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OLLSCOIL LUIMNIGH

Raymond McCarthy

0741868

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Stool vs. Back App: A study of lumbopelvic posture, discomfort and perceived effort of sitting

Raymond McCarthy, University of Limerick, Limerick, Ireland

Student ID: *0741868*

Supervisor: *Kieran O Sullivan*

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Authors Declaration

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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Abstract

Title: Back App vs. Stool: A study of lumbopelvic posture, discomfort and perceived effort of sitting.

Authors: Raymond McCarthy, Kieran O Sullivan (SMISCP MISOM M Manip Ther).

Background: Office workers are at substantial risk of developing low back pain (LBP). A dynamic chair called the Back App has been developed and is speculated to improve sitting posture.

Objectives: 1) To compare a) lumbopelvic posture and b) whole body discomfort whilst sitting on a stool, a stable back app and an unstable back app during the performance of controlled deskwork. 2) To determine the perceived effort required to maintain a lumbar lordosis at 30% lumbar range of motion (ROM) whilst sitting on a stool vs. a stable back app.

Methods: Ten subjects completed a ten-minute typing task, a thirty-second office task and a one-minute trial of maintaining a short lordotic posture whilst sitting on both the stool and back app device. Postural data between L3/S2 spinal levels and subjective ratings of perceived discomfort and effort were collected.

Results: A statistically significant increase in lumbopelvic flexion was noted during stool sitting when compared to both stable ($p=0.047$) and unstable ($p=0.018$) back app sitting. Both stable and unstable back app sitting induced lumbopelvic postures close to mid-lumbar ROM with no significant difference between the two ($p=0.241$). Discomfort was low for all sitting exposures with no significant difference between the three ($p>0.05$). No significant difference in perceived effort was noted between stool and back app sitting ($p=0.158$).

Conclusions: Both stable/unstable back app sitting promote lordotic sitting postures and may be effective alternatives to stool sitting. Future studies should investigate the effect of Back App sitting on posture and discomfort in LBP populations.

Keywords: Back App, lumbopelvic posture, discomfort, unstable.

1. INTRODUCTION

Low back pain (LBP) may be both related to work and responsible for the failure to return to work (Spyropoulos *et al* 2007; Iles *et al* 2008). Sedentary workers are at substantial risk with over half of office workers reporting LBP during their lifetime (Lloyd *et al* 1986). It has been suggested that LBP may be connected to increased computer use mediated by ergonomic factors including prolonged periods of sitting, mouse use, the adoption of inadequate postures and the performance of computer-specific tasks (Hakala *et al* 2002; Wilder *et al* 1988; Ortiz-Hernández *et al* 2003).

Furthermore, excessively small furniture forces individuals to sit in a kyphotic posture (Hanninen and Koskelo 2003). Commonly used chairs typically promote a 90º trunk-thigh angle. When individuals lean forward to read and write, the extent of motion is limited by the relative inflexibility of the hip joint and thus pelvic rotation and the modification of lumbar-spine posture are necessary to achieve the movement (Bendix and Biering-Sorensen 1983). Interestingly, sustained lumbar flexion in sitting appears to be no worse for disc health or LBP than relative extension in standing (Claus *et al* 2008). Comparatively, in a decade long follow-up of exposing school children to non-adjustable workstations, older children tended to report LBP more frequently than younger children (Widhe 2001). Equally, Koskelo *et al* (2007) found that exposing subjects to adjustable chairs and desks allowing a trunk-thigh angle of 135º promoted greater lordotic postures and thus decreased lumbar muscle tension and improved muscle strength over a two-year period. Hedman and Fernie (1997) showed that sustained lordotic sitting can both reduce the compressive forces in disc and promote a balancing of zygoapophysial joints forces. Therefore Pynt *et al* (2001) recommend the adoption of a lordotic sitting posture regularly interspersed with movement.

However, the optimal degree of lumbar curvature to achieve whilst sitting is unknown. Although sitting with a short lordosis is considered 'ideal' for standing, it induces the highest level of lumbar multifidus activity in sitting which may contribute to fatigue and pain if sustained (Claus *et al* 2009). Contrariwise it may encourage rehabilitation of the spinal stability system in LBP sufferers (Claus *et al* 2009). Similarly, a flat lordotic posture may be the most efficient as it demonstrates the lowest muscle activity (Claus *et al* 2009). Irrespective of muscle activity, no literature pertaining to the perceived effort of sitting currently exists and may prove useful in determining the difficulty of maintaining lordotic sitting postures on different chair exposures.

Although backrests help stabilise the lumbar-spine during sitting, they may instigate relative kyphotic increases, reduce spinal motion and thereby compromise disc nutrition (Bendix *et al* 1996). In light of this, the effects of unstable and unsupported sitting on lumbopelvic posture have been investigated. Although there is a paucity of literature in this field, it is postulated that unstable sitting facilitates the activation of spinal stabilising muscles around a neutral spine position (Farrell *et al* 2000). Gregory *et al* (2006) found no significant difference in lumbar-spine posture between back-supported office-chair sitting (mean= 43.4% flexion) and exercise-ball sitting (mean= 43% flexion) whilst performing four office tasks over two one-hour periods. Interestingly, O Sullivan *et al* (2006) found no significant difference in lumbar-spine kinematics and pelvic tilt between a five-minute exposure of sitting on a stool and an air-filled cushion. McGill *et al* (2005) reported a greater degree of posterior pelvic tilt during supported sitting (23.3°) when compared to exercise-ball sitting (18.3°); however no significant difference in spine flexion angle was observed between both exposures. Although no significant difference in posture between stable and unstable sitting has been documented, trials are flawed with methodological shortcomings and studies comparing both with a standardised sitting option are warranted to render closure to speculation. Callaghan and McGill (2001) found that prolonged unsupported sitting for a period of two hours on a backless office chair promoted lumbar spine postures ranging from 30-80% of maximal lumbar flexion. An incorporated element of uncontrolled deskwork may have been responsible for such variation. Therefore a study that standardises office tasks is warranted to determine whether unsupported sitting can induce specific changes in lumbopelvic curvature.

Studies pertaining to the effect of purposely designed office chairs on lumbopelvic posture are currently lacking. Gadge and Innes (2007) proposed a stable back-supported sitting device called the Bambach^{TM} saddle seat which allowed a seat angle of +105º. Pain-free subjects performed typing tasks whilst sitting for two-hours. When compared to a standard back-supported office chair which allowed a 90º seat angle, the Bambach^{TM} promoted greater trunk-thigh angles and thus facilitated more optimal sitting postures. Interestingly, such exposure induced significantly less low back discomfort but caused considerably more hip/buttock discomfort. In light of such findings, it would be interesting to compare the effect of sitting on both a stable saddle seat and a typical office-chair to an unstable saddle seat during the performance of a task to determine whether any differences in lumbopelvic posture or discomfort levels exist. 'Back app' [Figure 1] is a recently developed saddle-design chair that creates a hip angle of > 90° and therefore is speculated to promote greater lordotic sitting postures (Back App 2010). A cushion underneath the footplate of the back app is theorized to make movement more comfortable. The back app can function as a stable device by adjusting the stability component located at the base of the chair to the green zone or as an unstable device by adjusting to the black zone. It can also incorporate a training element by adjusting the base of the chair to the red zone [Figure 5]. Although theorised to allow gentle rotation about the vertical axis and promote a preferable sitting posture, its clinical applicability to the office environment cannot be assumed given there is currently no literature in existence that has investigated its role in ergonomic health.

Therefore the aims of this study were:

- To compare 1) lumbopelvic posture and 2) overall body discomfort whilst sitting on stable and unstable surfaces (stool* vs. stable back app vs. unstable back app) during the performance of controlled deskwork.

- To determine the perceived effort required to maintain a lumbar lordosis at 30% lumbar range of motion (ROM) whilst sitting on two different stable surfaces (stool vs. stable back app).

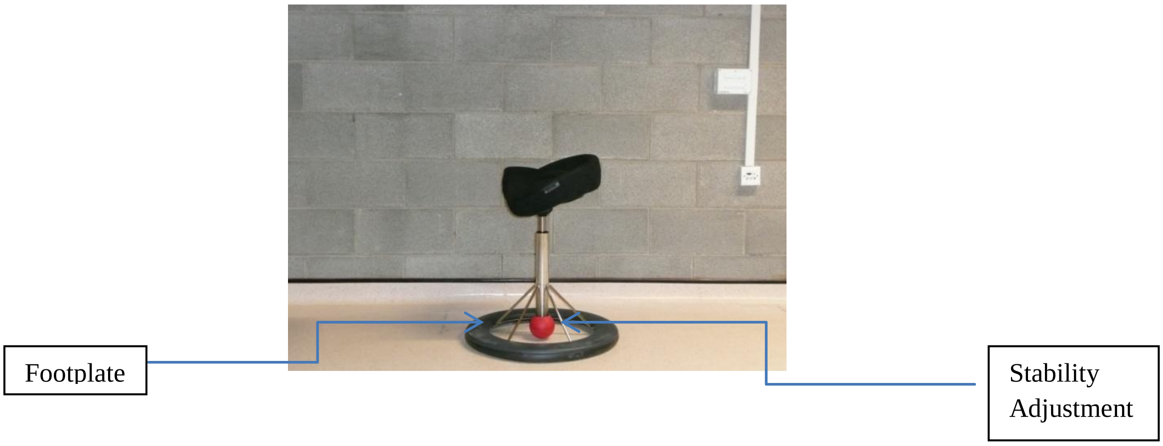

Figure 1: *Back App Chair*

** Stool sitting was examined as the standardised sitting option. Similar to 'Back app', stools are unsupported and thus the risk of a backrest-induced confounding effect to lumbopelvic posture, discomfort levels and effort was eliminated. Therefore valid comparisons could be made.*

2. MATERIALS AND METHODS

2.1. Ethics

Ethical approval was obtained from the Clinical Therapies Research Ethics Committee.

2.2. Study Design

A single session crossover repeated measures design was used. Testing was carried out within the Physiotherapy Department at the University of Limerick. This study was conducted as part of a larger collaborative experimental study which also investigated the effect of dynamic sitting on trunk muscle activation.

2.3. Subjects

Ten pain-free subjects were recruited from within the University of Limerick student population by word of mouth. Mean (±SD) age, height and body weights were 22.7 (±2.9) years, 1.70 (±0.5) metres and 66.8 (±10.9) kg respectively General exclusion criteria were: (I) aged < eighteen years, (II) currently pregnant, (III) currently taking pain medication, (IV) known allergy to tape, (V) a history of LBP over the previous year or (VI) a history of back surgery. As nine of the ten subjects were physiotherapy students/graduates, previous awareness of spinal posture and ergonomics was acknowledged. Investigators ensured that the information needs of participants were met through the supplementation of an information leaflet and the answering of questions [Appendix 1]. Written informed consent was obtained [Appendix 2].

2.4. The BodyGuard™ - Spinal Position Monitoring Device (SPMD)

In this study the BodyGuard™ was used to measure lumbopelvic posture [Figure 2]. This novel wireless device measures spinal sagittal plane posture and therefore was chosen to eliminate the risk of interference that cumbersome cables may have on the facilitation of normal movement patterns. The SPMD incorporates a strain gauge that provides information about the relative distance between anatomical landmarks. Thus an estimation of flexion/extension ROM can be expressed as a percentage of strain gauge elongation. Measurement of posture relative to ROM has been previously explored (Edmondston *et al* 2007).

The BodyGuard™ has been shown to have excellent reliability for analysis of lower lumbar spine sagittal posture both between days and between raters (O Sullivan *et al* 2011). Furthermore this device has been used to calculate spinal posture in recent studies that investigated lumbar spine repositioning sense; postural differences between rowers with/without LBP and the inter-rater reliability of positioning subjects into a neutral sitting posture (O Sullivan *et al* 2010a; MacManus and O Sullivan 2010; O Sullivan *et al* 2010b). Considering varying magnitudes of muscle activity are responsible for subtle changes in lumbar spinal curvature during sitting (Claus *et al* 2009), the SPMD can be justified as an appropriate measure for use in this study as it has been suggested to detect subtle local changes in lumbar posture in comparison to similar-sized devices which measure overall trunk flexion (Intolo *et al* 2010; Horton and Abbott 2008). Postural data collected was recorded in real time at 1 HZ.

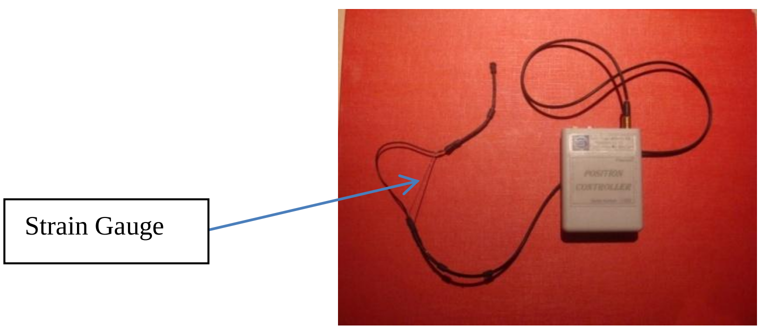

Figure 2: *The Bambach™*

2.5. Sitting Devices- Stool vs. Back App

Both a stool, stable Back App and an unstable Back App were compared for the purpose of this study. The stool was adjustable, backless and had wheels. The Back App has been previously discussed [page 8]. Both chairs were standardised to eliminate the effect of subject height variation on postural outcome. As the intra-rater and inter-rater reliability of goniometry for the knee joint is high (Rothstein *et al* 1983), goniometry was used to measure both hip and knee angles. The stool was adjusted to allow an angle of 90º for both the hips and knees with feet placed firmly on the floor [Figure 3]. The back app chair was adjusted to allow a 125º trunk-thigh angle with feet placed on the footplate [Figure 4]. The green (stable) and black (unstable) zones were examined in this study [Figure 5].

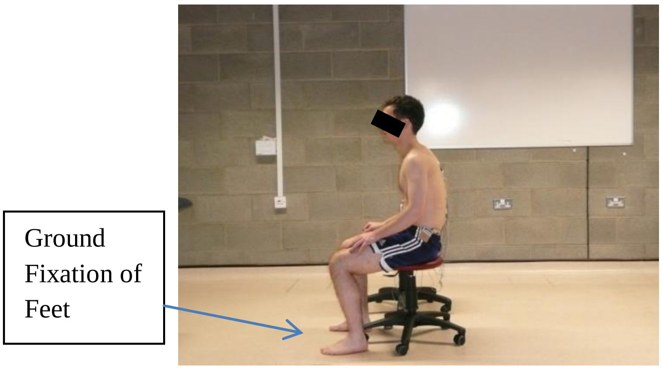

Figure 3: *Standardised Stool Sitting*

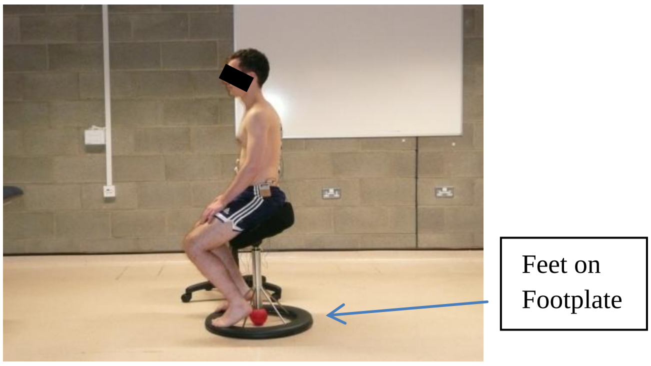

Figure 4: *Standardised Back App*

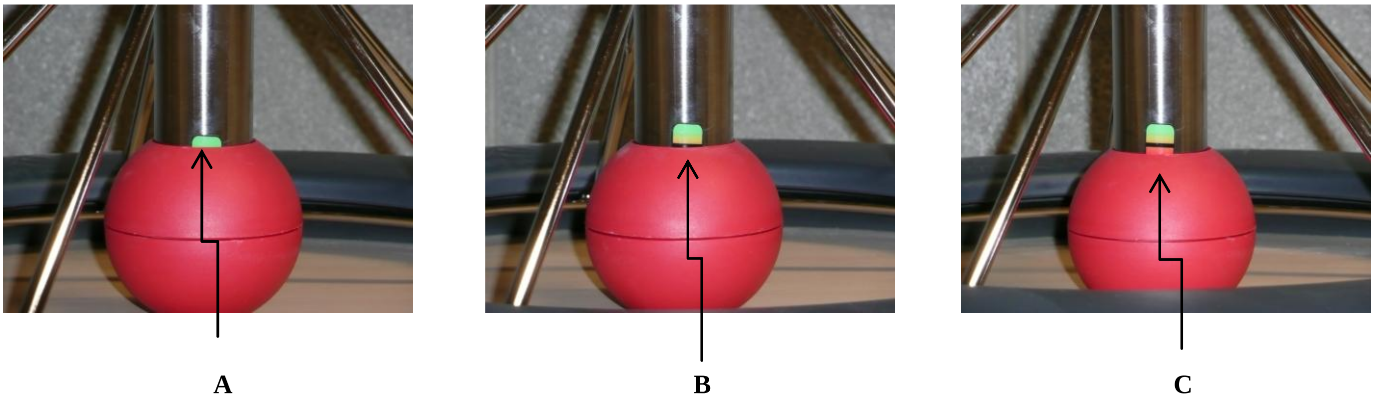

Figure 5: *Back App Stability Adjustment: A) Green Stable Zone, B) Black Unstable Zone, C) Red Training Zone [not examined in this study]*.

2.6. Simulation of an office environment

To accommodate for the element of deskwork **[see 2.8.]**, a work-station was created [Figure 6]. Considering that the self-selection of workstation set-ups can be associated with the adoption of less than optimal sitting postures (Gadge and Innes 2007); both the distance from and height of workstations were standardised. Whilst sitting stationary, subjects were asked to flex their elbows to a 90° angle and keep them fixed in line with the trunk. The desk which took the form of an adjustable plinth was then elevated until it reached the level of the elbow. Following this, the desk was positioned in line with the radial styloid process. The computer was placed directly in front of subjects, 10cm from the end of the plinth.

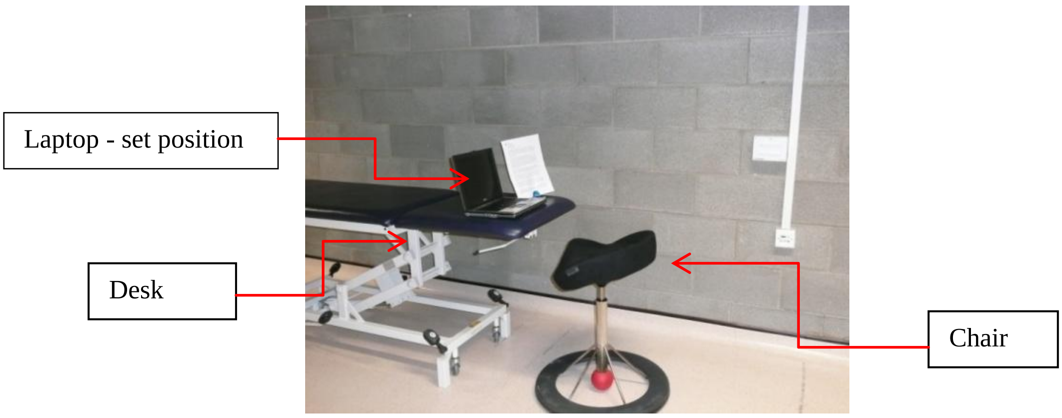

Figure 6: *Work-station set up*

2.7. Subject Preparation/ Calibration

Following standardisation, subject height and weight were measured. During preparation, subjects sat on a stool wearing shorts with their feet on the ground and arms resting on their thighs. As there is indirect evidence to suggest that prolonged sitting increases loading of the passive tissues surrounding the lower lumbopelvic intervertebral (IV) joints, sagittal spine posture between L3 and S2 was chosen for investigation in this study (Dunk *et al* 2009). Furthermore, the lower lumbar spine has been reported to be the most common site of non-specific chronic low back pain (Dankaerts *et al* 2006) and demonstrates functional independence from the upper lumbar spine (Dankaerts *et al* 2006; Mitchell *et al* 2008). Palpation of L3 and S2 spinal levels was achieved whilst subjects sat in a slightly flexed position. Landmarks were confirmed by a second investigator to ensure accuracy. As physiotherapy students with supplementary information are significantly better at identifying lumbar landmarks (Phillips *et al* 2008), both investigators underwent a revision session of lumbar anatomy prior to testing. Following hair removal and cleansing, the SPMD was positioned over these landmarks and secured with tape. Maximal lumbar ROM was then performed to ensure the device was safely attached. To calibrate the SPMD, manual and verbal facilitation were used to guide subjects into maximal lumbar flexion which was set as 100% of their lumbar ROM and then into maximal lumbar extension which was set as 0%. The commands used were *'slump your low back as far as it will go'* and *'arch your low back up as far as it will go'*. Thereafter, the primary investigator was blinded to the computer screen and assisted subjects through five trials of maximal flexion and extension to make sure maximal lumbar ROM was consistent with initial calibration points.

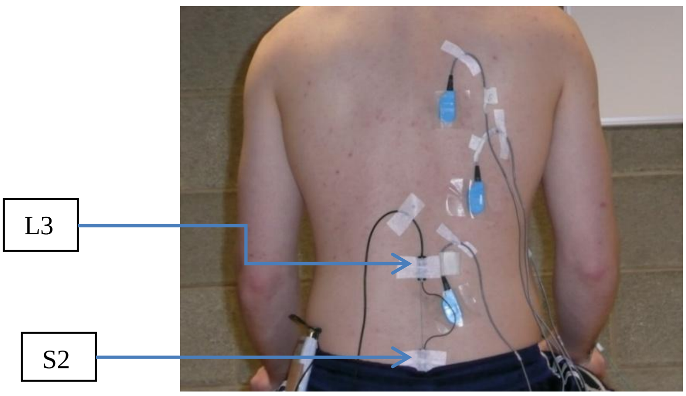

Figure 7: *Secured SPMD*

2.8. Procedure

Subjects were presented with three opaque sealed envelopes in which they randomly selected the order in which they would sit on the different chairs. Postural data collected was continuous for all measurements and output was saved to a laptop. Subjects were instructed to sit as they normally would and commenced a ten-minute typing task three times (one on each chair) [Figure 8]. All subjects typed the same piece of literature which was on a stand to the side of the computer screen. A laptop with a self-touch mouse was used. At baseline, five-minutes and ten-minutes of each sitting exposure, subjects were asked to rate their discomfort levels on the Body Part Discomfort Scale (BPDS) orally. The BPDS [appendix 3], developed by Corlett and Bishop (1976) is a perceived discomfort rating scale. The chart indicates 12 body parts and subjects rate their discomfort level on a 5-point scale where 0 = 'no discomfort' and 5 = 'extreme discomfort'. The BPDS has been extensively used and modified for chair and seat evaluation and has been reported as an easy to use scale requiring almost no training for subjects (Drury and Coury 1982; Thomas *et al* 1991). Considering discomfort was measured at three intervals throughout each sitting exposure during the typing task, the BPDS was chosen over other scales to minimize distraction from the typing task.

Following each ten-minute typing task, subjects performed a thirty-second office task whilst remaining seated. Such involved leaning forward to pick up a ringing phone from a set distance, answering it, placing it back down to its original position, arranging a number of coded pages in order of numbered sequence and stapling them together. Once both elements of deskwork were completed, a one-minute break was given between sitting exposures to provide a rest/change phase of muscle activation and low-back loading thereby minimising the confounding effects of fatigue and discomfort that could potentially influence the validity of data collected.

In the final stage of the trial, subjects were asked to maintain a posture 30% from maximal lumbar extension (short lordosis: flat/kyphotic thoracic with lordotic lumbar-spine) as they sat for a one-minute period on both the stool and the stable back app in randomised order. Following both trials, subjects were asked to determine the perceived effort of sitting on the stool vs. the stable back app using the Verbal Numerical Rating Scale (score of 0-10). At the end of data collection, lumbar ROM was recalibrated to ensure that initially calibrated maximal values were repeatable.

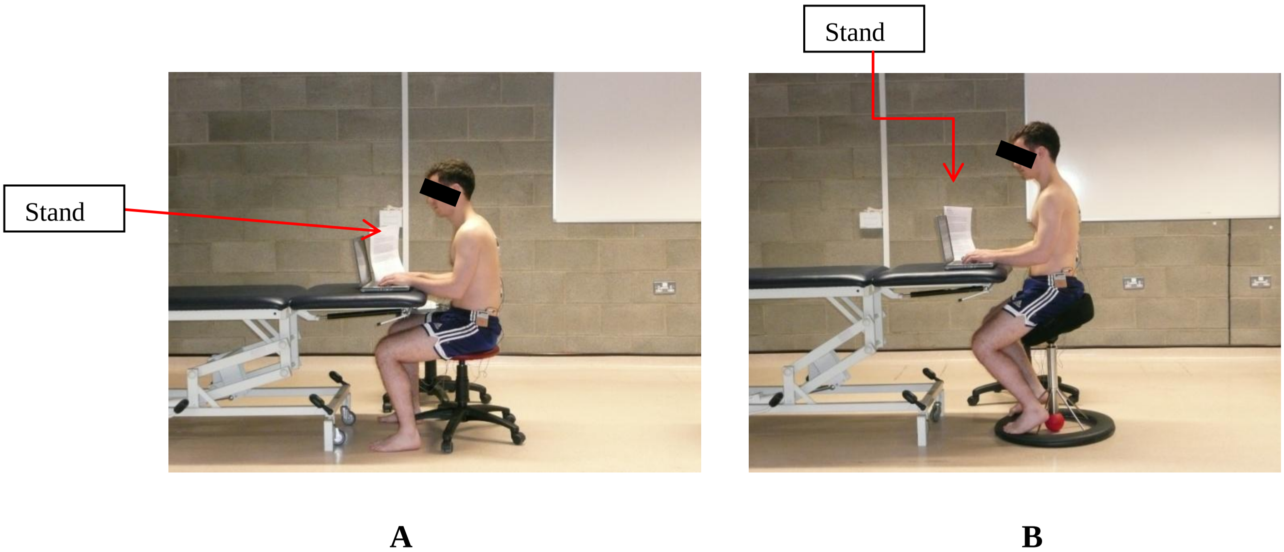

Figure 8: *Performance of a ten-minute typing task on A) the stool and B) the back app*

2.9. Data Analysis

Data was analysed using the Statistical Package for Social Sciences (SPSS version 16.0). As values of ROM did not change dramatically overtime during each exposure [Appendix 4b-d], one single mean and standard deviation were calculated for each sample of continuous data. Although the Shapiro-Wilk test confirmed that not all data was normally distributed ($p<0.05$), on visual inspection, data represented a normal distribution. All body parts were analysed collaboratively as 'overall body discomfort'. As some subjects reported the presence of discomfort prior to the initiation of typing task trials, the progression of discomfort overtime (overall body discomfort at ten-minutes – overall body discomfort at baseline) was analysed to accurately determine whether specific sitting devices expose subjects to a higher risk of discomfort. Repeated measures analysis of variance (ANOVA) with Least Significant Difference (LSD) post-hoc analysis was thus used to examine differences between (I) lumbopelvic posture on the three sitting devices during the performance of the ten-minute typing task and the thirty-second office task and (II) the progression of discomfort in the three sitting exposures. Mauchly's test showed that sphericity could be assumed for most data (>0.05) and if not, the Greenhouse-Geisser estimate was used. A paired sample test was used to examine the difference between 1) the perceived efforts required for maintaining a range 30% away from maximal lumbar extension and 2) the actual posture maintained whilst sitting for one-minute on the stool vs. the stable back app.

3. RESULTS

3.1. Subjects

All ten subjects selected for participation were included and completed the study. Baseline one-minute measures of lumbopelvic posture were taken for standing (mean = 10.22% ROM) and sitting on a supported office chair (mean = 53.65% ROM).

3.2. 10 Minute Typing Task

During the performance of the typing task, there was a statistically significant increase in lumbopelvic flexion in subjects sitting on the stool (mean = 70.13%) when compared to both the stable (mean = 46.34%; p-value 0.047) and unstable (mean = 45.73%; p-value 0.018) back app. There was no statistically significant difference in lumbopelvic posture between stable and unstable back app sitting (p-value 0.241).

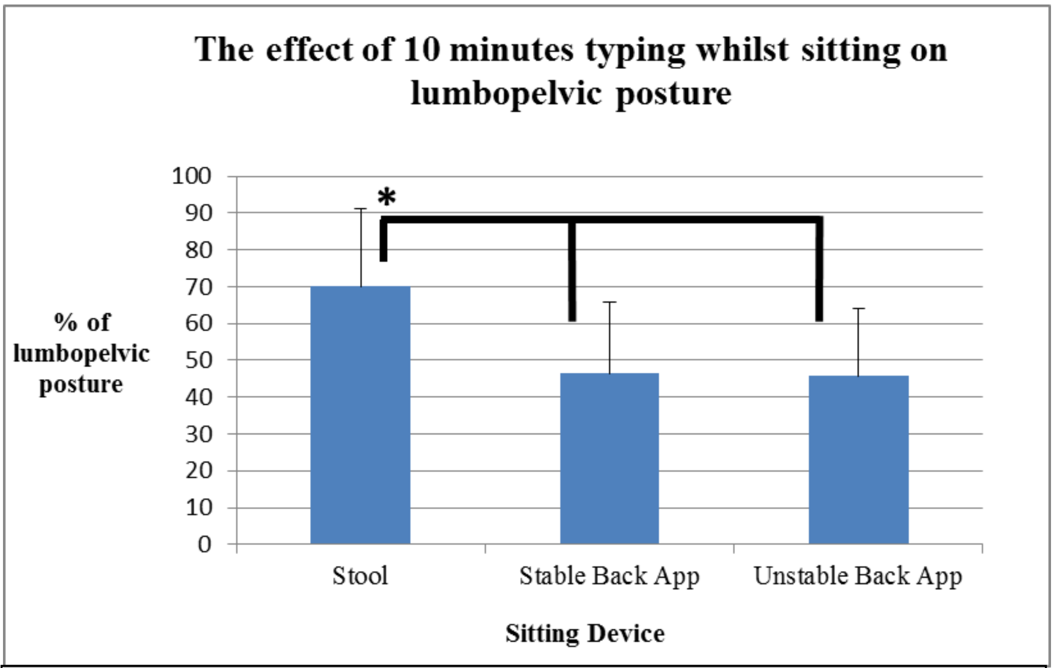

Figure 9 - * *shows a statistically significant difference in lumbopelvic posture between stool sitting and the other two sitting arrangements.*

3.3. 30 Second Office Task

During the performance of the 30 second office task, subjects sat closer to maximal lumbar extension on both the stable (mean = 53.54%) and unstable (mean = 49.05%) back app when compared to stool sitting (mean = 67.10%). However such differences in lumbopelvic posture were not statistically significant (p-value > 0.05).

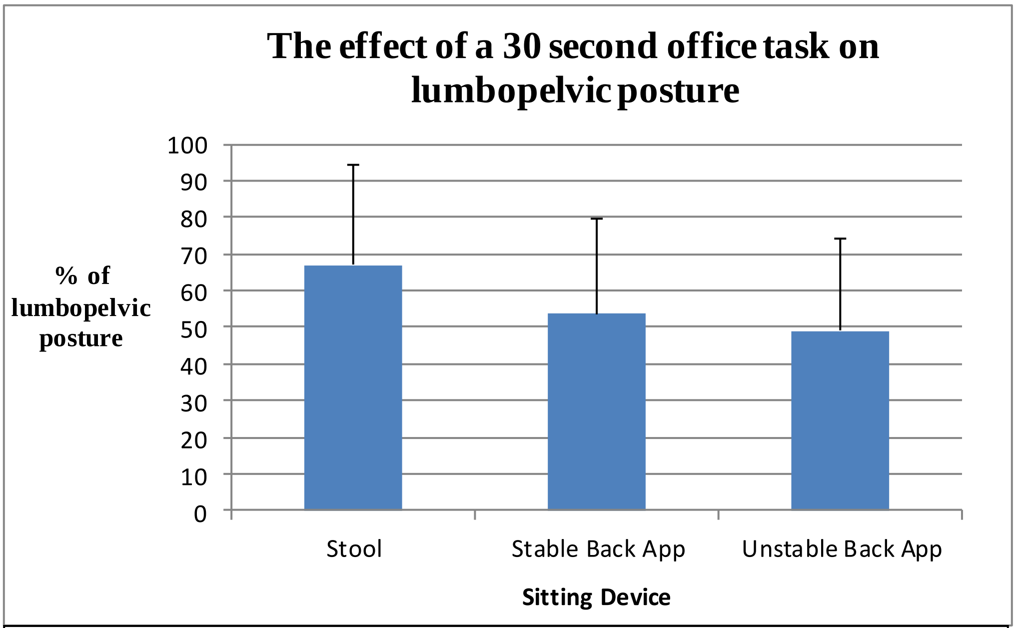

Figure 10: *No statistically significant difference in lumbopelvic posture between the three sitting exposures (p-values > 0.05)*

3.4. Progression of Discomfort

Regardless of chair type, body part discomfort levels amongst participants increased as the test advanced. The mean progression of discomfort during the typing task ranged from 0.16/5.0 (±0.17/5.0) on the randomised first chair to 0.21/5.0 (±0.19/5.0) and 0.23/5.0 (±0.24/5.0) on the second and third chairs respectively. Although evident, the increases in discomfort from the randomised first chair to the third chair were not statistically significant (p-values > 0.05). With regards to chair type, the progression of discomfort during the typing task was small on both the stool (0.18/5.0 ±0.16/5.0), stable back app (0.22/5.0 ±0.25/5.0) and unstable back app (0.19/5.0 ±0.18/5.0) and there was no statistically significant difference between the three (p-values > 0.05).

3.5. Effort at 30% of Lumbopelvic Posture

Although subjects found it more difficult to maintain a lumbopelvic posture 30% from maximal lumbar extension for 1 minute when sitting on a stool (mean= 4.1/10) in comparison to the stable back app (mean = 3.4/10), the difference in effort required was not statistically significant (p-value 0.158). The mean posture maintained on the stool (31.33%) and the stable back app (31.93%) was not significantly different (p-value 0.709).

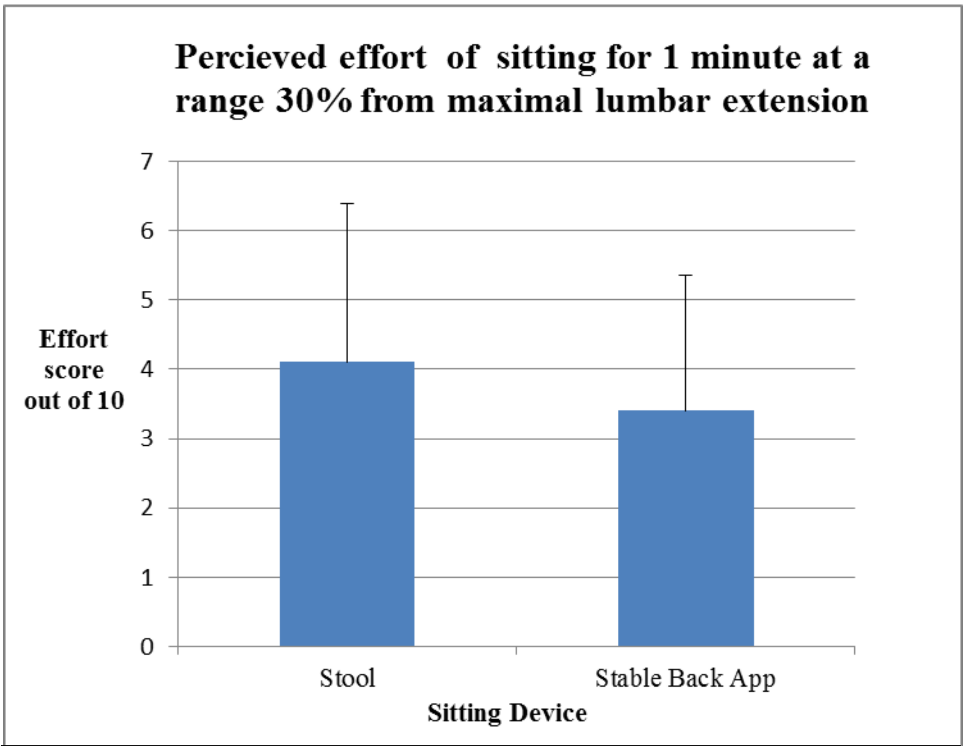

Figure 11: *No statistically significant difference in the perceived effort of sitting on a stool or stable back app at 30% lumbopelvic ROM for a 1 minute period*

4. DISCUSSION

4.1. Lumbopelvic Posture during controlled deskwork

The results of this study indicate that during a ten-minute exposure to typing [statistically significant] and a thirty-second exposure to an office task [although non-significant], subjects tend to sit closer to maximal lumbar flexion on an unsupported stool when compared stable and unstable back app sitting. Back app sitting may therefore be preferable considering flexion angles exceeding 75% ROM, can generate high tensile forces in the posterior ligaments of the spine (Adam *et al* 1994). Furthermore, the flexion-relaxation phenomenon reduces erector-spinae muscle activity thus potentially transmitting further load to passive spinal structures (Callaghan and Dunk 2002). Thus being the narrowest component of disc and least able to sustain large compressive loads, the posterior annulus may be at increased risk of weakening and herniation in slump sitting (Adams *et al* 1996). Although not examined in the current study, such evidence may be extrapolated to support speculations that back app sitting could promote optimal working environments.

Furthermore, DeCarvalho *et al* (2010) found that sitting postures encourage substantial flexion of IV joints. In upright sitting, L5/S1 spinal levels have been shown to flex to 60% of their total range of motion. In comparison, the lower three IV joints reach end of range flexion in slump sitting (Dunk *et al* 2009). Therefore as the back app encourages subjects to adopt a sitting posture closer to end of range lumbar extension, its clinical feasibility may exceed that of the standard stool considering the natural movement behaviour of the lumbopelvic region towards flexion.

Although sustained lordotic sitting postures have been shown to exhibit lower disc pressures than slumped postures (McMillan *et al* 1996), it has also been suggested that such may induce unreasonable stress on the lumbar multifidus and thus contribute to pain and fatigue (Claus *et al* 2009). However in the current study, lumbopelvic posture on the stable and unstable back app approximated at mid-range of lumbar motion for both the typing and office tasks. Thus considering a flat lordotic posture may be deemed the most efficient sitting posture, demonstrating the lowest muscle activity of all upright postures (Claus *et al* 2009); the back app may be justified as an effective choice of chair-design.

It is interesting to note that in the current study, there was a significant difference between the two stable sitting devices [back app and stool] during the ten-minute typing task. Such has been reported in a previous study where a stable saddle seat induced significantly greater trunk-thigh angles compared to a stable office chair during the performance of a thirty minute typing task (Gadge and Innes 2007). Authors of this study suggested that standard office-chair sitting at 90° seat angles encourage the buttocks to shift forwards thus inducing lordotic flattening. Therefore it may be suggested that by allowing greater trunk-thigh angles, the back app encourages forward inclination of the pelvis and thus preservation of a lumbar lordosis. Such may explain the significant difference between both exposures.

As anticipated, lumbopelvic posture didn't differ between stable and unstable sitting on a back app during both the ten-minute typing and thirty-second office tasks. This finding is consistent with a previous study which compared stable sitting on a stool to unstable sitting on a stool [sit-fit cushion] for a five-minute period. The same seat/seat angle was used to determine differences in stable and unstable sitting postures. As this strategy was also used in the current study, it may be suggested that altered stability doesn't affect lumbopelvic curvature. Furthermore, no significant differences in lumbopelvic posture were noted for standardised sitting on an exercise ball vs. a stool for thirty-minutes or an exercise ball vs. a back-supported chair for a one-hour exposure to typing and reading (McGill *et al* 2004; Gregory *et al* 2006). Although it can be argued that ten-minute exposures to sitting may have been too short to induce changes in lumbopelvic posture between stable and unstable devices, the previously mentioned studies investigated effects over longer time-frames with similar outcomes. Equally in the current study, the level of instability that the black zone allowed is questionable. Some subjects reported not being able to tell the difference in stability levels between both exposures. Therefore investigation of the red training zone of the back app may have been more informative.

Interestingly, stable sitting on a stool for a period of ten-minutes induced significantly more flexion than unstable sitting on a back app. As stable and unstable back app sitting didn't differ significantly, such further reinforces the line of reasoning that trunk-thigh angles may be associated with sustained lumbopelvic postures more so than stability components. As sitting with greater trunk-thigh angles (135°) during the performance of deskwork can positively influence sitting and standing posture, muscle tension and productivity over a two-year period (Koskelo *et al* 2007), future study of the effect of back app sitting on lumbopelvic postures and perceived symptoms in LBP populations would be useful.

With specific attention to the thirty-second office task, although stool-sitting induced more lumbar flexion, differences between stool-sitting and back app sitting were non-significant. Considering subjects performing a variety of tasks including reading, homework and computer tasks demonstrated postures that ranged from 30-80% of lumbar ROM over a two-hour period (Callaghan and McGill 2001), a thirty-second office task incorporating a variety of tasks may have been too short a time-frame to ascertain a mean posture that can represent the widespread effect of typical office tasks. Furthermore although the task was standardised, subjects may have spent more time doing specific parts of the task on specific chair exposures e.g. leaning forward to pick up the phone. Therefore isolating specific components of the task may have been useful in determining whether significant postural differences could be achieved between exposures. Also considering variation in time taken to perform specific task components as a possible limitation, ten subjects may have been too small a sample size to induce statistically significant differences in lumbopelvic posture between the back app and the stool and thus examination of a larger sample may have been useful.

4.2. Progression of Discomfort – typing task

Although non-significant, the progression of overall body discomfort reported in this study supports the already well-established relationship between time and discomfort (Smith *et al* 1998) where discomfort tends to increase with length of task performance time regardless of the seat being used (Gadge and Innes 2007).

Interestingly, there was no significant difference in the progression of discomfort between stable back app, unstable back app and stool sitting during the ten minute typing task and all induced very low discomfort levels. Previous literature has shown that supported sitting for 25-minutes with a trunk-thigh angle of 90º whilst reading and writing can induce significant discomfort in the lumbar and neck regions (Vergara and Page 2002). It is therefore interesting to note in the current study that overall body discomfort induced on an unsupported stool which was also standardized to allow a trunk-thigh angle of 90º did not differ from that of a back app allowing a 125º hip angle. Furthermore, in previous research, unstable components of sitting have been suggested to place strain on the lumbar-spine whereas backrests have been found to reduce such risk (Gale *et al* 1989; Leivseth and Drerup 1997). In light of such contrasting findings, ten-minute typing may potentially have been too small a timeframe to induce discomfort and thus may have been responsible for the non-significant difference amongst the three exposures. Equally, sustained static postures have been suggested to generate discomfort (Kroemer and Grandjean 1997). By ensuring a rest-break between exposures as recommended by Waersted and Westguard (1991), higher discomfort levels associated with static postures may have been prevented in this study.

It is encouraging that both stable and unstable back app sitting induced low levels of discomfort with no significant difference between the two. Gale *et al* (1989) demonstrated that saddle-chairs promote lordotic sitting postures and thus generate less low back discomfort. Similarly, Gadge and Innes (2007) found that back-supported sitting on the Bambach^{TM} saddle seat whilst performing 4 30-minute typing tasks resulted in significantly less low-back discomfort when compared to standardised office chair sitting. The analysis of individual body part discomfort was beyond the scope of the current study however considering saddle seats have been shown to induce consistently more lower-limb discomfort than standard chairs, it was important explore a broader view of discomfort (Gadge and Innes 2007). Furthermore, Gregory *et al* (2006) found that whole-body discomfort was significantly higher after a one-hour period of exercise-ball sitting when compared to a standard office-chair. In support of all sitting exposures in the current study, workstation set-up was standardised so that optimal postures could be adopted and such may have been responsible for the non-significant differences in discomfort progression. Equally, the stool was randomised as the first chair for 6/10 subjects which may have introduced a performance bias and thus validity of stool data may have been affected.

4.3. Effort at 30% of Lumbopelvic Posture

Interestingly the perceived effort required to maintain a lumbar lordosis at 30% of lumbar ROM for one-minute was low for both stool and stable back app sitting with no significant difference between the two. In support of this, postural data shows that 30% lumbopelvic ROM was sustained for both 1-minute trials without any macro-movement variation. This finding can be compared to previous work that suggests a relationship between backrest support and muscle activity (Chaffin and Andersson 1991). Gale *et al* (1989) found that sitting with inadequate back-support on both a saddle chair and a standard office-chair can induce resultant muscle fatigue overtime. Thus one-minute may have been too short a sitting time to accurately determine a true of measure of perceived effort for both unsupported options examined in this study. Furthermore, subjects were asked to maintain a short lordotic posture and such demonstrates higher muscle activation levels (16.8% Maximum Voluntary Contraction- MVC) than long lordotic, flat lordotic and slump sitting postures (Claus *et al* 2009). Considering 5% MVC's of erector spinae muscles can be maintained for thirty minutes (van Dieën *et al* 2009), sustained short lordotic sitting on the back app may exceed the endurance capacity of the erector spinae muscles given the greater trunk-thigh angle. Thus longer sitting trials are needed to determine whether perceived effort differs between standard stool and back app exposures. Furthermore for subjects whose lumbar multifidus activity is compromised by LBP, the short lordosis may be even harder to sustain (Claus *et al* 2009). Although lordotic sitting interspersed with movement is recommended (Pynt *et al* 2001), future investigation of the perceived effort of lordotic sitting on the back app is warranted in LBP populations to determine whether such work can be achieved reasonably.

5. CONCLUSION

Although study limitations exist and have been acknowledged in this report, efforts were made to minimise the risk of performance bias, confounding effects and data contamination. This study shows that by promoting postures closer to mid/end lumbopelvic ROM, the stable/unstable back app may be more preferable than stool sitting. Such findings are likely to be related to the greater trunk-thigh angles that the back app allows more so than its dynamic nature. Although both whole body discomfort and perceived effort of sitting do not differ between stool and back app sitting, both are low and thus the back app may be justified as an effective alternative to the stool. Therefore future study of both the short and long-term effects of back app sitting on lumbopelvic posture and perceived pain, discomfort and effort of sitting in LBP populations is warranted to determine whether 'back app' could be implemented as an effective component to therapy.

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8. APPENDICES

Appendix 1 – Subject Information Sheet

UNIVERSITY of LIMERICK

OLLSCOIL LUIMNIGH

Title of study:

Comparison of Trunk Muscle Activity and Lumbar Posture in Stable Seating versus Unstable Seating

Figure 1: 'Unstable' Office Chair

Figure 2: 'Stable' Office Stool

Figure 3: Posture device

Figure 4: Sample EMG equipment

Aim of Study:

The aim of this study is two-fold:

- To compare trunk muscle activity during prolonged sitting on a standard office stool and during prolonged sitting on an unstable office chair.
- To compare lumbo- pelvic posture during prolonged sitting on a standard office stool and during prolonged sitting on an unstable office chair.

What will you have to do?

- If you are willing to participate, you will be asked to undergo measurement of your trunk muscle activity and posture in a laboratory in the Health Sciences building at the University of Limerick.
- The testing will require you to expose the skin of your lower back and abdomen so that Electromyography (EMG) electrodes (figure 4) and a small posture monitoring device (SPMD) (figure 3) can be placed on your skin.
- The EMG electrodes will measure trunk muscle activity. They are non- invasive, they are adhered by a sticky underside and do not cause any discomfort. Your skin surface where electrodes are to be placed will be prepared by gently abrading the skin and cleansing with alcohol, and shaving the skin to remove hair if necessary. Following adherence of these electrodes you will be required to perform three sit up exercises and one back extension exercise to calibrate the EMG system.
- The posture device is non-invasive, is adhered by sticky tape and does not cause discomfort.
- Following calibration you will sit on three chairs for 10 minutes each while typing, with a two minute break in between each chair.
- You can withdraw from the testing at any stage should you be uncomfortable. All testing will be done in one session on one day and total participation time will be approximately 150 minutes.

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?

The researchers do not anticipate any significant risks to the participants apart from a minor risk of muscle stiffness. However if you;

- Are under 18
- Are pregnant
- Have an allergy to tape
- Have a history of back pain over the previous 2 years
- Have had previous back surgery
- Are on any current pain medications

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

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 any time, 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. A time and date can then be arranged when the testing will take place.

Investigators: Kieran O'Sullivan; Alison White; Raymond McCarthy; Wim Dankaerts, Leonard O'Sullivan.

Email contact: 0127965@studentmail.ul.ie (Alison White)
0741868@studentmail.ul.ie (Raymond McCarthy)

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

Appendix 2 – Subject Informed Consent Form

UNIVERSITY of LIMERICK
OLLSCOIL LUIMNIGH

Title of Study: Comparison of Trunk Muscle Activity and Lumbar Posture in Stable Seating versus Unstable Seating

Investigators: Kieran O'Sullivan; Alison White; Raymond McCarthy; 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

consent to involvement in this study and give my authorization 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* _______________

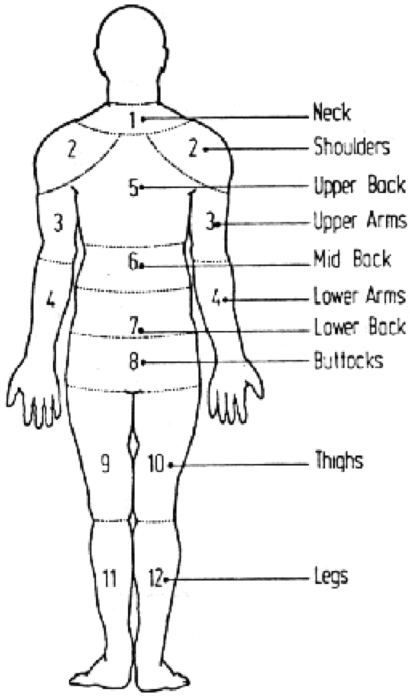
Subject

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: ______________

Appendix 3 – Body Part Discomfort Scale

A Technique for Assessing Postural Discomfort



Body regions.

Date: ______________________________

Subject: ____________________________

Time (0-10min):	Baseline	5min	10min
BPDS Score:	**(0-5)**	**(0-5)**	**(0-5)**
1. Neck			
2. Shoulders			
3. Upper Arms			
4. Lower Arms			
5. Upper Back			
6. Mid Back			
7. Lower Back			
8. Buttocks			
9. Left Thigh			
10. Right Thigh			
11. Left Leg			
12. Right Leg			

Appendix 4 – Raw Data

Subject No.	Standing	Supported Sitting
1	7.36	21.25
2	24.99	41.79
3	7.51	32.77
4	-3.68	85.96
5	7.23	80.52
6	13.15	85.67
7	19.75	73.85
8	12.64	47.83
9	10.91	56.83
10	2.34	10.08

A: *Mean Values for baseline 1 minute measures of standing and sitting on a Back- supported office chair.*

Subject No.	Min 1	Min 2	Min 3	Min 4	Min 5	Min 6	Min 7	Min 8	Min 9	Min 10	10 Min Mean	10mins STDEV
1	33.28	32.48	34.36	35.31	42.77	44.32	44.41	52.88	62.1	56.46	43.84	10.58
2	46.29	46.21	45.3	44.9	45.08	47.74	45.51	45.56	44.93	44.74	45.63	1.21
3	62.82	61.25	64.57	61.5	54.02	64.21	63.01	60.7	63.68	58.14	61.39	5.15
4	110.77	102.31	105.29	112.54	119.1	117.48	109.68	114.53	114.5	114.54	112.07	6.41
5	49.7	52.21	55.55	60.86	62.6	62.82	63.47	63.3	68.49	72.68	61.17	9.61
6	102.23	99.08	98.49	92.2	88.34	84.21	82.13	80.31	79.93	79.22	88.61	8.6
7	68.64	68.58	69.41	68.9	69.66	59.57	60.82	61.99	64.12	65.96	65.77	3.96
8	63.71	67.48	73.12	73.63	73.68	71.02	70.07	66.26	67.76	67.85	69.46	3.96
9	90.78	83.56	65.84	53.9	54.04	58.66	54.8	70.4	50.42	60.79	64.32	15.01
10	84.78	86.37	87.7	88.86	90.17	87.05	90.41	91.33	91.44	92.24	89.04	2.76

B: *Mean Values for each minute of the ten minute typing task whilst sitting on a STOOL. Mean value and standard deviation (STDEV) for the whole ten minute period also included.*

Subject No.	Min 1	Min 2	Min 3	Min 4	Min 5	Min 6	Min 7	Min 8	Min 9	Min 10	10 Min Mean	10 Min STDEV
1	60.98	59.49	56.71	55.55	56.85	60.28	60.09	59.51	57.51	57.92	58.47	2.08
2	29.28	29.46	26.73	29.25	31.46	31.25	30.38	30.32	30.05	29.24	29.74	1.67
3	33.38	36.48	32.3	26.67	33.61	34.74	36.17	27.06	28.35	27.56	31.63	5.1
4	49.54	57.77	63.07	64.43	60.89	58.58	52.02	51.16	54.17	55.13	56.68	6.23
5	4.15	8.91	13.11	15.66	15.92	17.81	23.06	22.85	25.85	27.01	17.43	10.71
6	67.5	59.32	57.44	57.34	56.52	57.14	56.79	59.93	58.03	59.12	58.61	2.82
7	59.97	63.13	63.06	63.24	65.1	68.27	69.95	70.35	70.78	70.98	66.48	3.94
8	54.92	45.17	42.12	55.35	62.88	62.02	68.84	69.67	66.6	68.64	59.62	11.11
9	70.15	69.25	68.56	66.48	64.49	63.33	62.23	62.77	64.68	63.63	65.56	2.93
10	22.22	21.7	20.4	19.54	18.8	16.74	16.04	15.3	19.55	21.63	19.19	3.25

C: *Mean Values for each minute of the ten minute typing task whilst sitting on a STABLE BACK APP. Mean value and standard deviation for the whole ten minute period also included.*

Subject No.	Min 1	Min 2	Min 3	Min 4	Min 5	Min 6	Min 7	Min 8	Min 9	Min 10	10 Min Mean	10 Min STDEV
1	37.17	37.13	34.82	34.04	34.19	34.37	34.51	34.49	33.84	33.69	34.82	1.31
2	32.39	32.53	33.22	33.9	33.91	34.22	33.78	32.81	32.76	32.82	33.23	1.14
3	52.43	51.02	47.35	44.11	40.35	38.37	37.01	41.57	42.58	47.62	44.24	5.64
4	50.38	51.99	56.13	53.59	59.39	58.57	61.44	53.69	52.74	54.91	55.91	5.72
5	21.09	21.13	22.66	20.53	20.35	19.78	20.33	19.71	16.64	18.54	20.08	3.03
6	67.72	66.2	63.92	62.55	61.88	63.96	60.85	60.08	59.46	57.99	62.46	3.13
7	65.13	67.74	68.29	69.52	69.86	72.12	73.64	73.76	73.31	73.7	70.71	3.07
8	52.04	55.7	56.16	55.82	57.9	53.68	49.63	47.17	47.06	48.45	52.36	4.61
9	68.66	67.39	66.87	65.74	65.1	63.88	62.47	61.83	61.13	60.21	64.33	2.89
10	16.27	17.46	18.99	19.47	19.15	20.41	18.92	20.54	20.33	20.35	19.19	1.97

D: *Mean Values for each minute of the ten minute typing task whilst sitting on an UNSTABLE BACK APP. Mean value and standard deviation for the whole ten minute period also included.*

Subject No.	Stool Mean	Stool STDEV	Stable Back App Mean	Stable Back App STDEV	Unstable Back App Mean	Unstable Back App STDEV
1	29.93	5.85	41.96	18.1	35.49	17.05
2	52.51	7.9	34.12	12.94	36.59	9.72
3	73.17	6.29	55.55	8.37	67	5.42
4	110.41	9.66	86.51	6.73	57.16	3.41
5	27	8.94	21.49	19.62	6.73	16.2
6	100.22	5.06	85.19	7.4	84.14	5.21
7	53.87	7.31	64.54	18.58	58.96	11.25
8	72.07	7.48	43.92	15.87	46.86	14.87
9	85.79	10.88	85.34	5.05	78.49	4.17
10	66.07	7.97	16.81	11.45	19.13	10.93

E: *Mean and Standard Deviation Values for the whole 30 second office task whilst sitting on a STOOL, STABLE BACK APP and an UNSTABLE BACK APP.*

Subject No.	Mean Posture whilst sitting on Stool	Perceived effort of Stool sitting [Out of 10]	Mean Posture whilst sitting on Stable Back APP	Perceived effort of sitting on a Stable Back App [Out of 10]
1	30.09	5	29.16	3
2	29.72	1	32.16	2
3	34.54	5.5	37.86	5
4	28.31	4.5	30.17	3
5	28.93	2	34.04	2
6	35.72	8	24.69	5
7	31.19	3	33.66	4
8	29.89	1	34.34	0
9	33.51	6	35.96	7
10	31.5	5	27.32	3

F: *Mean Values for the whole 1 minute period of maintaining a lumbar lordosis at 30% of lumbar ROM whilst sitting on a stool and a stable back app. The perceived effort score (out of ten) of each subject whilst sitting on both a stool and a stable back app for each 1 minute trial is also included.*

Subject No.	Stool	Stable Back App	Unstable Back App
1	0.25	0.17	0.25
2	0.08	0.08	0.09
3	0.38	0.17	0.17
4	0	0.17	0.25
5	0	-0.04	-0.04
6	0.08	0	0
7	0.25	0.42	0.08
8	0.09	0	0.18
9	0.5	0.58	0.55
10	0.17	0.67	0.42

G: *Mean Values for the progression of discomfort (Mean Overall Body Discomfort Score at ten minutes typing - Mean Overall Body Part Discomfort Score at baseline) whilst performing a ten-minute typing task sitting on a STOOL, a STABLE BACK APP and an UNSTABLE BACK APP*.

Subject No.	Chair 1	Chair 2	Chair 3
1	0.25	0.17	0.25
2	0.08	0.08	0.09
3	0.17	0.38	0.17
4	0	0.17	0.25
5	0	-0.04	-0.04
6	0	0.08	0
7	0.25	0.08	0.42
8	0.09	0.18	0
9	0.55	0.58	0.5
10	0.17	0.42	0.67

H: *Mean values for the progression of discomfort (Mean Overall Body Discomfort Score at ten minutes typing - Mean Overall Body Part Discomfort Score at baseline) whilst performing a ten-minute typing task on the RANDOMISED FIRST, SECOND and THIRD CHAIRS*