surfaces.’ *The Journal of orthopaedic and sports physical therapy*, 36(1), 19-25.

O’Sullivan, P., Dankaerts, W., Burnett, A., Chen, D., Booth, R., Carlsen, C. and Schultz, A. (2006) ‘Evaluation of the Flexion Relaxation Phenomenon of the Trunk Muscles in sitting’ *Spine*, 31(17), 2009-2016

O’Sullivan, P. B., Dankaerts, W., Burnett, A. F., Farrell, G. T., Jefford, E., Naylor, C. S. and O’Sullivan, K. J. (2006) ‘Effect of Different Upright Sitting Postures on Spinal-Pelvic Curvature and Trunk Muscle activation in a Pain-Free Population’, *Spine*, 31(19), 707-712.

Reeves, P., Everding, V., Cholewicki, J. and Morrisette, D. (2006) ‘The effects of trunk stiffness on postural control during unstable seated balance’ *Experimental Brain Research*, 174, 694-700

Richardson, C., Jull, G., Toppenberg, R. and Comerford, M. (1992) ‘Techniques for active lumbar stabilisation for spinal protection: a pilot study.’ *Australian Journal Physiotherapy*, 38, 105-12.

Shirado, O., Ito, T., Kaneda, K. and Strax, T. (1995) Flexion-Relaxation Phenomenon in the back muscles: A comparative study between healthy subjects and patients with chronic low back pain’ *American Journal of Physical Medicine & Rehabilitation*, 74(2), 89-95.

Stevens, V. K., Coorevits, P. L., Bouche, K. G., Mahieu, N. N., Vanderstraeten, G. G. and Danneels, L. A. (2007) ‘The influence of specific training on trunk muscle recruitment patterns in healthy subjects during stabilisation exercises’ *Manual Therapy,* 12(1) 271-279.

Storheim, K., Bo, K., Pederstad, O. and Jahnsen, R. (2002) ‘Intra tester reproducibility of pressure biofeedback in measurement of Transversus Abdominus function’ *Physiotherapy research international*, 7(4), 239-249.

Swinkels, A. and Dolan, P. (1998) 'Regional assessment of joint position sense in the spine', *Spine,* 23(5), 590-597.

Troke, M., Moore, A. P. and Cheek, E., (1996) ‘Intra-operator and inter-operator reliability of the OSI CA6000 Spine motion analyser with a new skin fixation system.’ *Manual Therapy,* 1, 92-98.

Troke, M., Schuit, D. and Petersen, C., 2007. Reliability of lumbar spinal palpation, range of motion, and determination of position *BMC Musculoskeletal Disorders,* 8, 103.

Tsao, H. and Hodges, P. (2007) ‘Immediate changes in feedforward postural adjustments following voluntary motor training’ *Experimental Brain Research*, 181, 537-546

Vezina, J. and Hubley-Kozey (2000) ‘Muscle Activation in Therapeutic Exercises to improve trunk stability’ *Archive Physical Medical Rehabilitation*, 81, 1370-9

Zazulak, B., Cholewicki, J. and Reeves, P. (2008) ‘Neuromuscular Control of Trunk Stability: Clinical Implications for Sports Injury Prevention’ Journal *American Academy Orthopedic Surgery,* 16(9), 496-505

6.0 Appendices

6.1 Appendix

UNIVERSITY *of* LIMERICK
OLLSCOIL LUIMNIGH

Subject Information Leaflet

Title of study:

To investigate low back posture and trunk muscle activation while exercising on an unstable chair (Flexchair®) in a healthy population.

Aim of Study:

To assess if there is a difference in low back posture and trunk muscle activation between different exercises performed on an unstable chair.

What will you have to do?

If you are willing to participate, you will be asked to undergo measurement of low back posture and trunk muscle activation while exercising on an unstable chair in a laboratory. The testing will require you to expose the skin of your lower back so that the electrodes can be placed on your back and abdomen. You will be asked to perform 6 specific low back exercises on the chair. These exercises will require you shifting your lower back posture in different directions while sitting on the chair. For example, you will be asked to tilt your pelvis so that there is more pressure on the front of the chair, or the back of the chair, as well as other directions. The exact order of these exercises will be randomised. Adequate rest periods will be given between each exercise while the electrodes remain attached. This session will last approximately 1.5 hours.

What are the benefits for you?

There are no direct benefits for you; however you will be helping the investigators complete an important piece of research, which is likely to help future research into low back pain.

What are the risks to you?

- There are minimal risks associated with this research study.

- There is a minimal risk of skin irritation due to shaving and sand-papering the skin or due to a possible allergic reaction to the adhesive tape. Subjects will be excluded if they have a known allergy to tape, and both the skin and skin attachments will be cleaned before use.

- There is a minimal risk of muscle fatigue which will be minimised by the completion of a warm-up protocol prior to testing and adequate rest periods.

- There is a minimal risk of a minor cut from shaving if excess hair needs to be removed prior to the placement of electrodes.

- The postures and movements involved require minimal exertion, so that the likelihood of the test procedures causing pain or discomfort is minimal. Any subject who reports increased pain during any test may stop testing at any stage.

However if you;

- Are aged < 18 years of age.
- Have any known spine disorders, neurological conditions, recent pelvic or abdominal surgery.
- Have recieved postural training in the past.
- Are pregnant.
- Have an allergy to adhesive tape
- Have had previous back surgery.
- Are currently on pain medications for low back pain.
- Have had low back pain within the previous 2 years.

Then you will not be eligible to participate in this study.

What are the alternatives?

You are not in any way obliged to participate.

Who is taking part?

Students of the University of Limerick, and members of the public will be taking part.

Could there be any complications?

Because procedures included are simple, the risk of complications occurring are small. Qualified and experienced physiotherapists will be in the building during testing times.

What if I have more questions or do not understand something?

If you require any further information or do not understand something you can at any point contact the project investigators through the contact details below or ask your instructor on the day of testing.

What happens to the data?

The study information will be safely stored in the Health Science Building. The data collected at the end of the study will be used in writing a research paper for this investigation. All data will remain confidential, so that any personal data about you will not be published or discussed with others.

Participants can withdraw at anytime, without any obligation or consequences. The investigators would request that you would contact them in such an event, or if you have any other queries at the details below.

If you would like to take part please contact the principal investigator via kieran.osullivan@ul.ie or on 061 234119. Alternatively you can contact assistant investigator John Dunne 0745936@studentmail.ul.ie or on 0877929755. A time and date can then be arranged when testing can take place.

Investigators: Kieran O'Sullivan; John Dunne, Wim Dankaerts, Leonard O'Sullivan

If you have concerns about this study and wish to contact someone independent, you may contact

Chairman Education and Health Sciences Research Ethics Committee
EHS Faculty Office
University of Limerick
Tel (061) 234101
Email : ehsresearchethics@ul.ie

UNIVERSITY of LIMERICK
OLLSCOIL LUIMNIGH

6.2 Appendix.

<u>Subject Consent Form</u>

Title of Project: To investigate low back posture and trunk muscle activation while exercising on an unstable chair (Flexchair®) in a non-patient population.

Investigators: Kieran O'Sullivan; John Dunne, Wim Dankaerts, Leonard O'Sullivan

You are of your own accord making a decision whether or not to participate in this research study. Your signature verifies that you have decided to participate in the study, having read and understood all the information accessible. Your signature also officially states that you have had adequate opportunity to discuss this study with the investigators and all your questions have been answered to your satisfaction.

I, (the undersigned)

____

Please PRINT

I consent to involvement in this study and give my authorisation for any results from this study to be used in any research paper, on the understanding that confidentiality will be maintained. I am fully aware of all the procedures involving myself and any risks and benefits associated with the study. I comprehend that I may withdraw from the study at any time without discrimination. If so, I will contact the researchers at the earliest opportunity.

Signature ___________________________ *Date* ________________

Subject

I have explained to the subject the procedures of the study to which the subject has consented their involvement and have answered all questions. In my appraisal, the subject has voluntarily and intentionally given informed consent and possesses the legal capacity to give informed consent to participate in this research study.
Investigator: ____________________ Date: _______________

6.3 Appendix

	Mean %	SD±
Stand	4.4798	17.20936
Sit	60.4563	30.18090
Lying	71.4043	14.76032

Table Ia *showing the mean and standard deviation of average baseline postures between subjects.*

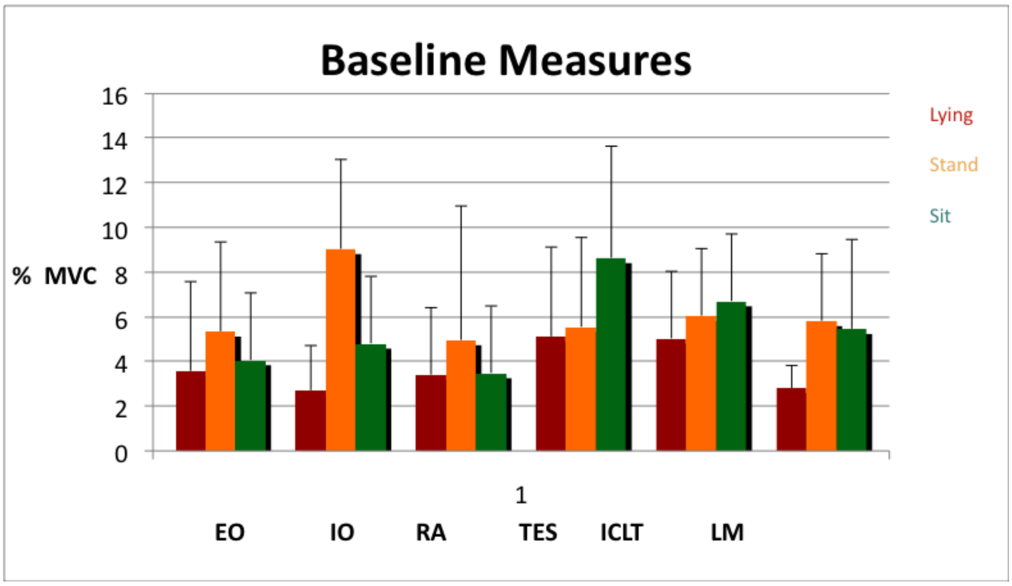


Figure Ib *illustration of baseline muscle activation during lying, stand and sit. Abbreviations: EO, external oblique; IO, Internal Oblique; RA, Rectus Abdominus: TES, Thoracic Erector Spinae; ICLT, Intercostalis Lumborum Thoracic; LM, Lumbar Multifidus; Maximum Voluntary Contraction MVC.*

6.4 Appendix.

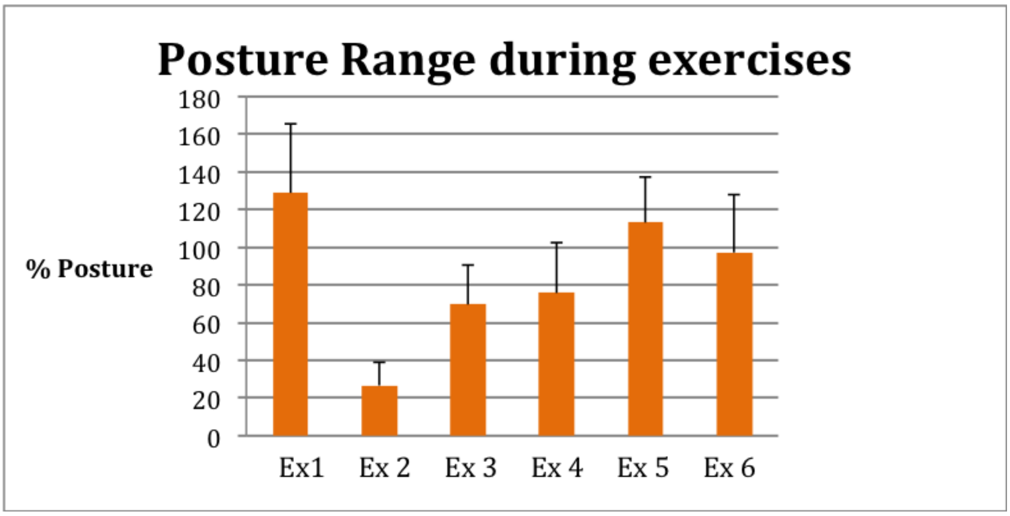
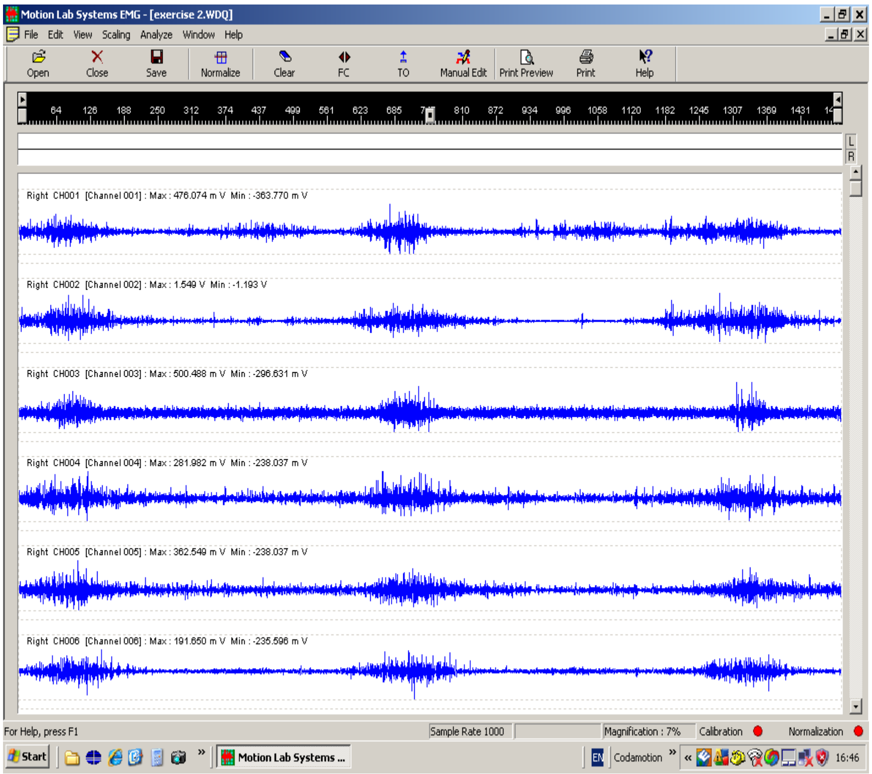


Figure IIa *illustrating the average percentage of range achieved between participants for each individual exercise. Abbreviations; exercise, ex.*

6.5 Appendix



E.O.

I.O.

R.A.

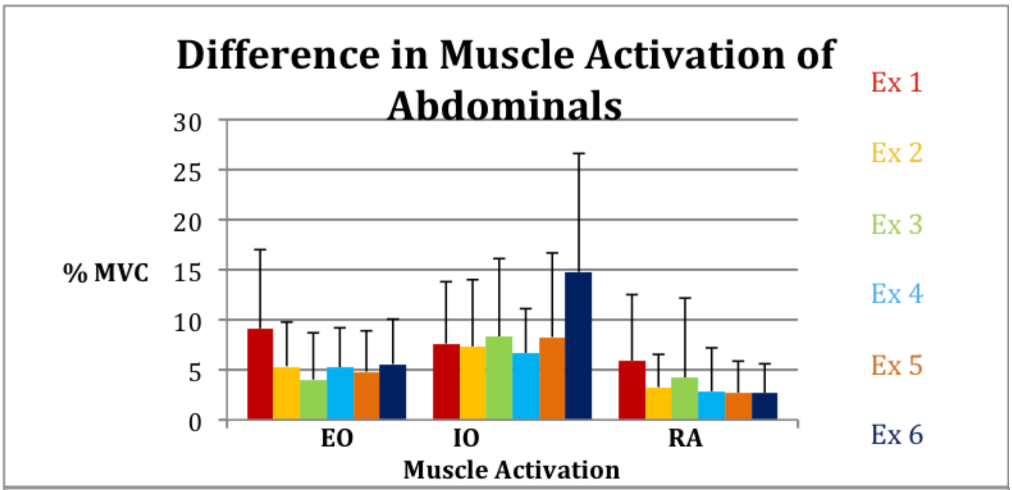
T.E.S.

I.C.L.T.

L.M.

Figure IIIa *Example of Raw EMG output from exercise 2. Abbreviations: Channel 1= EO, external oblique; Channel 2=IO, Internal Oblique;Channel 3= RA, Rectus Abdominus : Channel 4= TES, Thoracic Erector Spinae;Channel 5= ICLT, Intercostalis Lumborum Thoracic; Cahnnel 6= LM, Lumbar Multifidus*

6.6 Appendix



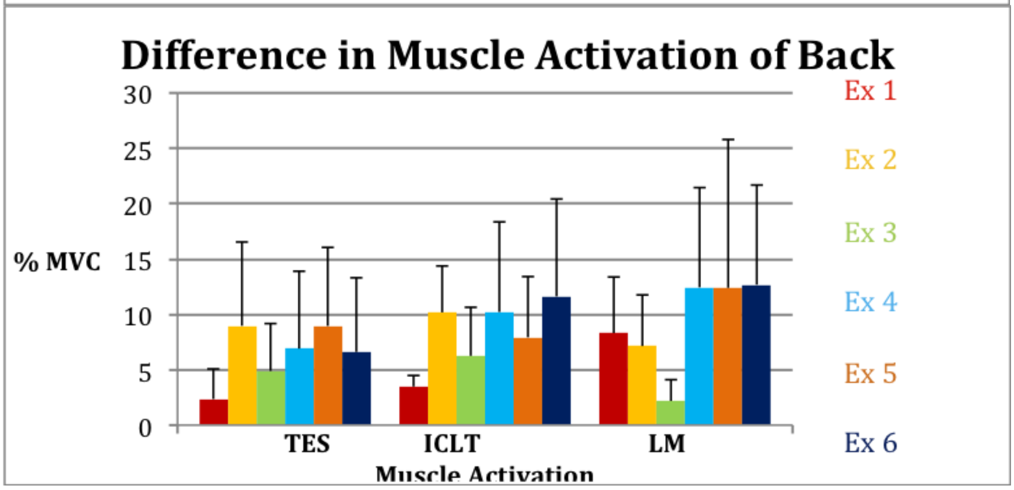


Figure IVa and IVb *Mean and Standard Deviations of muscle activity for each abdominal and back muscle during contraction/relaxation period. Abbreviations: EO, external oblique; IO, Internal Oblique; RA, Rectus Abdominus; TES, Thoracic Erector Spinae; ICLT, Intercostalis Lumborum Thoracic; LM, Lumbar Multifidus; MVC, Maximum voluntary contraction.*

6.7 Appendix

	Comfort	**Ease of use**	**Consider it useful**	**Enjoyable**	**Any other comments**
Positive	8/10	7/10 Visual feedback quite useful	10/10 Felt it could be beneficial to LBP population	10/10 Felt that it was a novel and interesting device	None
Negative	2/10 subjects reported seat was too hard	3/10 found exercise 5/6 quite difficult to perform	N/A	N/A	2/10 subjects felt chair seat needed to be made lower as available range was too high

Figure Va *illustrating the qualitative questions which each participant was asked to complete after participating in the study*

6.8 Appendix *illustrating raw SPMD data for all subjects (following page subjects 6-10).*

Subject 1	Average	Max	Min	Range	Mean
Stand	0.9943662				
Sit	93.4157143				
Lying	66.9224286				
Ex 1		134.33	-31.19	165.52	46.70196507
Ex 2		108.51	60.17	48.34	75.51028571
Ex 3		87.91	-1.77	89.68	41.18711864
Ex 4		110.68	-17.44	128.12	21.80064171
Ex 5		124.34	-13.72	138.06	63.74
Ex 6		127.1	-20.82	147.92	68.89141026
Subject 2	Average	Max	Min	Range	Mean
Stand	15.709				
Sit	68.664875				
Lying	78.29794521				
Ex 1		115.4	-0.71	116.11	64.22745098
Ex 2		92.15	46.55	45.6	73.26043478
Ex 3		111.51	19.83	91.68	68.66814815
Ex 4		84.48	33.06	51.42	73.40835294
Ex 5		118.57	13.15	105.42	75.59628571
Ex 6		108.87	38.35	70.52	79.06733333
Subject 3	Average	Max	Min	Range	Mean
Stand	-35.35216867				
Sit	55.98819444				
Lying	48.9608				
Ex 1		107.15	-22.81	129.96	36.8656
Ex 2		81.19	55.18	26.01	69.38125
Ex 3		89.44	5.05	84.39	38.09541667
Ex 4		111.14	8.98	102.16	50.3572
Ex 5		104.64	16.86	87.78	69.03333333
Ex 6		96.93	8.05	88.88	64.87458333
Subject 4	Average	Max	Min	Range	Mean
Stand	-6.484848485				
Sit	-0.936716418				
Lying	61.27955224				
Ex 1		163.52	-43.05	206.57	49.72727273
Ex 2		46.94	28.08	18.86	36.002
Ex 3		106.47	17.42	89.05	52.74413793
Ex 4		107.89	2.33	105.56	57.4392
Ex 5		121.42	-23	144.42	40.11826087
Ex 6		124.8	-30.93	155.73	44.84086957
Subject 5	Average	Max	Min	Range	Mean
Stand	-1.621011236				
Sit	83.65478873				
Lying	95.58764706				
Ex 1		130.37	-1.05	131.42	62.20615385
Ex 2		74.9	55.55	19.35	64.99759259
Ex 3		99.55	15.68	83.87	52.5125
Ex 4		96.61	33.47	63.14	62.94803922

Ex 5		115.3	18.01	97.29	70.23625
Ex 6		109.09	33.79	75.3	72.90791667
Subject 6	Average	Max	Min	Range	Mean
Stand	29.66319444				
Sit	74.4946988				
Lying	85.53985714				
Ex 1		151.09	41.41	109.68	97.03916667
Ex 2		95.38	66.88	28.5	82.47472727
Ex 3		123.02	70.71	52.31	97.645
Ex 4		118.79	56.07	62.72	86.36833333
Ex 5		145.94	43.84	102.1	92.96434783
Ex 6		137.98	59.38	78.6	98.30652174
Subject 7	Average	Max	Min		
Stand	11.11382353				
Sit	85.54584615				
Lying	81.01704225				
Ex 1		124.84	16.68	108.16	67.05375
Ex 2		61.61	41.72	19.89	50.52227273
Ex 3		95.16	25.49	69.67	55.43151515
Ex 4		102.82	39.51	63.31	63.37923077
Ex 5		148.83	15.28	133.55	71.44066667
Ex 6		124.84	19.48	105.36	70.30282051
Subject 8	Average	Max	Min	Range	Mean
Stand	11.75608108				
Sit	24.80695652				
Lying	68.79648649				
Ex 1		137.62	-7.94	145.56	76.9675
Ex 2		84.53	52.98	31.55	66.2725
Ex 3		115.18	72.04	43.14	95.80458333
Ex 4		117.63	43.01	74.62	88.16416667
Ex 5		157.16	12.38	144.78	78.39875
Ex 6		164.77	77.73	87.04	121.8266667
Subject 9	Average	Max	Min		
Stand	10.35424242				
Sit	41.89090909				
Lying	75.82261538				
Ex 1		89.82	-5.78	95.6	36.43695652
Ex 2		29.53	19.9	9.63	24.32521739
Ex 3		64.35	8.3	56.05	31.35
Ex 4		60.41	9.88	50.53	33.00130435
Ex 5		99.83	11.19	88.64	52.85434783
Ex 6		80.1	9.09	71.01	43.7448
Subject 10	Average	Max	Min	Range	Mean
Stand	8.665230769				
Sit	77.03727273				
Lying	51.81863636				
Ex 1		118.88	38.44	80.44	75.37
Ex 2		90.06	70.72	19.34	79.18521739
Ex 3		100.18	63.28	36.9	81.61875

Ex 4		114.42	58.38	56.04	88.59521739
Ex 5		137.07	47.45	89.62	91.03956522
Ex 6		121.38	29.12	92.26	71.86518519

Subject 1	**Channel**	**Back MVC (mV)**	**RA MVC (mV)**	**Left MVC (mV)**	**Right MVC (mV)**
EO	**1**		371.33	**562.58**	235.37
IO	**2**		607.27	151.1	**438.86**
RA	**3**		1326.7	664.77	761.48
TES	**4**	**157.11**			
ICLT	**5**	**416.95**			
LM	**6**	**418.81**			
	Baseline 1	**Baseline 2**	Baseline 3	Exercise 1 ON	Exercise 1 OFF
Best MVC	**Lying**	**Standing**	Stool		
562.58	**7.74**	**18.08**	8.92	153.30	10.36
607.27	**12.34**	**25.16**	5.33	188.60	87.50
1326.7	**7.56**	**7.44**	7.96	234.23	7.91
157.11	**4.92**	**10.94**	13.83	15.63	6.20
416.95	**6.34**	**8.02**	13.76	17.88	11.61
418.81	**5.43**	**32.67**	8.13	82.32	14.97
Exercise 2 ON	**Exercise 2 OFF**	**Exercise 3 ON**	Exercise 3 OFF	Exercise 4 ON	Exercise 4 OFF
84.13	**7.70**	**16.09**	12.96	51.88	9.64
128.92	**36.13**	**50.51**	6.78	69.56	8.36
77.90	**9.37**	**8.34**	9.06	39.36	11.91
14.60	**8.33**	**11.37**	5.29	23.81	4.74
18.29	**10.53**	**21.10**	11.21	28.06	15.03
54.53	**13.57**	**44.45**	21.38	76.03	11.89
Exercise 5 ON	**Exercise 5 OFF**	**Exercise 6 ON**	Exercise 6 OFF		
77.96	**16.83**	**78.66**	17.41		
59.04	**23.89**	**64.07**	8.28		
37.55	**9.35**	**23.14**	8.49		
43.00	**7.71**	**32.28**	8.11		
42.93	**14.46**	**26.84**	13.28		
207.48	**7.89**	**88.33**	7.74		

6.9 Appendix. *illustrating raw EMG (Electromyogram) output for subject 1 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown.*

		mV			
Subject 2	**Channel**	**Back MVC**	**RA MVC**	**Left MVC**	**Right MVC**
	1		10.44.29	**467.17**	844.86
	2		**364.72**	121.35	519.64
	3		480.24	**89.84**	219.66
	4	**174.63**			
	5	**160.3**			
	6	**241.91**			
	Baseline 1	**Baseline 2**	Baseline 3	Exercise 1 ON	Exercise 1 OFF
Best MVC	**Lying**	**Standing**	Stool		
844.86	**6.66**	**14.61**	9.29	74.54	18.04
364.72	**5.23**	**28.21**	22.98	112.11	50.39
480.24	**23.73**	**19.10**	15.79	111.97	34.59
174.63	**9.24**	**40.50**	31.46	25.33	23.43
160.3	**8.24**	**11.86**	11.55	24.38	23.91
241.91	**9.45**	**99.86**	38.26	15.30	11.28
Exercise 2 ON	**Exercise 2 OFF**	**Exercise 3 ON**	Ex 3 OFF	Ex 4 ON	Ex 4 OFF
69.67	**19.06**	**104.08**	30.08	85.09	12.80
195.10	**62.10**	**165.57**	23.97	63.94	20.18
69.42	**37.82**	**68.31**	40.50	39.64	32.44
55.77	**27.20**	**44.67**	26.65	17.63	9.27
53.71	**27.03**	**56.76**	40.51	15.93	9.06
34.33	**9.21**	**18.18**	13.20	19.02	11.10
Ex 5 ON	**Ex 5 OFF**	**Ex 6 ON**	**Ex 6 OFF**		
146.77	42.24	109.91	20.25		
147.51	36.41	176.63	17.10		
79.90	39.98	47.73	41.64		
39.58	37.24	43.00	25.17		
49.62	42.60	59.82	40.85		
39.76	9.91	37.20	10.45		

Illustrating raw EMG output for subject 2 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown.

		mV			
Subject 3	**Channel**	**Back MVC**	**RA MVC**	**Left MVC**	**Right MVC**
	1		66.87	**80.64**	40.91
	2		96.36	92.29	**111.66**
	3		**100.8**	97.61	97.13
	4	**390.73**			
	5	**119.28**			
	6	**117.44**			
	Baseline 1	**Baseline 2**	**Baseline 3**	**Ex 1 ON**	**Ex 1 OFF**
Best MVC	**Lying**	**Standing**	**Stool**		
80.64	6.79	7.94	8.16	7.57	7.23
111.66	7.01	8.38	5.82	9.67	7.32
100.8	8.82	10.63	9.62	42.08	40.20
390.73	8.24	5.12	10.54	18.47	6.43
119.28	6.56	6.74	8.00	19.18	9.04
117.44	5.85	6.87	6.00	33.93	18.86
Ex 2 ON	**Ex 2 OFF**	**Ex 3 ON**	**Ex 3 OFF**	**Ex 4 ON**	**Ex 4 OFF**
8.73	6.66	7.90	7.39	10.06	6.77
14.72	5.42	13.65	5.36	11.13	5.66
40.73	37.12	34.30	33.81	37.78	23.10
42.68	17.09	11.73	8.06	19.77	13.74
19.16	7.67	14.20	11.17	19.85	8.09
10.22	6.92	8.41	7.38	17.69	8.35
Ex 5 ON	**Ex 5 OFF**	**Ex 6 ON**	**Ex 6 OFF**		
7.55	7.33	7.79	6.89		
11.05	7.05	14.26	5.61		
40.20	38.61	40.40	38.90		
20.24	5.16	36.14	19.11		
18.53	6.48	16.46	12.16		
11.42	6.83	11.67	7.64		

Illustrating raw EMG output for subject 3 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown

		mV			
Subject 4	Channel	Back MVC	RA MVC	Left MVC	Right MVC
	1		490.55	421.81	838.02
	2		751.48	1429.36	634.92
	3		433.38	129.95	166.94
	4	158.04			
	5	293.83			
	6	217.31			
	Baseline 1	Baseline 2	Baseline 3	Ex 1 ON	Ex 1 OFF
Best MVC	Lying	Standing	Stool		
490.55	9.88	32.60	40.73	47.94	17.32
634.92	17.33	92.84	28.21	57.12	35.64
433.38	11.60	15.05	14.52	10.51	9.22
158.04	19.89	15.95	21.63	52.25	50.31
293.83	6.31	7.69	18.94	22.50	8.58
217.31	5.57	9.40	14.83	60.94	31.43
Ex 2 ON	Ex 2 OFF	Ex 3 ON	Ex 3 OFF	Ex 4 ON	Ex 4 OFF
81.18	23.34	84.81	18.12	47.41	24.67
21.65	11.72	218.21	18.37	54.84	29.29
7.92	7.89	119.19	8.52	8.70	8.21
68.08	29.71	46.95	41.17	55.33	18.29
41.35	9.31	49.73	9.44	47.29	7.00
42.20	31.13	22.58	18.77	55.74	19.11
Ex 5 On	Ex 5 OFF	Ex 6 On	Ex 6 OFF		
74.87	55.87	54.37	44.10		
64.65	19.59	67.45	25.32		
36.74	9.13	20.23	8.55		
41.54	21.76	44.77	11.76		
79.65	16.92	100.78	8.64		
78.15	65.64	93.09	35.22		

Illustrating raw EMG output for subject 4 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown

		mV			
Subject 5	**Channel**	**Back MVC**	**RA MVC**	**Left MVC**	**Right MVC**
	1		525.38	776.4	237.45
	2		1037.9	122.95	1216.48
	3		778.85	951.64	695.01
	4	688.89			
	5	194.98			
	6	463.88			
	Baseline 1	**Baseline 2**	**Baseline 3**	**Ex 1 ON**	**Ex 1 OFF**
Best MVC	**Lying**	**Standing**	**Stool**		
776.4	6.58	10.21	22.65	1068.73	23.18
1216.48	12.77	104.72	83.25	77.02	23.29
951.64	7.67	8.15	9.55	48.24	10.3
688.89	5.45	16.46	19.09	21.9	13.2
194.98	6.52	9.83	6.62	21.05	13.6
463.88	5.68	25.95	7.45	577.33	48.57
Ex 2 ON	**Ex 2 OFF**	**Ex 3 ON**	**Ex 3 OFF**	**Ex 4 On**	**Ex 4 OFF**
19.6	10.73	759.31	57.62	18.37	9.82
188.71	70.11	192.33	21.2	170.73	19.07
15.41	11.43	28.84	10.15	47.23	13.28
17.65	12.53	32.64	26.2	17.74	7.7
30.87	15.58	31.68	14.51	20.76	7.32
582.56	25.50	23.13	9.52	62.37	8.53
EX 5 On	**Ex 5 OFF**	**Ex 6 ON**	**EX 6 OFF**		
45.16	12.51	40.09	40.09		
151.79	76.02	252.68	68.99		
39.04	19.36	21.69	16.22		
16.93	7.42	19.88	8		
22.82	10.65	34.33	8.62		
54.16	14.51	55.67	7.60		

Illustrating raw EMG output for subject 5 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown

		mV			
Subject 6	Channel	Back MVC	RA MVC	Left MVC	Right MVC
	1		577.93	793.17	591.69
	2		405.82	2.628V	424.22
	3		226.48	424.29	222.65
	4	407.04			
	5	123.35			
	6	325.21			
	Baseline 1	Baseline 2	Baseline 3	Ex 1 On	Ex 1 OFF
Best MVC	Lying	Standing	Stool		
793.17	6.7	11.65	8.88	19.32	7.96
424.22	8.81	55.5	24.91	18.82	15.43
424.29	13.61	14.31	13.76	28.4	28.4
407.04	6.94	11.07	15.18	16.92	16.42
123.35	8.97	13.72	14.3	18.26	11.99
325.21	6.25	16.48	13.23	19.51	7.22
Ex 2 ON	Ex 2 OFF	Ex 3 ON	Ex 3 OFF	Ex 4 ON	Ex 4 OFF
13.82	8.74	16.51	9.77	8.34	7.45
21.53	10.4	21.71	13.02	22.62	15.10
25.03	25.91	31.18	30.58	34.14	32.24
40.77	12.14	34.96	8.49	25.83	9.85
23.08	11.54	14.96	12.34	27.26	10.07
13.78	7.47	8.02	7.21	30.60	7.60
Ex 5 ON	Ex 5 OFF	Ex 6 On	Ex 6 OFF		
29.43	12.88	33.26	9.58		
72.61	29.44	76.48	39.95		
37.84	37.96	41.89	41.47		
24.93	11.77	49.28	14.99		
22.22	9.09	17.41	9.85		
16.09	6.76	11.68	6.76		

Illustrating raw EMG output for subject 6 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown

		mV			
Subject 7	**Channel**	**Back MVC**	**RA MVC**	**Left MVC**	**Right MVC**
	1		249.67	306.33	3.6V
	2		368.92	131.69	467.02
	3		484.78	454.27	441.67
	4	167.12			
	5	111.98			
	6	153.77			
	Baseline 1	**Baseline 2**	**Baseline 3**	**Ex 1 On**	**Ex 1) OFF**
Best MVC	**Lying**	**Standing**	**Stool**		
306.33	7.24	23.3	7.83	40.75	10.9
467.02	5.63	35.32	5.53	36.98	8.11
484.78	6.97	7.93	7.84	47.38	8.99
167.12	6.12	6.81	11.06	7.17	7.07
111.98	9.99	8.52	8.34	7.14	7.33
153.77	5.24	11.85	5.42	20.89	11.27
Ex 2 ON	**Ex 2 OFF**	**Ex 3 On**	**Ex 3 OFF**	**Ex 4 ON**	**Ex4 OFF**
28.16	12.2	15.03	11.22	24.44	9.81
29.54	6.42	11.19	13.69	11.39	8.32
43.36	9.55	15.85	8.1	15.46	8.35
10.36	8.57	9.40	6.66	13.49	8.15
25.74	10.69	10.69	8.45	13.67	6.55
31.30	8.55	16.74	8.49	30.28	7.49
Ex 5 On	**Ex 5 OFF**	**Ex 6 ON**	**Ex 6 OFF**		
26.14	13.37	30.77	10.49		
27.63	6.31	33.51	7.88		
41.52	10.15	49.34	10.95		
11.2	8.73	13.86	4.58		
9.72	7.96	14.53	7.24		
24.14	**5.93**	**42.95**	**13.07**		

Illustrating raw EMG output for subject 7 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown

		mV			
Subject 8	Channel	Back MVC	RA MVC	Left MVC	Right MVC
	1		274.83	1.88	147.98
	2		1139.92	96.12	607.48
	3		878.08	476.96	688.24
	4	308.45			
	5	291.33			
	6	446.88			
	Baseline 1	Baseline 2	Baseline 3	Ex 1 On	Ex 1 OFF
Best MVC	Lying	Standing	Stool		
274.83	10.52	39.42	18.48	28.14	6.87
607.48	5.25	42.19	13.84	36.68	19.62
688.24	7.82	11.73	8.22	14.71	11.71
308.45	282.04	292.78	208.42	40.36	39.34
291.33	6.79	10.24	13.05	27.31	10.74
446.88	5.28	6.76	26.17	53.22	6.72
Ex 2 ON	Ex 2 OFF	Ex 3 ON	Ex 3 OFF	Ex 4 ON	Ex 4 OFF
15.76	7.12	25.70	7.31	18.71	7.08
72.41	31.76	50.04	27.11	33.77	14.83
10.03	8.94	11.62	11.43	11.92	11.22
291.83	286.28	69.09	29.92	36.78	29.50
45.04	8.12	42.47	29.93	44.67	8.66
17.45	6.85	13.10	10.66	34.75	7.36
Ex 5 ON	Ex 5 OFF	Ex 6 ON	Ex 6 FF		
20.31	7.55	33.79	21.06		
50.72	21.28	96.28	8.77		
14.22	12.18	11.67	11.13		
53	24.13	138.65	121.11		
40.92	16.36	52.71	8.9		
43.93	25.50	13.50	7.38		

Illustrating raw EMG output for subject 8 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown

		mV			
Subject 9	**Channel**	**Back MVC**	**RA MVC**	**Left MVC**	**Right MVC**
	1		97.13	204.82	191.77
	2		93.53	74.29	130.48
	3		105.47	94.77	102.85
	4	133.99			
	5	106.93			
	6	159.65			
	Baseline 1	**Baseline 2**	**Baseline 3**	**Ex1 On**	**Ex 1 OFF**
Best MVC	**Lying**	**Standing**	**Stool**		
204.82	6.5	9.23	7.47	42.99	6.67
130.48	7.41	19.3	14.12	24.65	11.81
105.47	7.71	21.5	8.13	8.86	7.57
133.99	16.67	16.39	17.27	19.12	9.72
106.93	7.93	8.65	9.52	11.84	9.26
159.65	5.48	6.97	7.17	17.26	7.26
Ex 2 On	**Ex 2 OFF**	**Ex 3 ON**	**Ex 3 OFF**	**Ex 4 ON**	**Ex 4 OFF**
10.68	6.03	11.85	6.27	12.79	6.45
38.58	8.53	16.72	6.81	20.33	8.88
8.94	7.16	8.08	7.57	8.56	7.66
19.41	6.28	15.50	7.97	26.70	10.54
20.34	6.31	10.90	7.53	40.71	8.99
24.95	6.56	8.10	6.99	61.66	6.60
Ex 5 ON	**Ex 5 OFF**	**Ex 6 On**	**Ex 6 OFF**		
20.72	9.06	11.77	7.26		
25.89	11.43	37.48	7.72		
8.39	8.39	8.95	8.25		
16.91	7.62	23.72	9.28		
14.76	8.30	24.82	8.89		
18.01	6.54	34.67	7.42		

Illustrating raw EMG output for subject 9 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown

		mV			
Subject 10	Channel	Back MVC	RA MVC	Left MVC	Right MVC
	1		299.14	264.97	242.23
	2		285.8	198.55	229.08
	3		191.16	238.72	191.07
	4	163.96			
	5	96.49			
	6	149.04			
	Baseline 1	Baseline 2	Baseline 3	Ex 1 ON	Ex 1 OFF
Best MVC	Lying	Standing	Stool		
299.14	36.46	8.72	8.09	58	37.85
285.8	12.18	26.29	14.47	76.51	37.63
238.72	7.93	7.66	8.12	41.9	17.27
163.96	7.33	7.73	14.16	22.44	19.29
96.49	6.61	7.4	7.42	11.42	8.56
149.04	6.46	15.27	8.18	19.25	13.29
Ex 2 ON	Ex 2 OFF	Ex 3 ON	Ex 3 OFF	Ex 4 ON	Ex 4 OFF
51.65	30.07	91.42	61.34	75.26	33.45
25.32	17.27	44.84	15.62	33.34	10.54
50.64	30.86	20.29	21.86	28.49	21.04
30.68	12.75	16.74	15.36	21.66	15.35
14.46	8.32	10.92	7.21	8.94	7.68
21.56	13.18	13.80	13.66	21.74	12.33
Ex 5 ON	Ex 5 OFF	Ex 6 On	Ex 6 OFF		
118.35	67.61	77.65	43.79		
48.23	35.91	112.48	77.96		
50.58	35.27	29.99	13.37		
23.22	17.36	23.73	25.11		
16.58	12.96	13.01	7.58		
46.45	16.99	31.32	12.34		

Illustrating raw EMG output for subject 10 where 3 baseline measures were taken along with MVC (Maximum Voluntary Contraction). Subject then performed the 6 exercises as shown

6. 10 Appendix

Glossary of Terms

ANOVA = A repeated Analysis of Variance

ASIS = Anterior Superior Iliac Spine

EMG = Electromyogram

EO = External Oblique

ES = Erector Spinae

ICLT = Illicostalis Lumborum par Thoracis

LBP = Low Back Pain

LM = Lumbar Multifidus

LSD = Least Significant Difference

MVIC = Maximal Voluntary Isometric Contraction

PSIS = Posterior Superior Iliac Spine

RA = Rectus Abdominus

ROM = Range of Motion

SPMD = Spinal Posture Monitor Device

TES = Thoracic Erector Spinae

TrA = Transverse Abdominus

TrIO = Transverse fibers of Internal Oblique