ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ

ΤΜΗΜΑ ΕΠΙΣΤΗΜΗΣ ΦΥΣΙΚΗΣ ΑΓΩΓΗΣ ΚΑΙ ΑΘΛΗΤΙΣΜΟΥ

Καλή και κακή καθιστή στάση. Πώς η παρατεταμένη “κακή” στάση επηρεάζει την ιδιοδεκτικότητα της σπονδυλικής στήλης.

Good and bad sitting posture. How bad posture affects spinal proprioception.

ΚΟΡΑΚΑΚΗΣ ΒΑΣΙΛΕΙΟΣ

ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ

ΓΙΑΚΑΣ ΙΩΑΝΝΗΣ

Μεταπτυχιακή Διατριβή που υποβάλλεται στο καθηγητικό σώμα για τη μερική εκπλήρωση των υποχρεώσεων απόκτησης του μεταπτυχιακού τίτλου του Προγράμματος Μεταπτυχιακών Σπουδών «Άσκηση και Υγεία» του Τμήματος Επιστήμης Φυσικής Αφωγής και Αθλητισμού του Πανεπιστημίου Θεσσαλίας.

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Περίληψη

Η καμπτική καθιστή στάση (ΚΚΣ) συχνά υιοθετείται σε καθημερινές δραστηριότητες και όταν παρατείνεται έχει προταθεί να επηρεάζει τις βιολογικές ιδιότητες των ιστών της σπονδυλικής στήλης (ΣΣ) και να επιδρά αρνητικά στην ιδιοδεκτικότητα. Ο σκοπός της παρούσας μελέτης ήταν η αξιολόγηση της καθιστής στάσης σχετικά με το κεφάλι, τη ΣΣ και τη λεκάνη σε υγιεί άτομα, η χρονοεξαρτώμενη επίδραση της ΚΚΣ στην ιδιοδεκτικότητα και η επιρροή μιάς διαδικασίας της Μηχανικής Διάγνωσης και Θεραπείας (ΔΜΔΘ) στο ιδιοδεκτικό έλλειμμα.

Με τη χρήση συγχρονικού σχεδιασμού επαναλαμβανόμενων μετρήσεων (N=47) τα άτομα αξιολογήθηκαν σχετικά με τη συνήθη καθιστή στάση τους (ΣΚΣ), την αντίληψή τους για την σωστή στάση (ΑΣΣ), την ικανότητα να υιοθετήσουν μία εκπαιδευμένη σωστή στάση (ΕΣΣ) και την ακρίβεια με την οποία μπορούν να επαναπροσδιορίσουν την ΕΣΣ άμεσα, μετά από 10 και 30 λεπτά στην ΚΚΣ και μετά από τη ΔΜΔΘ. Οι εξαρτημένες μεταβλητές ήταν εννέα γωνίες στο προσθιοπίσθιο επίπεδο.

Τα αποτελέσματα παρουσίασαν ότι η ΣΚΣ ήταν πιο καμπτική από από την ΑΣΣ και την ΕΕΣ ($p<.05$) και η ΑΣΣ ήταν σημαντικά πιό καμπτική από την ΕΣΣ ($p<.05$). Η αξιοπιστία του εξεταστή να τοποθετεί τα άτομα στην ΕΣΣ ήταν πολύ καλή (ICCs από 0.79 έως 0.91). Δεν παρουσιάστηκαν στατιστικά σημαντικές διαφορές στον άμεσο επαναπροσδιορισμό της ΕΣΣ, ενώ σηματικές διαφορές αναγνωρίστηκαν στην οσφυϊκή γωνία (ΟΓ) μετά από 10 λεπτά στην ΚΚΣ και στην ΟΓ, την γωνία της κεφαλής και την αυχενο-θωρακική γωνία μετά από 30 λεπτά στην ΚΚΣ. Ο επαναπροσδιορισμός της στάσης μετά την ΔΜΔΘ εξάλειψε το ιδιοδεκτικό έλλειμμα στην κεφαλή και τη ΣΣ. Το λάθος επαναπροσδιορισμού της στάσης έδειξε στατιστικά σημαντικές διαφορές για την ΟΓ και την ΓΚ.

Abstract

Flexed sitting posture is commonly adopted in daily sitting activities and when sustained has been proposed to affect biological properties of spinal tissues and act detrimentally on proprioception. The objective of this study by using an optical motion analysis system was to assess sitting posture regarding the head, spine and pelvis, in healthy individuals; the time effect of flexed posture (FSP) on proprioception and the impact of an MDT procedure on proprioceptive deficit.

Using a cross sectional repeated measures design (N=47) subjects were assessed regarding their habitual sitting posture (HSP), perception of optimal posture (SPOP), ability to adopt an instructed sitting posture (IOSP) and accuracy to reproduce the criterion posture immediately, after 10 and 30 minutes in FSP and after the "slouch-overcorrect" procedure (SOP). Dependent variables were nine sagittal upper body angles.

Results revealed that HSP was more flexed than SPOP and IOSP ($p<.05$) and SPOP was significantly more flexed than IOSP ($p<.05$) in most measured angles. The intra-tester reliability of positioning the subjects in IOSP was very good (ICC ranged from 0.79 to 0.91, SD from 0.98° to 2.2°). There was no significant difference in immediate repositioning to IOSP, while significant differences were identified in the lumbar angle (LU) after 10 minutes in FSP and in LU, head (HE) and cervico-thoracic (CT) angles after 30 minutes in FSP. Repositioning to IOSP after SOP abolished proprioceptive deficit in head and spine. Postural repositioning error showed significant differences for LU and HE angles.

The findings suggest that healthy individuals habitually sit in more flexed posture than SPOP and IOSP. Postural education can be actualized in a reliable way and subjects can adopt an educated posture. Furthermore FSP challenged postural proprioception, but SOP increased proprioceptive accuracy.

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List of abbreviations

MDT	Mechanical Diagnosis and Therapy
HSP	Habitual sitting posture
SPOP	Self-perceived optimal posture
IOSP	Instructed optimal sitting posture
FSP	Flexed sitting posture
BMI	Body mass index
FLSP	Fully lordotic sitting posture
REP1	Immediate repositioning trial
REP2	Repositioned posture after 10 minutes in FSP
REP3	Repositioned posture after 30 minutes in FSP
REP4	Repositioned posture after the slouch-overcorrect procedure
OCC	Occiput marker
FHEAD	Marker in the front of the head
ORBVM	Virtual marker in the midline of the two orbit markers
PELVM	Virtual marker defined as the vector midpoint between the two anterior superior iliac spines’ markers
SACRVM	Virtual marker defined as the vector midpoint of the two posterior superior iliac spines’ markers
RE	Reposition error
HE	Head angle
NE	Neck angle
HT	Head tilt angle

HP	Head protraction angle
CT	Cervico-thoracic angle
TH	Thoracic angle
TL	Thoraco-lumbar angle
LU	Lumbar angle
PEL	Pelvic angle
RE1	Reposition error between IOSP and REP1
RE2	Reposition error between IOSP and REP2
RE3	Reposition error between IOSP and REP3
RE4	Reposition error between IOSP and REP4
ICC	Intra-class correlation coefficient
CV	Coefficient of variation

1. INTRODUCTION

Due to the demands of life in modern society the amount of time spent in sitting posture is increasing steadily (Egger, Vogels, & Westerterp, 2001). Slouched, kyphotic or flexed posture are terms usually used to reflect a non-upright sitting posture including lumbar, thoracic and lower cervical spine flexion. Such a posture is commonly adopted in daily sitting activities (P. Dolan, Adams, & Hutton, 1988) and is related to the appearance of symptoms (cervical, thoracic and lumbar spine) in healthy individuals or aggravation of symptoms in subjects with spinal pathology (Womersley & May, 2006).

An extensive literature review (Pynt, Higgs, & Mackey, 2001) comparing the effect of lordosed and kyphosed seated postures concludes that kyphosed postures, when sustained, are more harmful to the health of the lumbar spine. Furthermore, evidence supports that sustained flexed neck and thoracic posture is capable of producing symptoms in asymptomatic individuals (Harms-Ringdahl & Ekholm, 1986). Given that sustained flexed or slouched posture challenge the spine in terms of health and symptoms' production is of significant, clinical and scientific, importance to evaluate the effect of such a sustained posture regarding the whole spine. Despite that sitting posture predominates in modern lifestyle and workplace the definition of the optimal or ideal sitting posture diverge in the literature (P. O'Sullivan, 2005; Pynt, et al., 2001). The argument is related not only to the quantitative description of the posture, but the designation of the curves among spinal segments, with qualitative descriptions lacking in consensus about the specification of ideal spinal curves (A. P. Claus, Hides, Moseley, & Hodges, 2009b). The upright sitting posture is regarded as a base for the correct posture and most of the descriptions include normal lumbar lordosis as a substance of correct posture (A. P. Claus, et al., 2009b; K. O'Sullivan, et al., 2010) since the lordotic curve is a physiological resting position of the lumbar spine. Education of subjects to sit in upright posture with lumbar lordosis is evaluated in several studies, providing evidence that trained subjects can sit in a predefined posture for an adequate period of time (Falla, Jull, Russell, Vicenzino, & Hodges, 2007; Scannell & McGill, 2003).

Position sense as part of proprioception is used in studies investigating joint position error as a measure of proprioceptive ability in healthy and symptomatic individuals (Brumagne, Lysens, & Spaepen, 1999a, 1999b; K. J. Dolan & Green, 2006; Edmondston, et al., 2007; Newcomer, Laskowski, Yu, Johnson, & An, 2000; P. B. O'Sullivan, et al., 2003). Proprioceptive input and reflex control of spinal movements, in specific, derive from mechanoreceptor afferents that are found in a variety of spinal tissues including muscles, joints, fascia and skin (Gandevia, McCloskey, & Burke, 1992; Yahia, Rhalmi, Newman, & Isler, 1992; Yamashita, Minaki, Oota, Yokogushi, & Ishii, 1993).

Taking the former into account, flexed posture challenges the neutral zone and the spinal stability, as well as the reflexive activation of the muscles that is dependent on the creep developed in the viscoelastic tissues during static load (Youssef, et al., 2008). Increasing neuromuscular neutral zones after a given protocol is applied, in this case flexed posture, indicate deteriorating stability since the muscle forces are not available at the required timing and manner (Solomonow, 2011). Recent evidence supports that flexed posture is potentially exposing the spine to injury as reflex lumbar and thoracic muscles activation is delayed in response to a sudden perturbation because of the creep in viscoelastic tissues (Sánchez-Zuriaga, Adams, & Dolan, 2010). One hour in flexed posture increases the peak lumbar flexion by 4.1% and the muscle activation latency in both lumbar and thoracic regions (Sánchez-Zuriaga, et al., 2010). Furthermore, prolonged flexion moment in sitting posture for 20 minutes results in viscoelastic tissues creep that cannot fully recover the following 30 minutes of rest (McGill & Brown, 1992). In point of cervical spine, symptoms are usually associated with sustained static loading in non-neutral spinal postures (Côté, et al., 2008) with increased muscle activation resulting in higher levels of cervical spine loading

(Falla, Jull, et al., 2007; Szeto, Straker, & O'Sullivan, 2005). Slouched sitting posture in terms of lumbar flexion is found to be related with increased thoracic flexion and head/neck flexion (Black, McClure, & Polansky, 1996; Caneiro, et al., 2010) with a greater anterior translation of the head and also higher levels of compressive loading in the cervico-thoracic region (Caneiro, et al., 2010). In addition, loss of proprioceptive control has been associated with subgroups with cervical, thoracic and lumbar pathology (Edmondston, et al., 2007; Falla, O'Leary, Fagan, & Jull, 2007; P. B. O'Sullivan, et al., 2003). On the one hand, assessing the proprioception of the spine in terms of reposition sense after prolonged flexed posture is of clinical significance since evidence link sustained flexion load with reduced neuromuscular proprioceptive reflexes. On the other hand, loss of proprioceptive control or, more specifically, impaired sensorimotor control mechanisms reduce muscle protection of the underlying spine and support a potential link between flexed posture and spinal pathology and pain.

Taking into consideration all the evidence, flexed spinal sitting posture challenge the spinal proprioceptive structures and viscoelastic properties of spinal tissues in a time dependent manner. To our knowledge, regarding the effect of flexed sitting posture on proprioception to the whole spine in asymptomatic subjects research has never been conducted for a prolonged period of time (over thirty minutes). The assessment of the spine, head and pelvis as a unit is reinforced by evidence linking different sitting postures with changes in cervical spine and head position driven from the pelvis and lumbar spine (Black, et al., 1996; Caneiro, et al., 2010; A. P. Claus, et al., 2009b). Nevertheless, studies have investigated the reposition accuracy of healthy individuals' lumbar spine (K. J. Dolan & Green, 2006) or in comparison with a symptomatic subgroup of Low Back Pain (P. B. O'Sullivan, et al., 2003) and neck pain (Edmondston, et al., 2007). Results from a previous study in a similar setting (K. J. Dolan & Green, 2006) support the present research project, as lumbar spine reposition sense of healthy individuals is significantly reduced following five minutes in a slouched posture as compared to three seconds in the same sitting posture.

The Mechanical Diagnosis and Therapy (MDT) approach describes the “postural syndrome” as a clinical entity mainly affecting sedentary individuals that subject the spinal tissues to prolonged static loading and furthermore, propose procedures to facilitate the correct sitting posture (R. McKenzie, & May, S, 2003). A specific procedure is utilized by MDT, termed as “slouch-overcorrect”, in order to educate, facilitate and encourage individuals to achieve and attain the correct posture. This procedure is argued to increase the spinal proprioception by determining the limits of its available movement and facilitating the muscular proprioceptive function.

The hypotheses of the present study are: a) the habitual sitting posture (HSP) will be the same as the perceived correct posture (SPOP); b) the perceived correct posture will be the same as the instructed upright optimal sitting posture; c) the subjects will be able to reposition their spine to the instructed upright sitting posture (IOSP) from a flexed sitting posture (FSP) immediately d) the prolonged flexed posture (10 and 30 minutes) will not reduce the repositioning accuracy of the subjects and e) the “slouch-overcorrect” MDT procedure will not affect spinal proprioception.

2. LITERATURE REVIEW

2.1. The optimal spinal sitting posture

Correct and “bad” sitting postures are two terms usually used in clinical practice and supported with generally accepted clinical concepts, while postural education is a basic scope in clinical setting and ergonomic advice (Pope, Goh, & Magnusson, 2002). Recent evidence based and clinical textbooks on musculoskeletal assessment and treatment (Jull, 2008; Lee, 2007; R. McKenzie, & May, S, 2003; R. McKenzie, & May, S., 2006; Richardson, 2008) define the upright sitting posture based on the optimal standing posture. More specifically, a "good posture" is considered to be a position in which the lumbar spine is positioned in a moderate degree of lordosis; the thoracic spine is in slight kyphosis, while the head and shoulders are evenly and neutrally aligned over the pelvis. With reference to the cervical spine, several studies have found the average sagittal cervical configuration to be a lordosis (Harrison, Janik, Troyanovich, & Holland, 1996). Although, the ideal posture has been described in the literature for more than a century, the sagittal alignment of the spine cannot be specified from posture.

At this point, a plausible debate was raised taking into account the results of a recent review (Kuntz Iv, Levin, Ondra, Shaffrey, & Morgan, 2007) regarding the neutral upright sagittal spinal alignment and the wide variation of the regional undulating lordotic and kyphotic spinal curves in standing. The authors concluded that despite the wide variation in asymptomatic adults, sagittal balance was maintained in a narrower range for alignment of the spine over the pelvis and femoral heads (Kuntz Iv, et al., 2007). Notwithstanding these results, a diversity of spinal curves from the occiput to the pelvis met the criteria for neutral upright spinal alignment and made inexplicit, in research and clinical reality, not only the quantitative definition of neutral posture but the aims of postural education and evaluation.

Exercise programs and education have been used in several studies so that individuals can sit in a posture, during which the lumbar spine mimics the positioning described for standing. In a study, a 12-week exercise program was used to improve neuromuscular control and assess the training effect on the lordosis of the lumbar spine (Scannell & McGill, 2003). The exercise program managed to change the lumbar posture of the subgroups included, towards the mean of the distribution of lordosis among a screened population. However, despite that these effects and the intervention, all the subjects sat in a more flexed lumbar position than they had adopted during standing (Scannell & McGill, 2003).

Several studies have been conducted comparing quantitatively the spinal curves in both sitting (supported or not) and standing (Andersson, Murphy, Ortengren, & Nachemson, 1979; Dunk, Kedgley, Jenkyn, & Callaghan, 2009; Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999). Recently, a study has demonstrated that the upright unsupported sitting posture involved more flexion in the lumbar spine than in standing (Dunk, et al., 2009). The findings of a study were variable regarding the segmental flexion that compared supported sitting and standing, but in accordance with the general agreement of increased lumbar kyphosis during sitting. These differences could be attributed to the lumbar support in sitting.

Given the idea that the lumbar kyphosis is driven by rotation of the pelvis (Dunk, et al., 2009) several considerations give possible explanations and link the differences in spinal flexion between sitting and standing. It was observed in side-lying that hip flexion similar to that in sitting caused the subjects to adopt a kyphotic lumbar curve, whereas the opposite was caused by hip extension. It was argued by Claus et al., (2009) that “the difference in hip positions between standing and sitting could be a reason for lordosis to be commonly achieved in standing but not in sitting.” Moreover, the authors reasoned that the assumed natural lumbar lordosis could be the reflection of hip extension effect to the pelvis. From another perspective, lower limb muscles flexibility has been shown to affect lumbo-pelvic posture due to their direct attachments to the pelvis. The posterior trunk-thigh muscles were held to play a major role in the flattening of the lumbar spine in sitting and the anterior trunk-thigh muscles in accentuating the lumbar curve in standing (A. P. Claus, et al., 2009b).

Consequently, defining the optimal sitting posture based on the standing posture is partially achievable but rather vague. Taking the optimal standing posture as reference standard only qualitative characteristics could be used and transferred in sitting posture. Evidence has established the differences between sitting and standing and elucidated the deviation in quantitative designation of the spinal curves in seated posture.

2.3. Spinal health, stability and proprioceptive control

According to the model of spinal stability (Panjabi, 1992a, 1992b), muscles in terms of proprioceptive neuromuscular reflexes control the spinal “neutral zone”, the few degrees of spinal movement that the passive subsystem is not engaged in stability. Moreover, the neuromuscular neutral zones (Solomonow, Eversull, He Zhou, Baratta, & Zhu, 2001), that have been defined as the elongation or tension range above which the neuromuscular system is proprioceptively activated and starts to apply stabilizing function, are extending the stability model and stressing the major role of muscles in spinal health.

The upright spinal postures have been proposed to approach a mid-range position for the spinal segments and are prone to bent, twist and shear (Panjabi, 1992b). In flexed posture where the neutral position is lost, the spine is potentially exposed to injury (Panjabi, 1992a, 1992b).

Several studies have proved that upright neutral spinal postures are activating key trunk muscles in both lumbar and cervical spine (A. P. Claus, Hides, Moseley, & Hodges, 2009a; Falla, Jull, et al., 2007; P. B. O'Sullivan, et al., 2006). The deep and superficial fibers of lumbar multifidus, the transversus abdominis and obliquus internus have been found to be more active in the “short lordosis” posture (A. P. Claus, et al., 2009a; P. B. O'Sullivan, et al., 2006; P. B. O'Sullivan, et al., 2002). These muscles have been proposed to provide spine segmental stability (Bergmark, 1989) and further have a particularly high density of muscle spindles compared with the long multi-segmental muscles, which are suggested to play an important role in control of the spinal posture and movement. In cervical spine, upright posture with lumbar lordosis have been found to facilitate the activity of deep neck muscles (Caneiro, et al., 2010; Falla, Jull, et al., 2007), that have been proposed to be important for the control and support of the cervical lordosis, the maintenance of cervical spine postural form and the control of cervical posture due to their muscle fiber composition and muscle spindles density (Boyd-Clark, Briggs, & Galea, 2001, 2002).

In conclusion, the stability and health of the spine are dependent on neuromuscular proprioceptive control and related to the activation of key trunk muscles. Different spinal postures have a significant effect on the activation of these muscles, while upright spinal posture facilitate and enhance their functional and proprioceptive role.

2.4. The rational and the objective of the present study

The rationale of the present study is clinically and ergonomically relevant. The prolonged period of time in sustained unsupported sitting posture is able to reflect the effect on proprioception of commonly adopted “bad” postures during daily activities, such as unsupported writing on a desk, reading a book or a magazine or even working on a notebook. The results have implications in clinical practice not only in the patient’s education, but also in ergonomic consultation and postural advice in healthy individuals. Moreover, the outcome will shed light on research linking sustained postures with spinal pathology and pain.

The objectives of the present study are the evaluation, in asymptomatic subjects, of: a) the unsupported habitual sitting posture; b) the self perception of optimal / upright / correct sitting posture; c) the effect of clinical postural education in unaware subjects and the efficiency of the subjects to achieve an educated upright optimal sitting posture; d) the ability of repositioning the spine to a predetermined posture, e) the effect of sustained flexed posture on proprioception of the spine and f) the effect of MDT “slouch-overcorrect” procedure on spinal proprioception.

3. METHODS

3.1. Study design

This study used a single session, cross-sectional, repeated measures design. The design was used to allow comparison of the habitual unsupported sitting posture (HSP), self perceived “optimal” posture (SPOP), instructed “optimal” posture (IOSP) and repositioning ability in the IOSP of healthy individuals. The posture repositioning ability of individuals in the IOSP was used to designate the effect of flexed unsupported sitting on reposition sense immediately after spinal flexion and after prolonged spinal postural flexion (10 and 30 minutes). The dependent variable, outcome measure and measure of proprioception were sagittal angles in degrees derived among markers and between segments.

All study measurements took place in one occasion to secure the placement of the reflective markers and to reduce potential error. The researcher was blind to the data since the data need further processing in order to be available.

3.2. Subjects

Forty-seven subjects were recruited through poster advertising at the campus of the University of Thessaly and the city of Trikala. The physical characteristics of the subjects are summarized in **Table 1**.

TABLE 1. Descriptive characteristics of the participants

	Men (No=29)	Women (No=18)	Total (N=47)
Age (years)	25.7 (5.3)	22.4 (3.4)	24.4 (4.9)
Height (cm)	179.1 (5.0)	163.1 (8.6)	173.0 (10.2)
Weight (kgs)	76.2 (9.0)	55.6 (7.0)	68.3 (13.0)
BMI (kg/m^2)	23.2 (2.4)	20.4 (3.3)	22.2 (3.1)

Note. Characteristics of the participants are presented as mean and (SD).

The inclusion criteria were men and women aged between 18 and 45 years, full and asymptomatic range of motion of the spine (cervical, thoracic and lumbar) and the pelvis (K. J. Dolan & Green, 2006; Edmondston, et al., 2007).

Participants were excluded if they had diagnosed spinal pathology or history of back, thoracic or neck pain that required treatment or rest from normal activities for more than two days within the last two years, had scoliosis, history of respiratory conditions, were pregnant; had neurological conditions, were currently experienced dizziness and/or fainting., had ear or visual disturbances, had body mass index greater than 28 or body type that could affect the placement of the markers, were experienced spinal, hip or shoulder pain in the test procedures and had undertaken postural control training or received formal postural education (A. P. Claus, et al., 2009b; K. J. Dolan & Green, 2006; Edmondston, et al., 2007).

Ethical approval was granted by the Human Research Ethics Committee of the University of Thessaly. Participants received information sheets, gave informed consent prior to testing and also were informed that were free to withdraw from the study at any time **(APPENDIX 1).**

3.3. Apparatus

Measures of spinal posture, head and pelvis position and repositioning accuracy (dependent variables) were collected and determined via a ten-camera three-dimensional optoelectronic motion analysis system (Vicon T-series, Oxford, UK), sampling at 100Hz and using Nexus software (Vicon, Oxford, UK).

Prior to data collection, the motion analysis system (Vicon) was calibrated to a maximum of 0.1 mm error range. Reflective markers adhered to the skin surface were used to record position data.

3.4. Procedure

3.4.1. Subject preparation and markers placement

Each subject was suitably disrobed to allow skin marking with ink over the anatomical landmarks that the reflective markers were placed. Manual palpation and ultrasound imaging were used to identify anatomical landmarks **(FIGURE 1).** All landmarks were located by an experienced physiotherapist, verified by a second investigator (Edmondston, et al., 2007; Edmondston, Sharp, Symes, Alhabib, & Allison, 2011; P. B. O'Sullivan, et al., 2003) and all but the head landmarks were confirmed by a portable computer based ultrasound scanner (A. P. Claus, et al., 2009b) (Echo Blaster 128 EXT-1Z kit and linear transducer HL9.0/60/128Z, Telemed Ltd, Lithuania).

FIGURE 1.Anatomical landmarks location and confirmation with ultrasound imaging.

Fifteen reflective markers (14mm diameter) were placed over the marked anatomical landmarks and firmly secured using double-sided adhesive tape. For attachment of the back body-part markers subjects were placed in prone lying so that the skin surface and the designation of the spinal curves were closer to the neutral spinal position. For the attachment of the front body-part markers subjects were standing erect and for the head markers subjects were comfortably seated.

Markers were applied to the pelvis, bilaterally over the anterior and posterior superior iliac spines, to the posterior upper part of the body over the C7, T5, T10, L3, S2 spinous processes and to the front upper part of the body over the sternal notch and xiphoid process (A. P. Claus, et al., 2009a, 2009b; Edmondston, et al., 2007). The boundary between lumbar and thoracic curves was defined as being located at the T10 spinal segment as previously has been reported and justified (A. P. Claus, et al., 2009a, 2009b).

Furthermore, markers were adhered to the head bilaterally over the lateral margin of the orbit (Edmondston, et al., 2007; Edmondston, et al., 2011), over the base of the occiput by using an elastic band and on the main protuberance of the forehead between the eyebrows (Caneiro, et al., 2010; Szeto, Straker, & Raine, 2002) **(FIGURES 2 AND 3).**

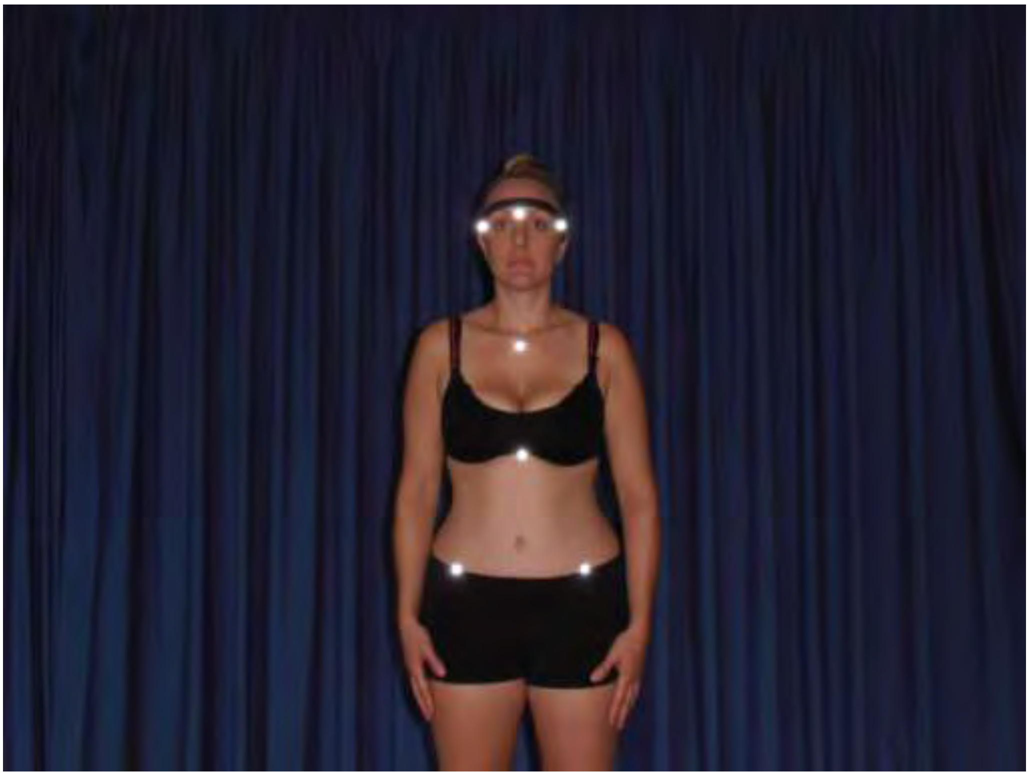

FIGURE 2. Markers at the front upper part of the body

FIGURE 3. Markers at the back part of the body

3.4.2. Experimental Protocol

During testing participants were seated unsupported on a stool adjusted to accommodate 90⁰ of knees, hips and ankles flexion with feet stable on the ground, knees and ankles shoulder width apart and arms placed relaxed on the thighs. The positioning on the stool was conducted by one of the researchers and was identical for all the participants regarding the joint angles of the lower limbs **(FIGURE 4).** The participants wore only undergarments to the upper part of the body if they were women and nothing if they were men, in order to reduce sensory cues from clothing and to secure the fixity of the reflective markers.

During all trials of the session the subjects were requested to fix their gaze on a wall marker ahead about 5 meters away, advised to breath naturally and avoid talking and instructed not to adjust their contact with the seat.

FIGURE 4. Placement of the subject on the chair

Prior to the commencement of testing the subjects were asked and assisted in moving through their available spinal, pelvic and head range of motion, in order to accustom with the limitations of the specific posture and the sensation of the adhered markers and to ensure the fixity of the reflective markers.

Each posture during the experimental procedure was held by the participants and captured for 10 seconds. Investigators and participants were blinded to the data of the measured postures since further processing was required in order to be available.

3.4.3. Habitual sitting posture (HSP)

Subjects were asked to sit as they usually do and engaged in conversation by one of the investigators that was standing ahead in a distance to distract their attention from their posture (Edmondston, et al., 2011). Covertly their HSP was recorded (Edmondston, et al., 2007; Edmondston, et al., 2011; K. O'Sullivan, et al., 2010) and data was captured over a 10 seconds period during subjects were relatively stable.

3.4.4. Self-perceived optimal posture (SPOP)

Subjects were asked to sit in a posture which they think is the optimal seated posture (SPOP) (K. O'Sullivan, et al., 2010). They had an adequate period of time to accomplish the request of the investigator and they did not receive any manual facilitation, feedback or further instructions regarding their posture. They remained stable and the SPOP was captured.

3.4.5. Flexed (FSP) and fully-lordotic sitting posture (FLSP)

Subjects were facilitated into FSP and FLSP by one of the investigators using manual and verbal facilitation. FSP was defined as active available end-range posterior rotation of the pelvis, active available end-range flexion of the lumbar, thoracic and lower and upper cervical spine **(FIGURE 5).** The FSP was the only captured posture that the participants were not instructed to fix their gaze on the wall-marker ahead.

FIGURE 5.Flexed sitting posture (FSP).

Fully lordotic sitting posture was defined as the active available end-range anterior rotation of the pelvis, the active available end-range lordosis of the lumbar spine, the active available end-range extension of the thoracic spine, shoulder blades retracted, cervical spine and head in end-range available retraction **(FIGURE 6).** These two postures were selected in order to designate the limits of each subject's achievable sitting posture (A. P. Claus, et al., 2009a; K. O'Sullivan, et al., 2010). Data from these postures helped to distinguish lordotic and kyphotic angles and posture limits among different postures and repositioning trails.

FIGURE 6. Fully lordotic sitting posture (FLSP).

3.4.6. Instructed optimal sitting posture (IOSP)

Subjects were then facilitated by an experienced physiotherapist to the IOSP **(FIGURE 7).** This posture was defined as a position in which the lumbar spine was positioned in a moderate degree of lordosis, the thoracic spine was in slight kyphosis, while the head and shoulders were evenly and neutrally aligned over the pelvis with the chin over the chest, moderately retracted rather than protruded (Jull, 2008; Lee, 2007; R. McKenzie, & May, S, 2003; R. McKenzie, & May, S., 2006; Richardson, 2008). Subjects were shown pictures of the IOSP, were verbally instructed regarding the spinal and head curve features and the posture was demonstrated. In addition, manual facilitation and guidance were provided (A. P. Claus, et al., 2009b), while subjects were instructed to tilt their pelvis anteriorly, neutrally align their head over the pelvis and moderately retract their chin (R. McKenzie, & May, S., 2006). All subjects were informed to remember the procedure and the position because they would be asked to find it as accurately as possible during the test trials.

Furthermore, the investigator stressed the importance of their attention. Immediately prior to the positioning of the subjects to the criterion position and the repositioning trials all the participants were asked to practice the previous procedure.

FIGURE 7. Instructed optimal sitting posture (IOSP).

An experienced physiotherapist then guided and positioned the subjects to the IOSP that was defined as the criterion position. The subjects remained stable and the IOSP was captured for 10 seconds.

3.4.7. Slouch-overcorrect procedure

The MDT approach (R. McKenzie, & May, S, 2003; R. McKenzie, & May, S., 2006) utilizes a specific procedure (slouch-overcorrect) in order to educate, facilitate and encourage the individuals to achieve and attain the correct posture. The individual from a relaxed slouched posture with the lumbar and thoracic spine flexed and the head and neck protruded smoothly moved into the extreme of the erect sitting. Clinician guidance using manual facilitation on the subject's lumbar, thoracic spine and chin assisted in the learning process. The individual then was instructed to relax back into the FSP. This cycle should be repeated ten times, in order the individual to move from the extreme of FSP to the extreme of upright extended and retracted posture.

This specific procedure is used to educate patients to attain correct posture, to retrain postural habit, to strengthen trunk muscles and to help recognize poor posture (R. McKenzie, & May, S, 2003; R. McKenzie, & May, S., 2006).

3.4.8. Posture repositioning

The subjects then were instructed to relax into the FSP for a while (less than 60 seconds) before asked to reproduce the criterion position without any feedback and guidance by the investigator (Edmondston, et al., 2007; P. B. O'Sullivan, et al., 2003). They reproduced the criterion position and remained stable as the posture was captured for 10 seconds and defined as the immediate repositioned posture (REP1).

The same protocol was followed two more times, after 10 minutes in FSP and after 30 minutes in FSP. The repositioning session after prolonged flexed posture was started immediately after the first reposition trial. The second repositioned posture trial (REP2) to the criterion position was captured after 10 minutes of FSP. During the FSP subjects were allowed to read a magazine and place their arms on their thighs in a relaxed manner rather than supporting their body weight and were not allowed to move their head and spine towards extension **(FIGURE 8).** After the recording of the REP2 the subjects returned immediately to the FSP, in order to remain in that posture for 20 more minutes. After a total of 30 minutes in FSP with a small interval for the REP2, the subjects were asked to reproduce for one more time the criterion posture and the third repositioned posture trail (REP3) was captured for 10 seconds.

Finally, the individuals were requested to accomplish the “slouch-overcorrect” procedure for ten repeated times and to reposition for the last time their spines to IOSP. This was the REP4 trial and captured as previously.

The participants were given no feedback as to their repositioning performance and accuracy during testing.

FIGURE 8. The position that subjects remained for the time period of 10 and 30 minutes, before repositioning trials.

3.5. Spinal curve, head and pelvis position analysis

Data collection, processing and reconstruction of the sagittal trajectories of the reflective markers were conducted by using Nexus 1.7.1 software (Vicon Motion Systems, Oxford, UK). All skin markers were manually identified and automatically digitized. Postures were captured for 10 seconds and analysis of the first available second of data capture of each posture was performed and the mean (95%CI) was used in further processing. Recording of each posture was conducted once the subjects were ready and relatively stable in order to reduce the risk of data contamination because of the beginning of movement (A. P. Claus, et al., 2009b; Edmondston, et al., 2007; K. O'Sullivan, et al., 2010).

Segment parameter information was based on the Plug-In Gait modeler (Vicon, Oxford Metrics, Oxford, UK).

Three segments were created and defined regarding the markers used. The occiput marker (OCC) was set as origin marker on the head segment, the line connecting OCC and the marker in the front of the head (FHEAD) defined as primary axis and the line connecting the two orbit markers defined as secondary axis. An extra virtual marker (ORBVM) was created and defined as the vector mid-point of the two orbit markers and was used in data analysis. The thoracic segment was designated by the markers on T5 and C7 spinous processes and the clavicle marker on the sternal notch. The T5 marker was set as origin marker, the line connecting T5 and C7 markers was set as primary axis and the line connecting T5 and sternal notch markers was set as secondary axis. The pelvic segment was set according to “PlugInGait” model routinely used in gait analysis. Two extra virtual markers were created using the four markers on the pelvis. The first virtual marker was defined as the vector midpoint between the two anterior superior iliac spines’ markers (PEL VM) and the second virtual marker defined as the vector midpoint of the two posterior superior iliac spines’ markers (SACR VM).

3.5.1. Posture variables

Sagittal angles were derived among markers and between segments, calculated and extracted. These angles were used as posture variables representing the dependent variables in the present study. The position of the head and pelvis and the spinal curve configuration, in terms of angles, were obtained mostly based on methodology previously used and published (A. P. Claus, et al., 2009a, 2009b; Edmondston, et al., 2007; Szeto, et al., 2002). The sagittal angles processed, calculated and exported for the designation of HSP, SPOP, FFSP, FLSP, IOSP and the posture repositioning error (RE) and were as follows.

3.5.1.1. Head angle (HE)

An angle based on Euler theorem and defined as the angle between the segments of the head and thorax in regard the z axis in their embedded 3-axis co-ordinate system. The Z was set vertical **(FIGURE 9).**

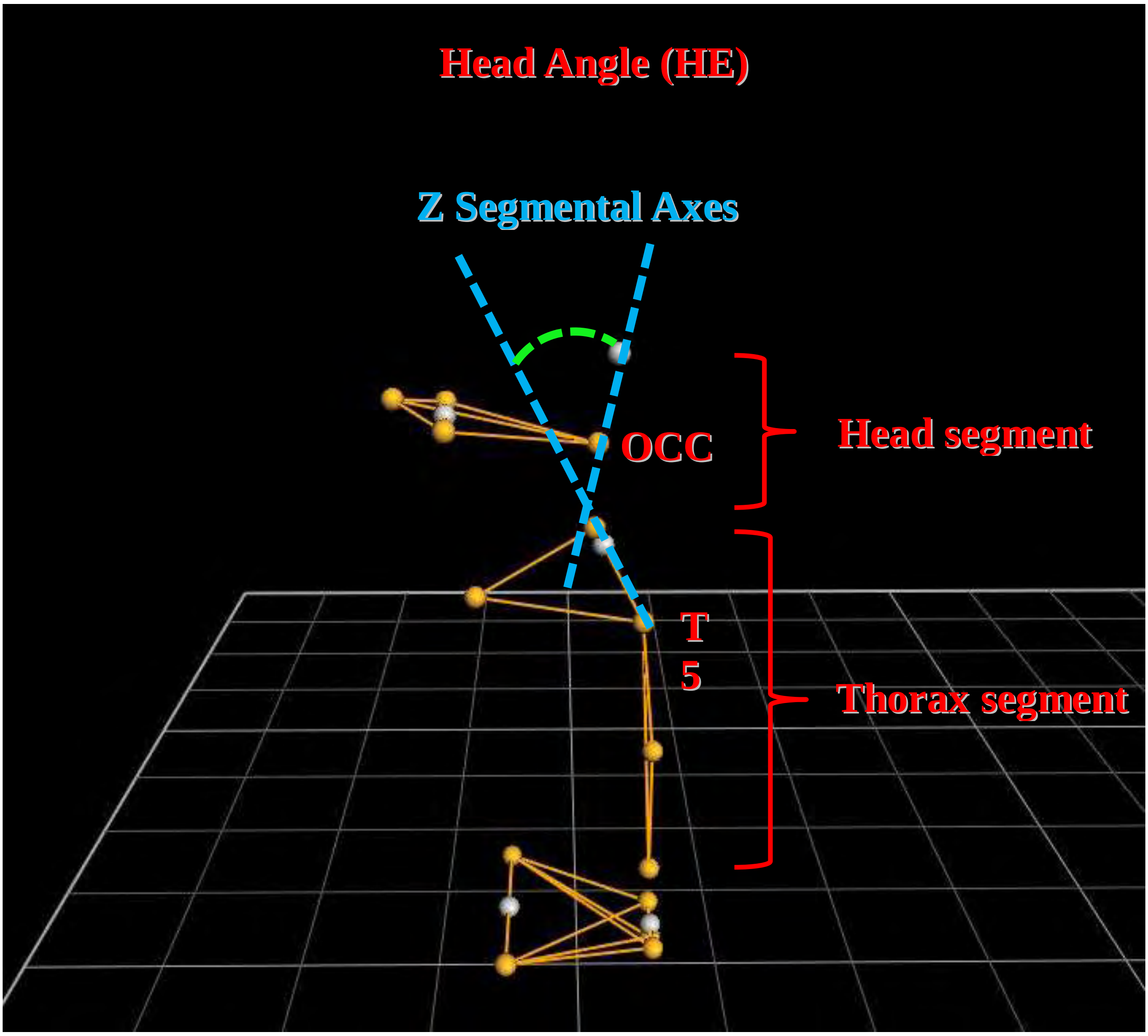

FIGURE 9. Representation of the Head angle (HE) as is formed among markers.

3.5.1.2. Neck angle (NE)

The NE is defined as the angle formed between the vector connecting the C7 marker and the virtual marker derived from the two orbit markers (ORB VM) and the z global axis set on a right hand Cartesian co-ordinate system embedded on C7 marker **(FIGURE 10).**

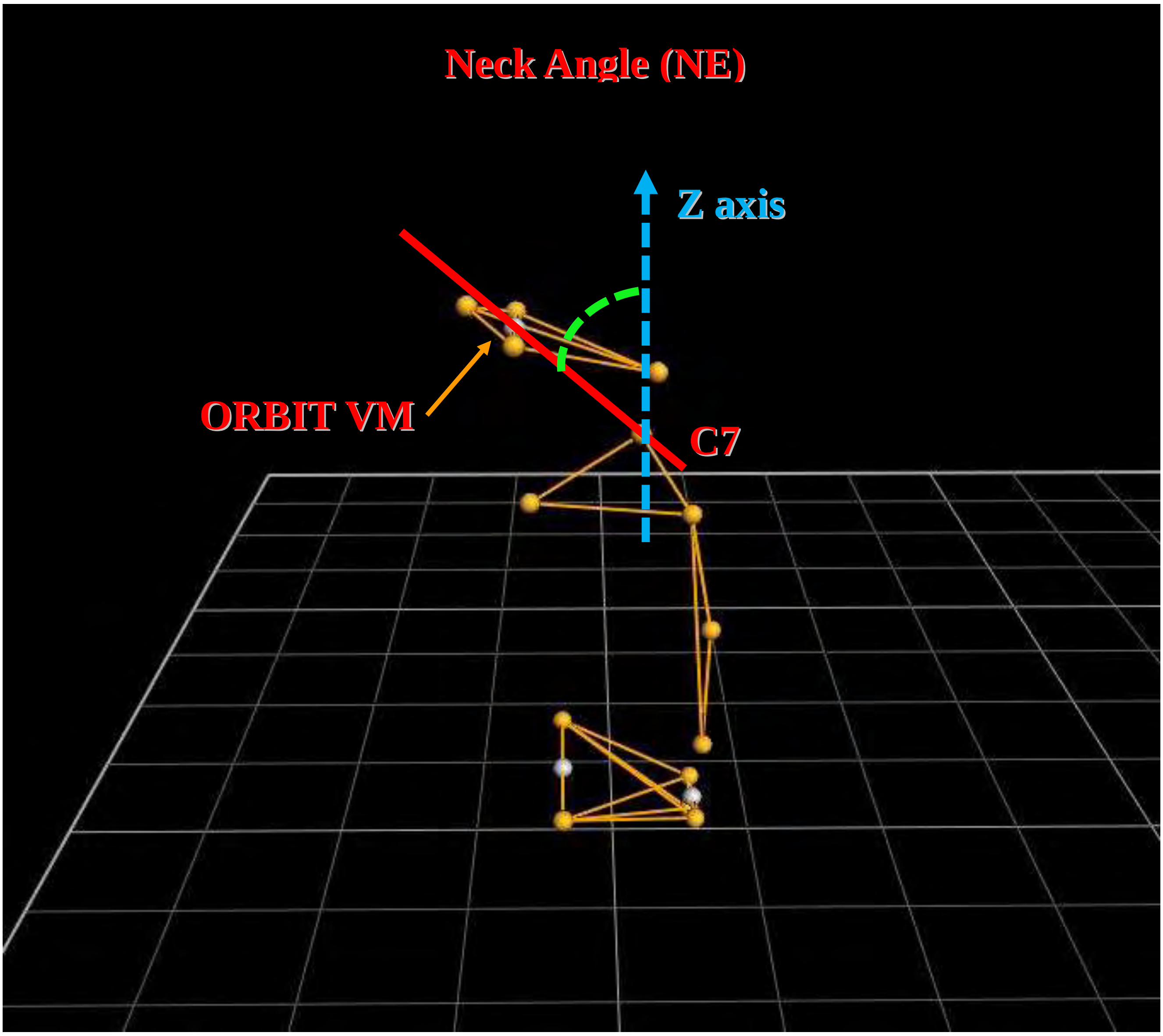

FIGURE 10.Representation of the Neck angle (NE) as is formed among markers.

3.5.1.3. Head tilt angle (HT)

This is defined as the angle formed between the vector connecting the virtual marker created by the two orbit markers (ORB VM) and the marker in the front of the head

(FHEAD) and the z global axis set on a right hand Cartesian co-ordinate system embedded on the orbits virtual marker **(FIGURE 11).**

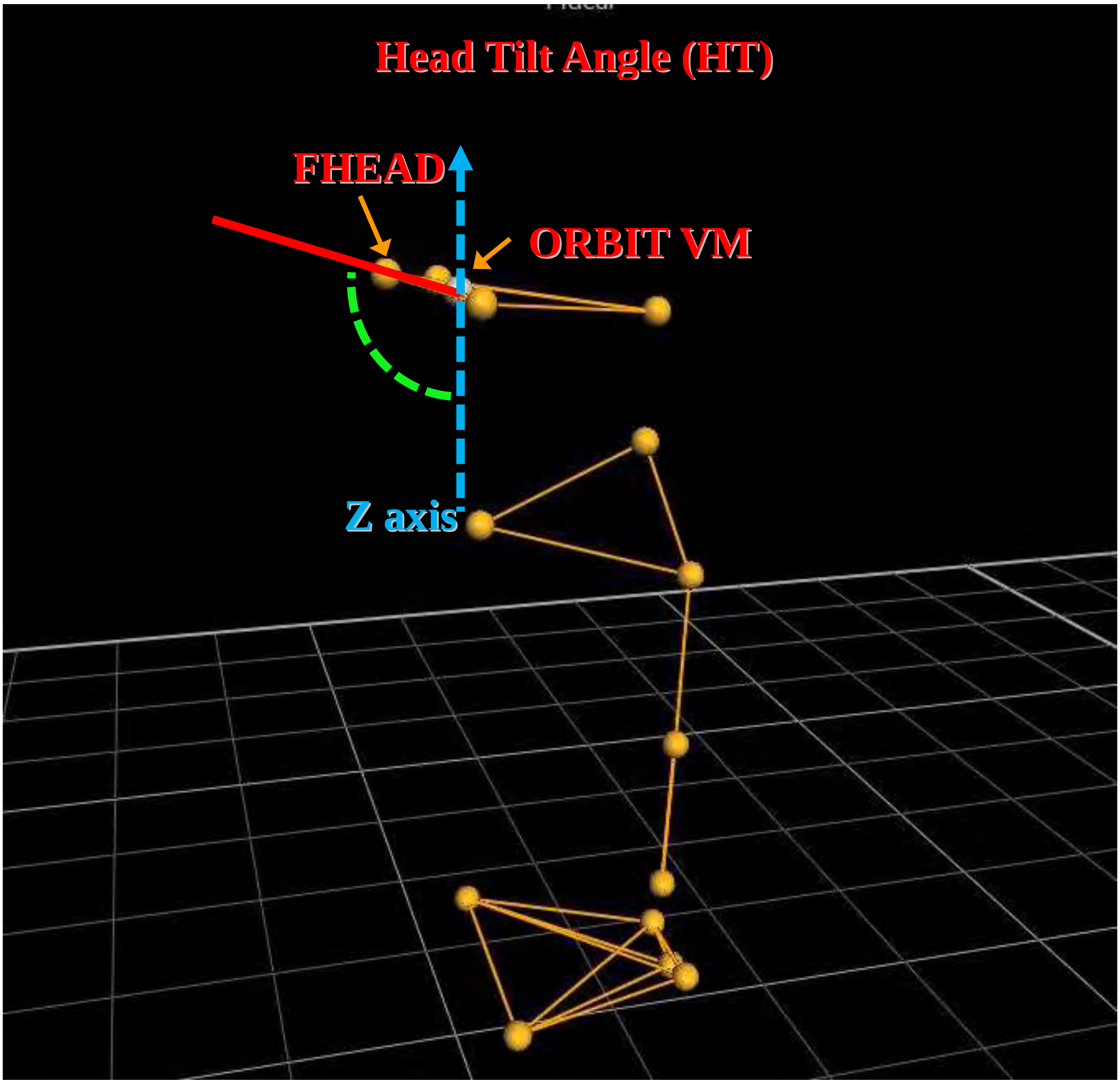

FIGURE 11. Representation of the Head tilt angle (HT) as is formed among markers.

3.5.1.4. Head protraction angle (HP)

An angle defined as the aggregation of HT and NE angles.

3.5.1.5. Cervico-thoracic angle (CT)

The sagittal angle obtained between segments connecting the virtual marker of two orbits (ORB VM) and C7 spinous process marker and the C7 - T5 spinous process markers **(FIGURE 12).**

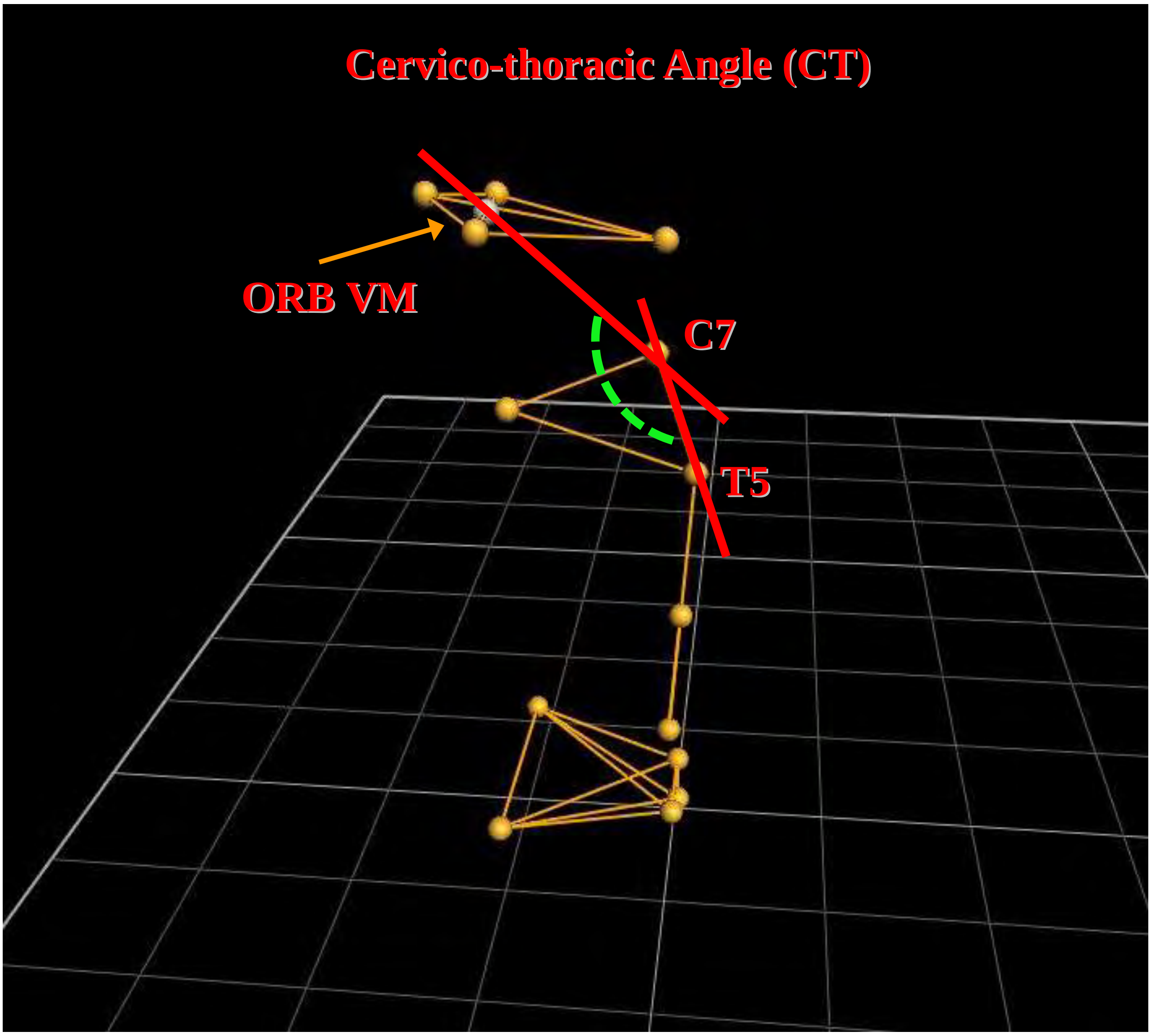

FIGURE 12. Representation of the Cervico-thoracic angle (CT) as is formed among markers.

3.5.1.6. Thoracic angle (TH)

The sagittal angle obtained from C7 - T5 spinous process markers segment and the T5 - T10 spinous process markers segment. This angle represented the thoracic kyphosis **(FIGURE 13).**

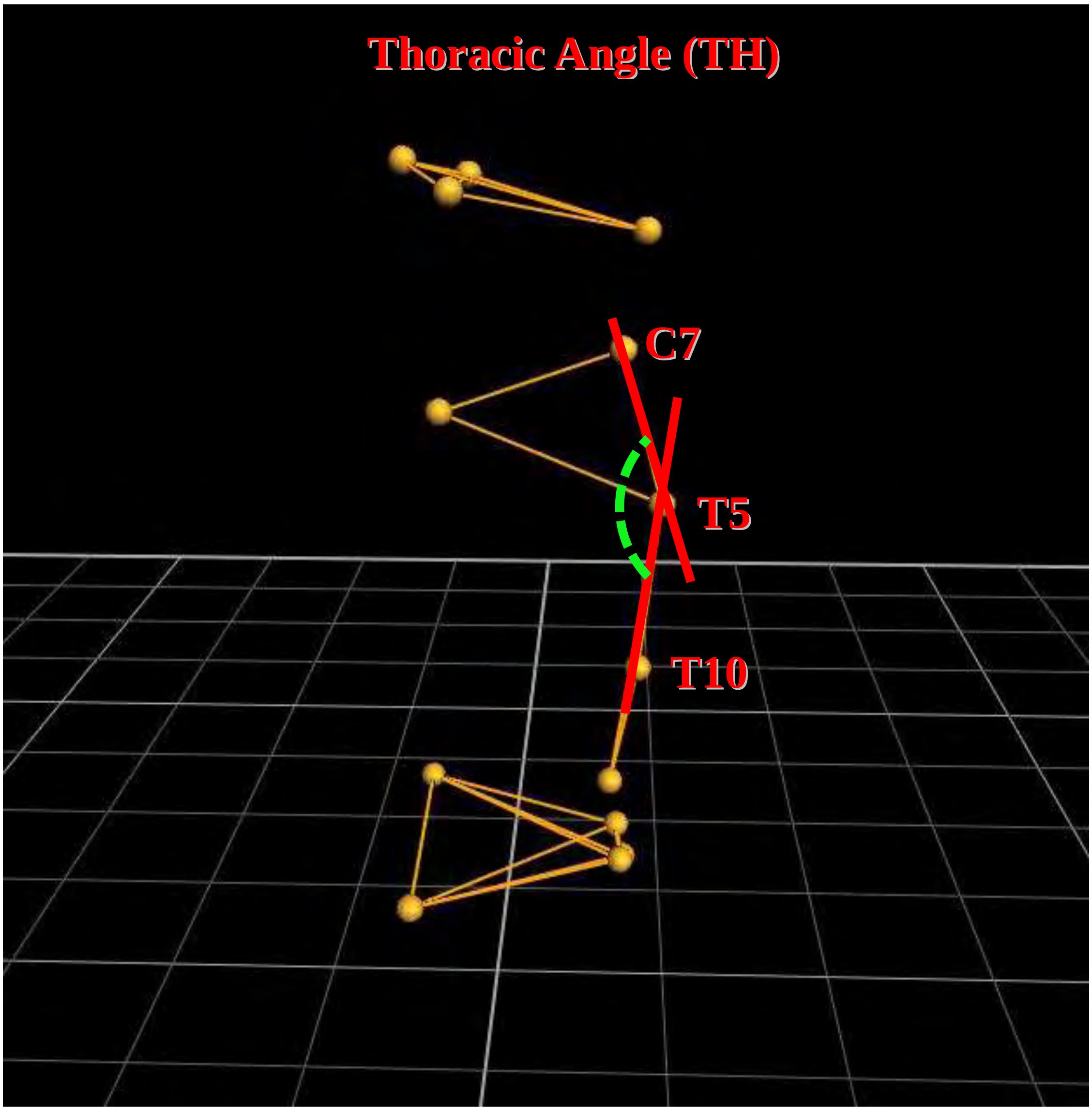

FIGURE 13. Representation of the Thoracic angle (TH) as is formed among markers.

3.5.1.7. Thoraco-lumbar angle (TL)

The sagittal angle obtained from T5 - T10 spinous process markers segment and the T10 - L3 spinous process markers segment **(FIGURE 14).**

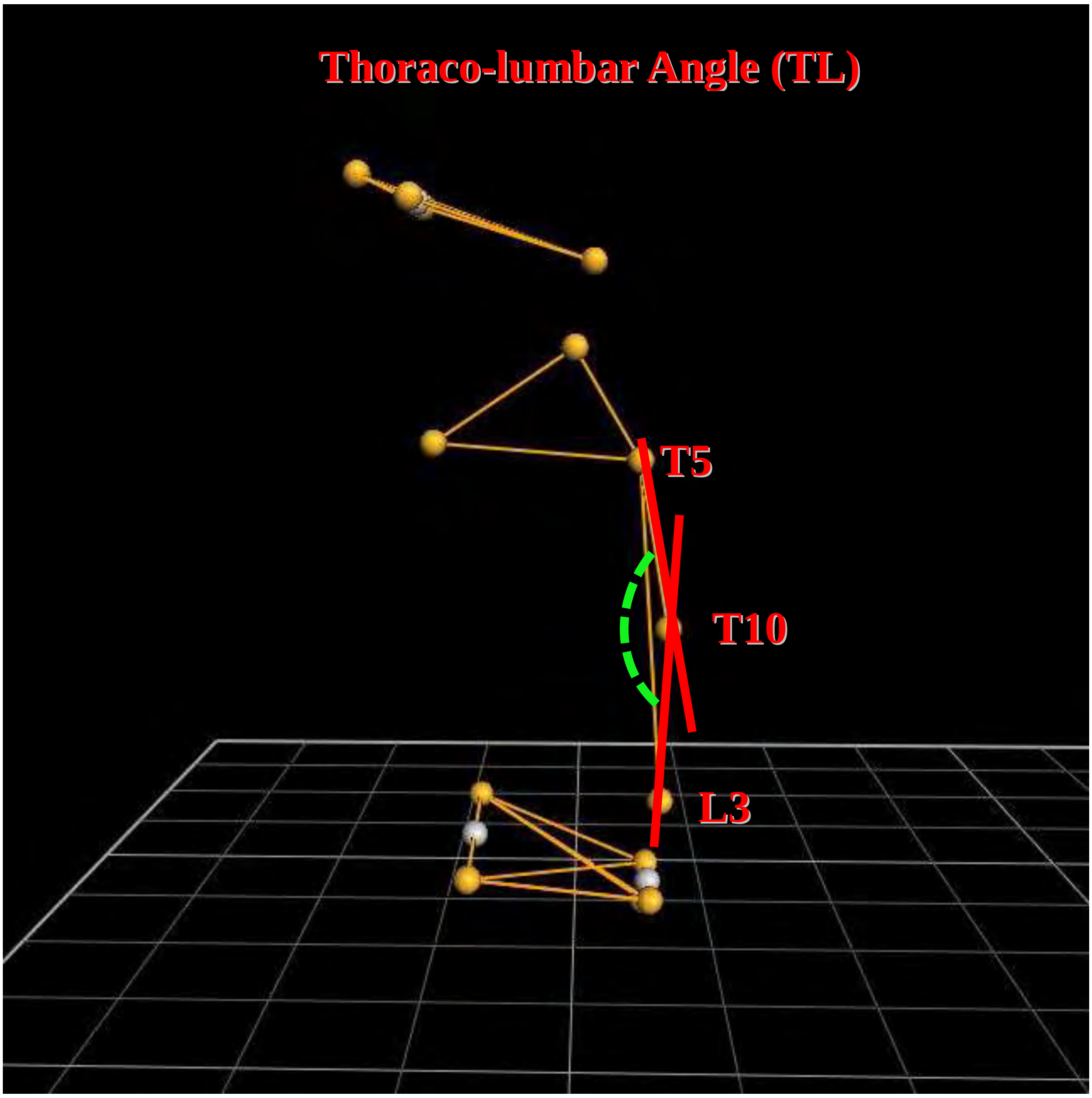

FIGURE 14. Representation of the Thoraco-lumbar angle (TL) as is formed among markers.

3.5.1.8. Lumbar angle (LU)

The sagittal angle obtained from T10 – L3 spinous process markers segment and the L3 – S2 spinous process markers segment. This angle represented the lumbar lordosis **(FIGURE 15).**

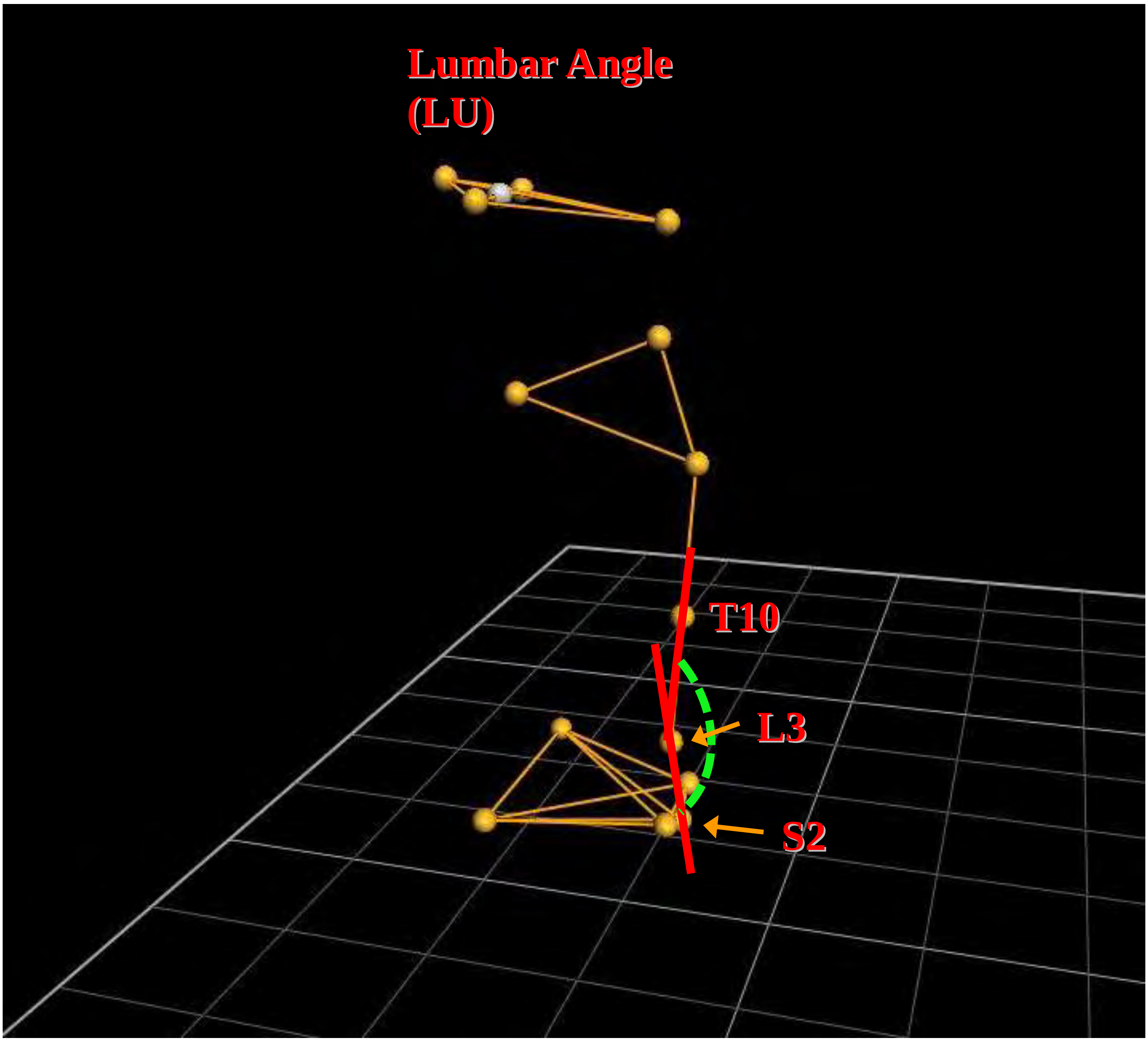

FIGURE 15. Representation of the Lumbar angle (LU) as is formed among markers.

3.5.1.9. Pelvic angle (PEL)

This is defined as the angle obtained from the global x axis and the line connecting two virtual markers representing the mid-point of the two anterior superior iliac spines PELVM) and the two posterior superior iliac spines (SACRVM). This angle represented the sagittal pelvic tilt and had negative values for posterior tilt beyond the x axis **(FIGURE 16).**

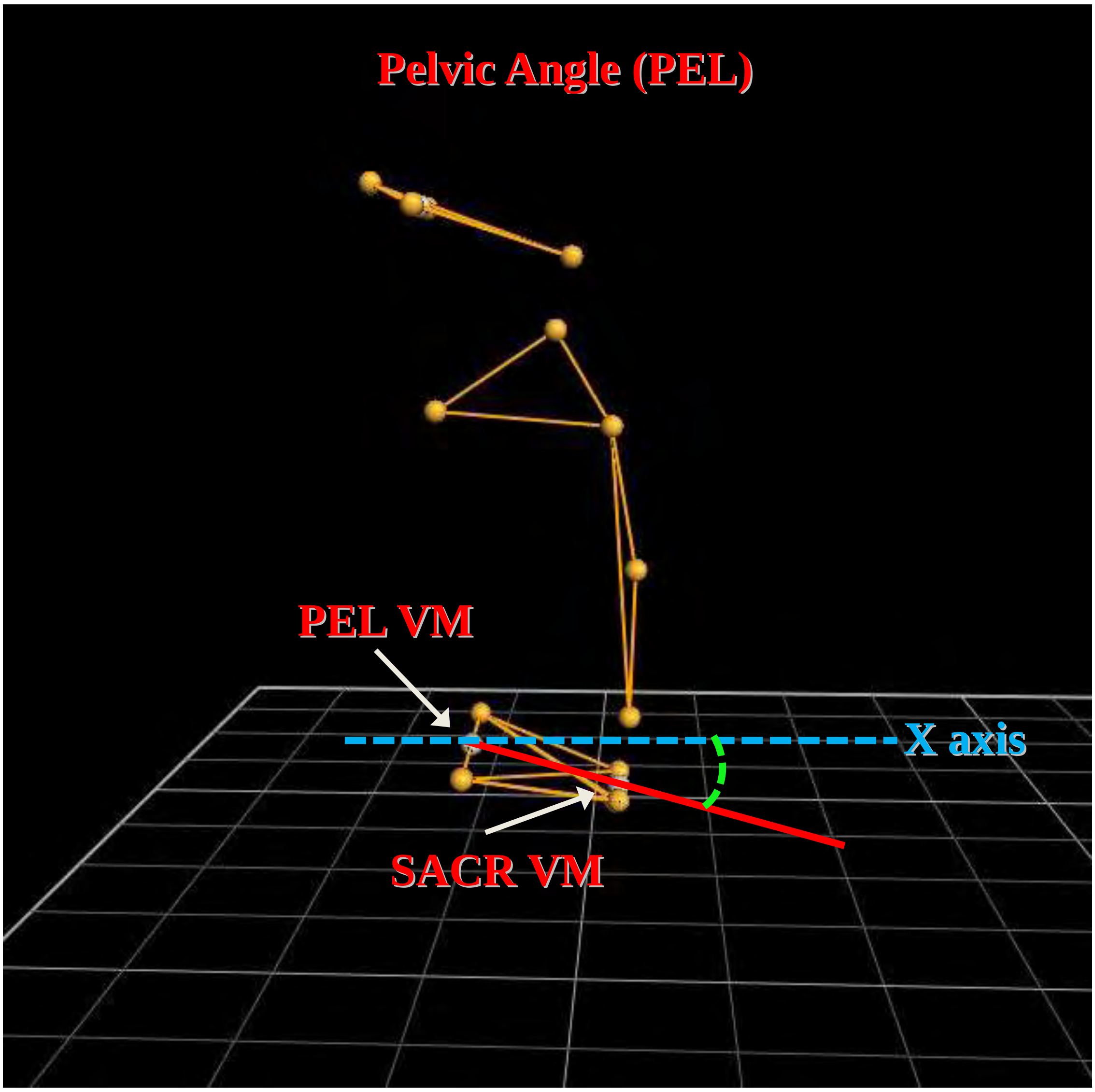

FIGURE 16. Representation of the Pelvic angle (PEL) as is formed among markers.

3.5.2. Reposition error (RE)

Reposition error was calculated for all the angles that revealed statistically significant differences between different postures and measures. In the present study constant error was calculated as it describes whether the predetermined position has been overestimated or underestimated (Armstrong, McNair, & Taylor, 2008; Strimpakos, 2011). Reposition error (RE) was represented as the difference of angles of reposition trails from angles from IOSP. In this way, reposition error 1 (RE1) was defined as the difference of angles of IOSP form reposition 1 (IOSP-REP1) and so on for reposition errors 2, 3, 4 (RE2, RE3 and RE4).

3.6. Reliability

The intra-rater reliability study was conducted in order to determine the extent that the investigator was reliable to place the participants to the IOSP (Shrout & Fleiss, 1979). All the markers were adhered to the participants and remained in position through the procedure; the stool that was used was adjusted for each participant and all the participants were placed in position by the same investigator. A single investigator was manually placed 10 participants (N=10) to the IOSP 10 repeated times with intervals of 3 minutes. During the rest periods the subjects were allowed to move loosely around the laboratory.

3.7. Statistical Analyses

The nine spinal, head and pelvis angles were compared between the seven procedure conditions (seven levels – HSP, SPOP, IOSP and four repositioning trials) with a repeated measures analysis of variance using one repeated measure (posture). All statistical analyses were performed using SPSS statistical analysis software, version 17.0 (SPSS, Chicago, IL). Descriptive statistic analysis was performed to summarize the postural measurements (angles) and reposition error (RE) for all the participants in all the procedure postures. Data were analyzed for normality and parametric analysis was performed. Pair-wise comparisons of the angles between postures were undertaken with Bonferroni adjustment for multiple comparisons. The alpha level for statistical significance was set at $p<.05$. Furthermore, repeated measures analysis of variance was used to determine whether the reposition error varied significantly among the repositioning trails.

Reliability was determined by using a two-way mixed Intra-class Correlation Coefficient (ICC $_{(3,1)}$) and additionally Coefficient of Variation (CV %) was calculated (SD/MEAN %).

4. RESULTS

4.1. Reliability

Intra-tester reliability for positioning subjects into IOSP was very good and the results are presented in **Table 2**.

TABLE 2. Descriptive data of the reliability study

Angles	ICC	Cronbach's α	CV%	SD (degrees)
HE	0.90	0,99	9.71	2.20
NE	0.79	0.98	3.50	1.60
HT	0.92	0.99	1.77	1.91
CT	0.91	0.99	1.00	1.45
TH	0.89	0.99	0.60	0.98
TL	0.89	0.99	0.57	1.00
LU	0.92	0.99	1.35	2.15
PEL	0.90	0.99	-20.05	1.28

Note.ICC=Intra-class Correlation Coefficient, CV= Coefficient of Variation, SD= Standard deviation in degrees, HE= Head Angle, NE= Neck Angle, HP= Head protraction, HT= Head tilt, CT= Cervico-thoracic angle, TH= Thoracic angle, TL= Thoraco-lumbar angle, LU= Lumbar angle, PEL= Pelvic angle

4.2. Results of examined postures

Data obtained for each angle in each sitting posture are presented in **Table 3.**

TABLE 3. Angles obtained from different sitting postures.

	HSP	SPOP	IOSP	REP1	REP2	REP3	REP4
HE	44.7 (12.8)	38.3 (10.0)	26.5 (7.2)	27.7 (8.3)	30.3 (8.9)	31.7 (9.4)	29.5 (8.6)
NE	56.6 (7.4)	51.0 (2.9)	48.6 (4.1)	48.5 (4.6)	49.4 (5.8)	49.1 (4.6)	48.8 (5.2)
HP	162.5 (10.8)	159.9 (6.8)	155.3 (6.6)	155.5 (6.7)	156.8 (6.6)	157.2 (6.6)	155.1 (9.1)
HT	105.9 (13.7)	108.7 (6.8)	106.6 (7.9)	107.0 (7.8)	107.4 (8.8)	108.0 (7.7)	107.4 (7.8)
CT	158.1 (8.9)	154.6 (6.7)	147.4 (5.3)	148.2 (5.5)	149.4 (6.1)	150.3 (6.5)	149.0 (6.3)
TH	158.4 (5.1)	159.6 (4.6)	158.8 (4.9)	159.7 (5.1)	159.0 (5.3)	159.3 (4.8)	159.6 (5.0)
TL	164.3 (7.8)	170.3 (6.4)	174.4 (3.6)	174.3 (3.9)	173.3 (4.1)	173.1 (4.3)	173.7 (4.3)
LU	170.8 (5.9)	170.3 (7.3)	162.9 (9.2)	164.8 (8.4)	167.6 (8.5)	168.3 (8.3)	166.2 (9.2)
PEL	-13.3 (7.2)	-10.4 (8.0)	-2.1 (5.2)	-2.4 (5.6)	-3.9 (6.7)	-4.1 (7.1)	-2.9 (6.3)

Note. Values are presented in degrees, mean (SD). HE= head angle, NE=neck angle, HP= head protraction angle, HT=head tilt angle, CT= cervico-thoracic angle, TH= thoracic angle, TL= thoraco-lumbar angle, LU= lumbar angle, PEL= pelvis angle. HSP= habitual sitting posture, SPOP= self perceived optimal posture, IOSP= ideal posture, REP1= immediately repositioned posture, REP2= repositioned posture after 10 minutes, REP3= repositioned posture after 30 minutes, REP4= repositioned posture after slouch-overcorrect procedure.

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that there was a statistically significant interaction between angles and postures examined (p<.001). The mean angle differed significantly between postures for HE angle ($F_{(3.803,\ 167.323)} = 43{,}931$, $p < .001$), NE angle ($F_{(2.692,\ 115.748)} = 22{,}829$, $p < .001$), HP angle ($F_{(2.643,\ 116.292)} = 12.381$, $p < .001$), CT angle ($F_{(3.761,165.470)} = 36.068$, $p < .001$), TL angle ($F_{(2.832,\ 124.599)} = 37.981$, $p < .001$), LU angle ($F_{(3.225,\ 141.893)} = 9.794$, $p < .001$) and PEL angle ($F_{(3.523,\ 155.026)} = 65.349$, $p < .001$). No statistically significant interaction was shown between the mean angle and postures for HT angle ($F_{(2.363,\ 103.957)} = 1.034$, $P = 0.369$) and TH angle ($F_{(3.869,\ 170.224)} = 2.60$, $p = 0.04$). Post hoc tests using the Bonferroni correction revealed the individual differences as presented in **Tables 4 and 5**. The difference in angle between postures was described separately for each of the angles examined in two different sessions of the procedure. One session was referred to HSP, SPOP and IOSP and the other was referred to repositioning trails.

In **Figures 17-23** are presented the angles in each posture with means, SD and the statistically significant differences.

4.2.1. Habitual (HSP)

Post hoc analysis with Bonferroni correction revealed that HSP was statistically significant different in all angles examined in relation to the FFSP (p<.05) except the PEL angle. The PEL angle (mean ±SD in degrees, HSP -13.3±7.2, FFSP -13.7±7.5) was not significantly different between HSP and FFSP (p=1.00).

In point of HSP and FLSP analysis showed statistically significant differences (P<.05) between all angles examined except HT (mean ±SD in degrees, HSP 105.9±13.7° and FLSP 109.9±8.5°) and TH angle (mean ±SD in degrees, HSP 158.4±5.1° and FLSP 159.7±6.2°) (p=1.00).

4.2.2. Habitual (HSP) and self-perceived optimal posture (SPOP)

Post-hoc analysis showed that between HSP and SPOP, HE angle, NE angle, TL angle and PEL angle were revealed statistically significant differences (p<.05), but other angles comparisons were not statistically different. The HE angle between head and thoracic segment showed less relative flexion between the segments in SPOP than in HSP (38.3°, SD10.0 and 44.7°, SD12.8 respectively). The NE angle showed less flexion in regard the thoracic segment in SPOP than in HSP (51.0°, SD2.9 and 56.6°, SD7.4, respectively). The TL angle revealed less thoraco-lumbar kyphosis in SPOP than in HSP (170.3º SD6.4 and 164.3º SD7.8, respectively). The PEL angle revealed increased posterior pelvic tilt in HSP than in SPOP (-13.3º SD7.2 and -10.4º SD8.0, respectively). In regard the other obtained angles no statistically significant differences were shown for HP (p=.774), HT (p=1.000), TH (p=.106) and LU (p=1.000), but a trend towards greater cervico-thoracic flexion in HSP (p=.061).

4.2.3. Instructed optimal sitting posture (IOSP)

Comparisons between IOSP and HSP, and IOSP and SPOP showed significant differences (p<.05) for HE, NE, HP, CT, TL, LU and PEL angles, but comparisons for HT (IOSP-HSP p=1.000 and IOSP-SPOP p=.31) and TH (IOSP-HSP p=1.000 and IOSP-SPOP p=.41) angles were not different. HE angle was associated with significantly greater relative head/thoracic segment flexion in HSP and SPOP than in IOSP (44.7º SD12.8, 38.3º SD10.0 and 26.5º SD7.2, respectively). NE angle in IOSP when compared with HSP and SPOP showed significantly less flexion (48.6º SD4.1, 56.6º SD7.4 and 51.0º SD2.9). HP angle demonstrated significantly greater neck and head flexion in HSP and SPOP than in IOSP (162.5º SD10.8, 159.9º SD6.8 and 155.3º SD6.6, respectively). The cervico-thoracic kyphosis was revealed significantly greater in HSP and SPOP than in IOSP (158.1º SD8.9, 154.6º SD6.7 and 147.4º SD5.3, respectively). The TL angle showed to differ significantly between HSP, SPOP and IOSP, with increasing trend toward extension from HSP to SPOP and IOSP (164.3º SD7.8, 170.3º SD6.4 and 174.4º SD3.6, respectively). In regard the LU angle IOSP was associated with significantly greater lumbar lordosis than the HSP and the SPOP (162.9º SD9.2, 170.8º SD5.9 and 170.3º SD7.3, respectively). The PEL angle was associated with significantly decreased posterior pelvic tilt in IOSP than in HSP and SPOP (-2.1º SD5.2, -13.3º SD7.2 and -10.4º SD8.0, respectively).

TABLE 4. Pair-wise comparisons of angles among habitual, self perceived optimal and instructed optimal sitting posture

	HSP-SPOP	HSP-IOSP	SPOP-IOSP
HE	*	*	*
NE	*	*	*
HP	p=.774	*	*
HT	p=1.00	p=1.00	p=.31
CT	p=.061	*	*
TH	P=.106	p=1.00	p=.41
TL	*	*	*
LU	p=1.00	*	*
PEL	*	*	*

Note. HSP= Habitual Sitting Posture, SPOP=Self Perceived Optimal Posture and IOSP=Instructed Optimal Sitting Posture. HE= Head Angle, NE= Neck Angle, HP= Head protraction, HT= Head tilt, CT= Cervico-thoracic angle, TH= Thoracic angle, TL= Thoraco-lumbar angle, LU= Lumbar angle, PEL= Pelvic angle.

** Indicates statistically significant differences (p<.05).*

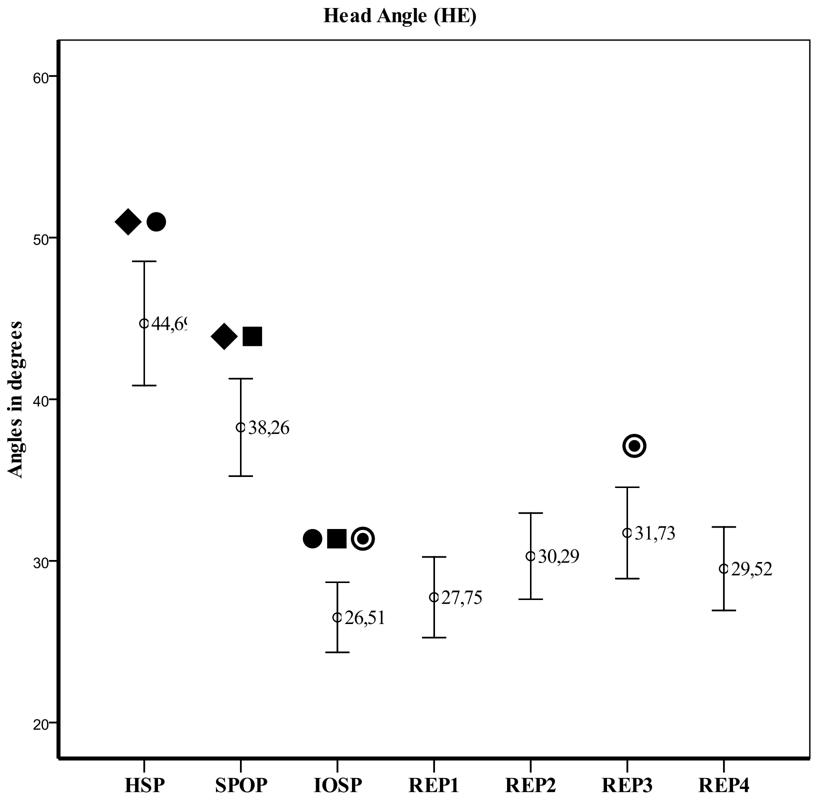

FIGURE 17. Head angle represented in mean and SD (degrees) among different examined postures.

◆●◉■ Indicate statistical significant differences (p<.05)

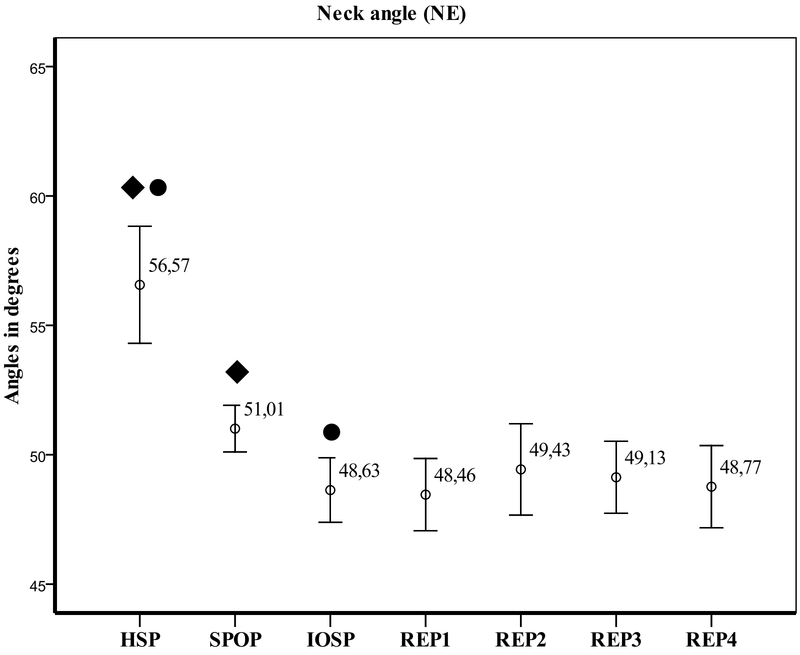

FIGURE 18. Neck angle (NE) represented in mean and SD (degrees) among different examined postures.

◆● Indicate statistical significant differences (p<.05).

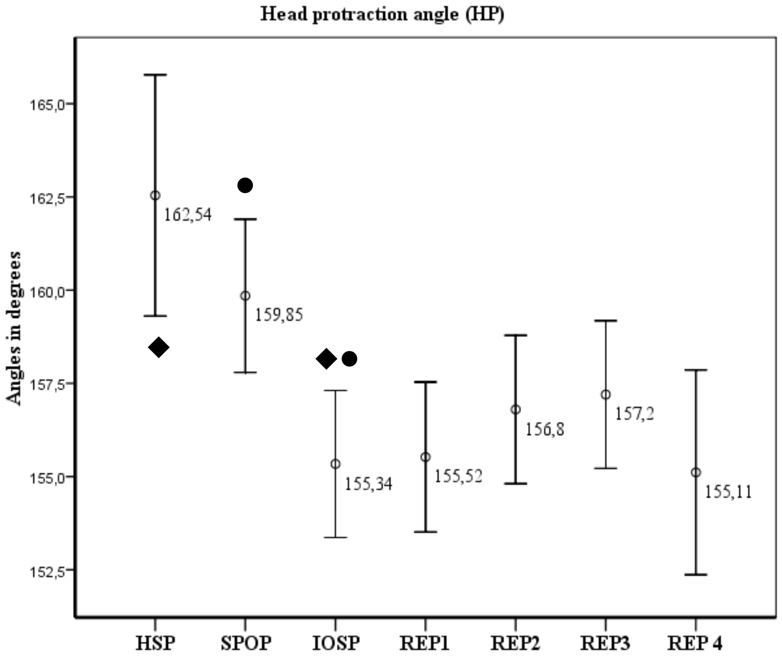

FIGURE 19. Head protraction angle (HP) represented in mean and SD (degrees) among different examined postures.

●◆ Indicate statistical significant differences (p<.05).

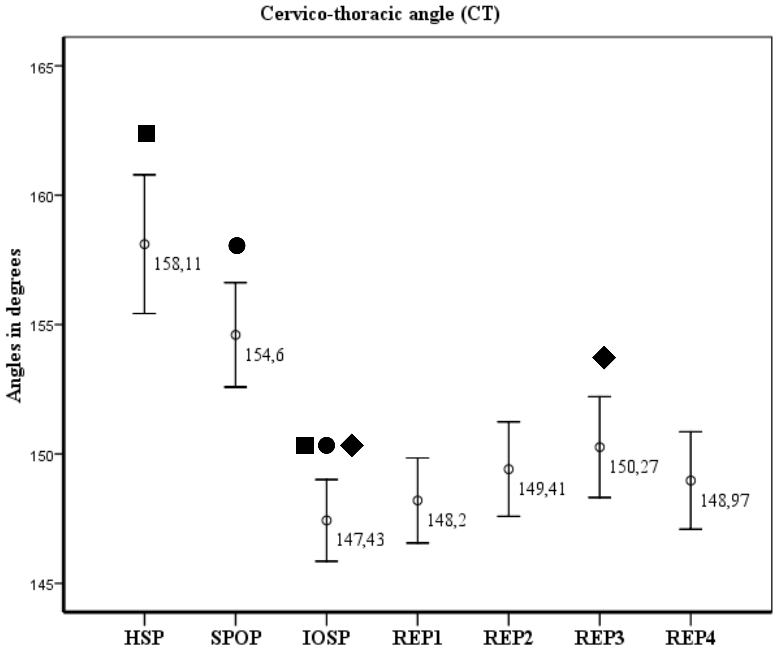

FIGURE 20. Cervico-thoracic angle (CT) represented in mean and SD (degrees) among different examined postures.

■●◆ Indicate statistical significant differences (p<.05).

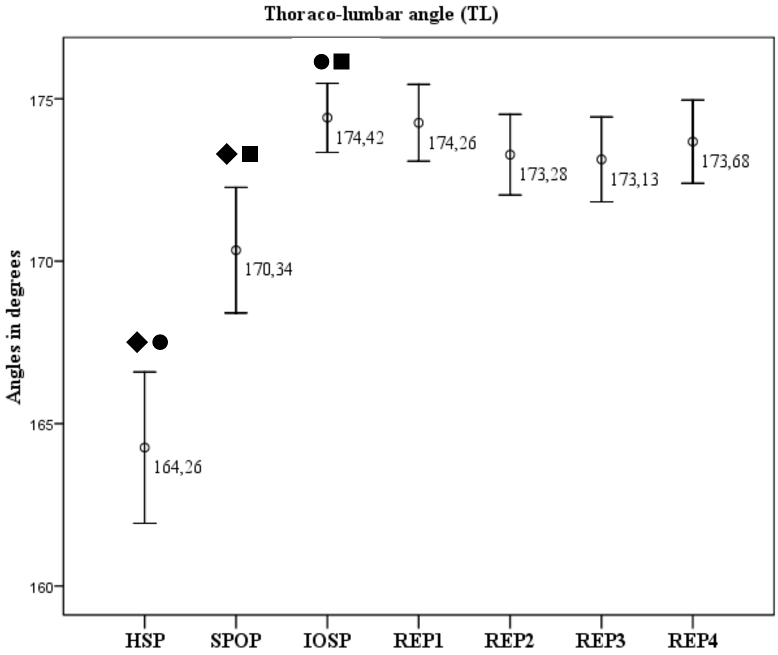

FIGURE 21. Thoraco-lumbar angle (TL) represented in mean and SD (degrees) among different examined postures.

◆■● Indicate statistical significant differences (p<.05).

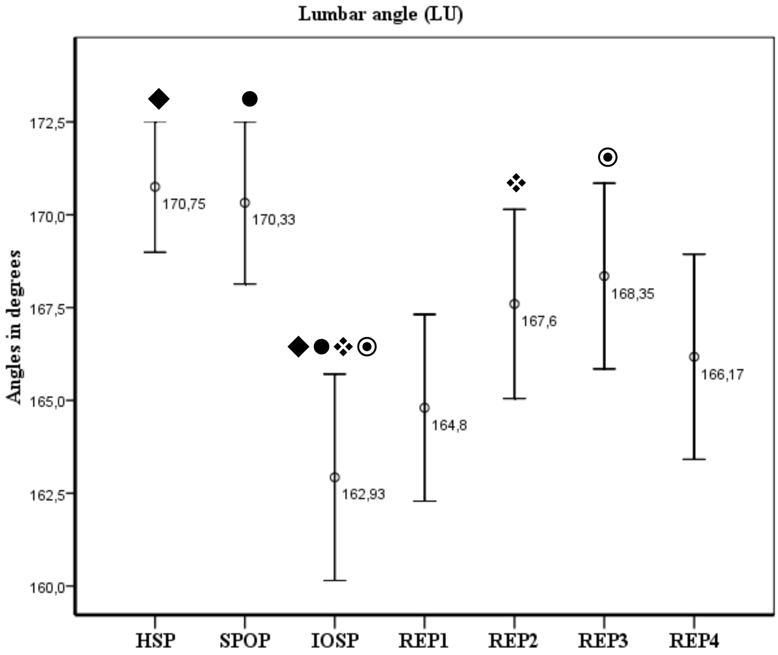

FIGURE 22. Lumbar angle (LU) represented in mean and SD (degrees) among different examined postures.

■●◆⦿❖ Indicate statistical significant differences ($p<.05$).

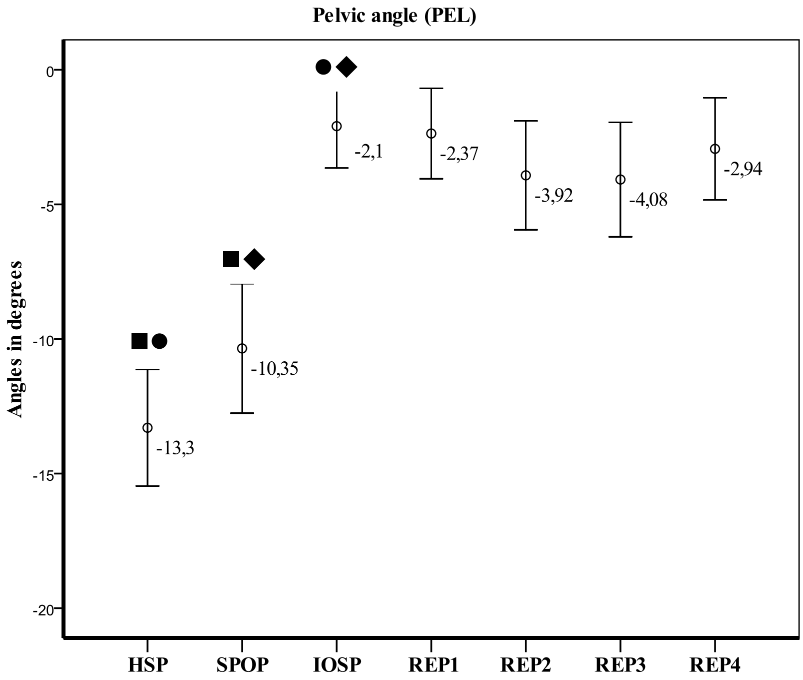

FIGURE 23. Pelvic angle (PEL) represented in mean and SD (degrees) among different examined postures.

■●◆ Indicate statistical significant differences (p<.05).

4.2.4. Instructed Optimal Sitting Posture (IOSP) and repositioning trails

Comparisons between IOSP and repositioning trails showed significant differences (p<.05) for HE, CT and LU angles, but comparisons for all the other angles were not different **(Table 5).**

TABLE 5. Pair-wise comparisons of angles among instructed optimal posture and repositioned postures.

	IOSP-REP1	IOSP-REP2	IOSP-REP3	IOSP-REP4
HE	p=1.00	p=.113	*	p=.188
NE	p=1.00	p=1.00	p=1.00	p=1.00
HP	p=1.00	p=.832	p=.334	p=1.00
HT	p=1.00	p=1.00	p=1.00	p=1.00
CT	p=1.00	p=.364	*	p=.689
TH	p=.293	p=1.00	p=1.00	p=1.00
TL	p=1.00	p=.745	p=.84	p=1.00
LU	p=.892	*	*	p=.91
PEL	p=1.00	p=.149	p=.271	p=1.00

Note. IOSP= Instructed Optimal Sitting Posture, REP1= Immediately Repositioned posture, REP2= Repositioned posture after 10 minutes in FFSP (Fully flexed spinal posture), REP3= Repositioned posture after 30 minutes in FFSP and REP4= Repositioned posture after slouch-overcorrect procedure. HE= Head Angle, NE= Neck Angle, HP= Head protraction, HT= Head tilt, CT= Cervico-thoracic angle, TH= Thoracic angle, TL= Thoraco-lumbar angle, LU= Lumbar angle, PEL= Pelvic angle.

* *Indicates statistically significant differences (p<.05).*

No statistically significant differences were revealed in all angles examined between IOSP and REP1 (immediate repositioning of IOSP) posture. Reposition error (mean ± SD) was for HE (-1.2º±5.6), NE (0.4º±3.6), HP (-0.1º±3.2), HT (-0.5º±4.8), CT (-0.8º±3.8), TH (-0.9º±2.3), TL (0.2º±3.3), LU (-1.9º±5.9) and PEL (0.4º±2.7).

Comparison of IOSP and REP2 (repositioning to IOSP after 10 minutes in FFSP) showed significant difference (p<.05) for LU angle (162.9º SD9.2 and 167.6º SD8.5, respectively). Comparison of IOSP and REP3 (repositioning to IOSP after 30 minutes in FFSP) showed significant differences (p<.05) for HE (26.5º SD7.2 and 31.7º SD9.4, respectively), CT (147.4º SD5.3 and 150.3º SD6.5, respectively) and LU (162.9º SD9.2 and 168.3º SD8.3, respectively) angles.

No statistically significant differences (p>.05 in all angles) were revealed in all angles examined between IOSP and REP4 (repositioning of IOSP after slouch overcorrect procedure) posture.

4.3. Reposition Error

A repeated measures analysis of variance revealed statistically significant differences between HE ($F_{(3,135)}$=5.516, p<.001) and LU ($F_{(3,135)}$=6.852, p<.001) reposition errors, but the means of CT reposition errors were not significantly different ($F_{(3,135)}$=3.482, p=.018). The descriptive characteristics of reposition errors for HE, CT and LU angles are presented in **Table 6.**

Post hoc tests using Bonferroni correction showed that statistically significant differences were evident between RE1 and RE2 for LU angle and between RE1 and RE3 for HE and LU angles (p<.05). In contrast, for CT angle only a trend was revealed between RE1 and RE3 (p=.064) **(TABLE 7)**.

The subjects generally overestimated HE, CT and LU angles in their reposition trail after 30 minutes in FFSP, and also, the participants overestimated the LU angle in their reposition trail after 10 in FFSP.

The difference in reposition errors are presented by box plots in **FIGURES 24, 25 and 26.**

TABLE 6.Summary of descriptive data for reposition error of HE, CT and LU angles

Outcome for RE	(1) – (2)	Mean (deg)	Standard deviation	Standard error of mean (deg)
HE RE1	IOSP-REP1	-1.18	5.62	0.83
HE RE2	IOSP-REP2	-3.90	8.62	1.27
HE RE3	IOSP-REP3	-5.34*	8.86	1.31
HE RE4	IOSP-REP4	-3.04	7.30	1.08
CT RE1	IOSP-REP1	-0.76	3.87	0.57
CT RE2	IOSP-REP2	-2.06	5.34	0.79
CT RE3	IOSP-REP3	-2.88**	5.49	0.81
CT RE4	IOSP-REP4	-156	4.64	0.68
LU RE1	IOSP-REP1	-1.89	5.95	0.88
LU RE2	IOSP-REP2	-4.78*	7.45	1.10
LU RE3	IOSP-REP3	-5.49*	8.47	1.25
LU RE4	IOSP-REP4	-3.24	7.16	1.06

Note. HE= head angle, CT= cervico-thoracic angle, LU= lumbar angle and RE= reposition error. All data are presented as degrees.

**Indicates statistically significant differences p<.05*

*** Indicates a trend to significant differences p=.064*

TABLE 7. Reposition error results of pair-wise comparisons of HE, CT and LU angles

	(1)-(2)	Mean Difference (1-2)	Std. Error	Sig.	Lower Bound	Upper Bound
					95% Confidence Interval	
HE	**RE1-RE3**	4.17	1.20	0.007	0.87	7.47
CT	**RE1-RE3**	2.11	0.79	0.064*	-0.076	4.3
LU	**RE1-RE2**	2.88	0.75	0.002	0.81	4.95
LU	**RE1-RE3**	3.60	0.88	0.001	1.16	6.04

The mean difference is significant at the .05 level.

**Indicate a trend towards significant difference.*

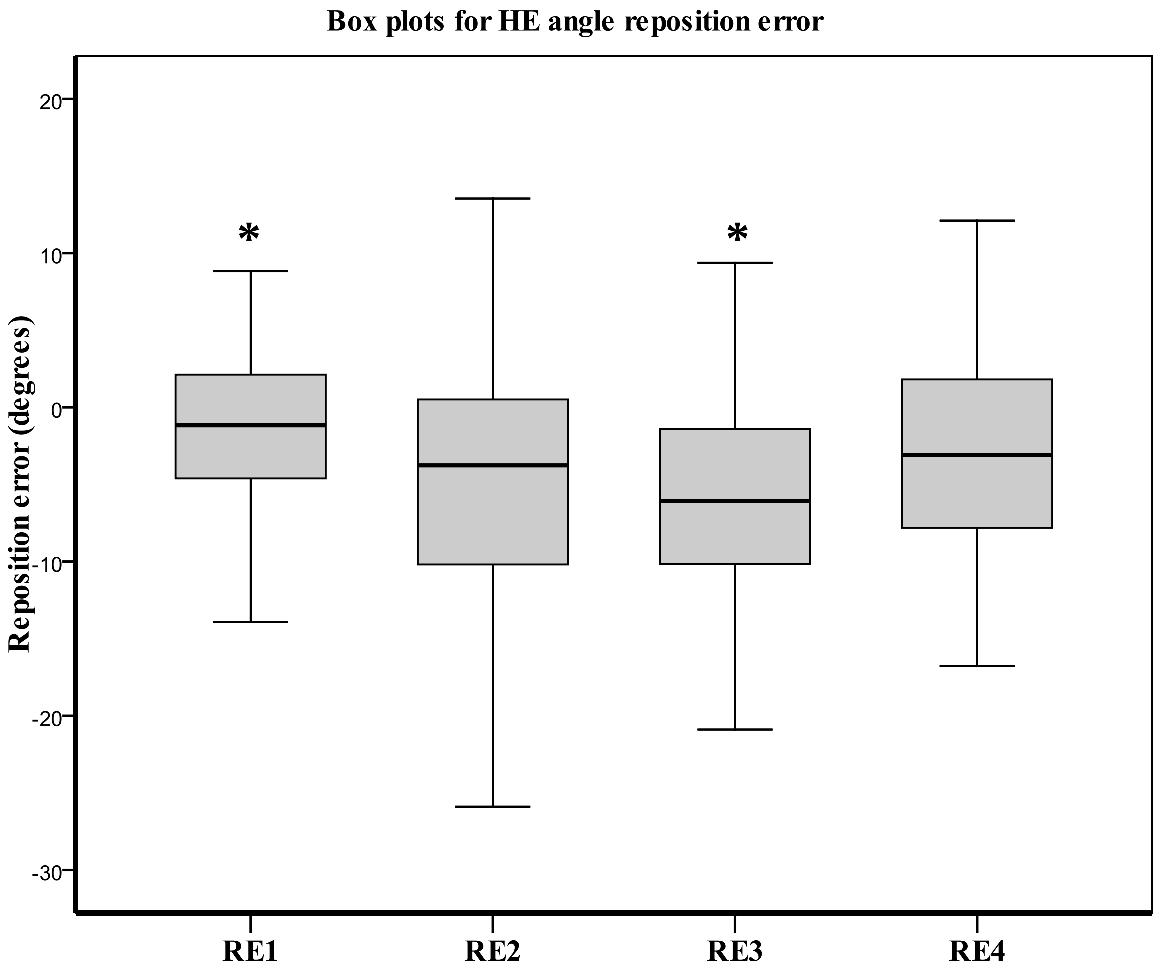

FIGURE 24: Box plots showing median values and data dispersion for HE angle reposition error in each trial.

RE1= error in immediate reposition trial to IOSP, RE2= error in reposition to IOSP after 10 minutes in FSP, RE3= error in reposition to IOSP after 30 minutes in FSP, RE4= error in reposition to IOSP after slouch overcorrect procedure.

** Indicates statistical significant differences p<.05.*

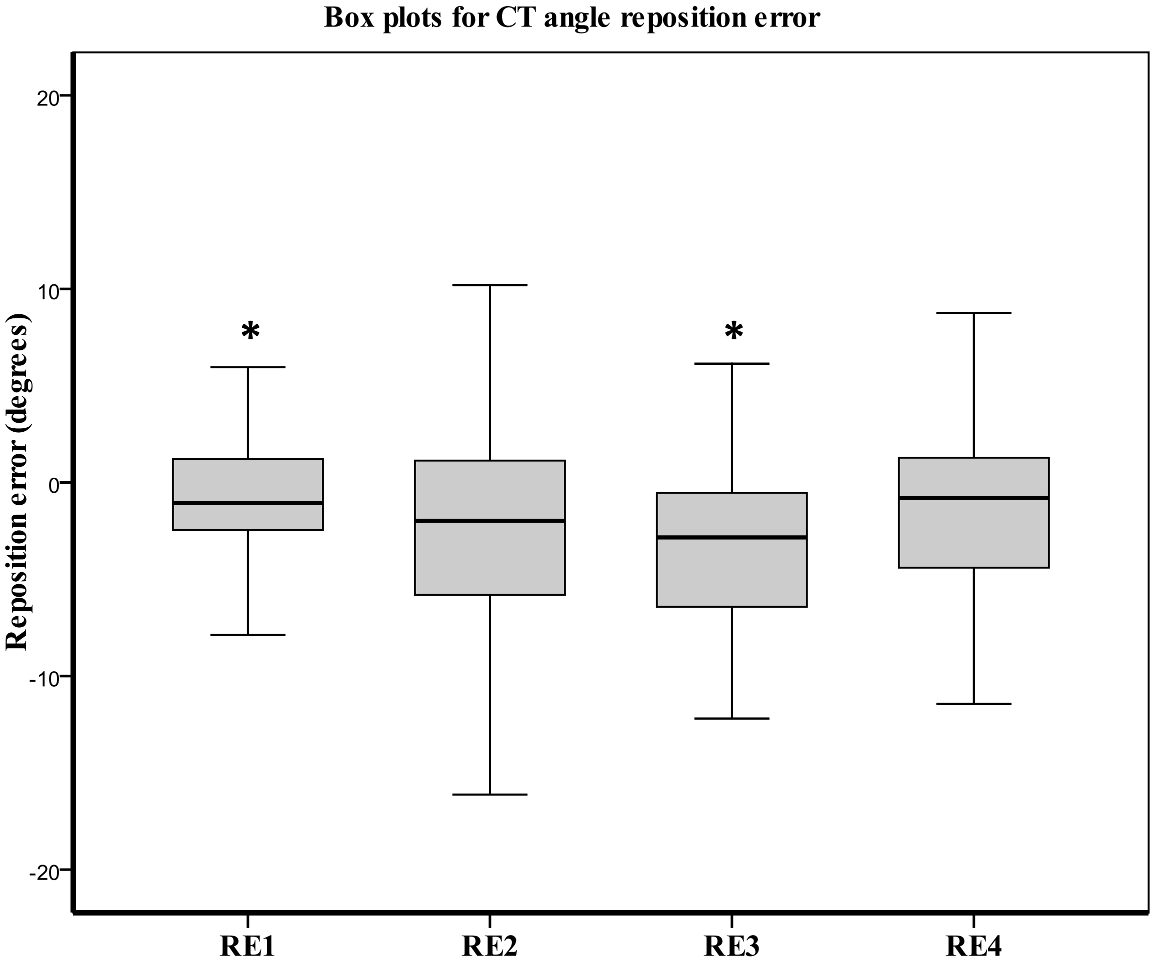

FIGURE 25: Box plots showing median values and data dispersion for CT angle reposition error in each trial.

RE1= error in immediate reposition trial to IOSP, RE2= error in reposition to IOSP after 10 minutes in FSP, RE3= error in reposition to IOSP after 30 minutes in FSP, RE4= error in reposition to IOSP after slouch overcorrect procedure.

** Does not indicate statistical significant differences but a trend as p=.064*

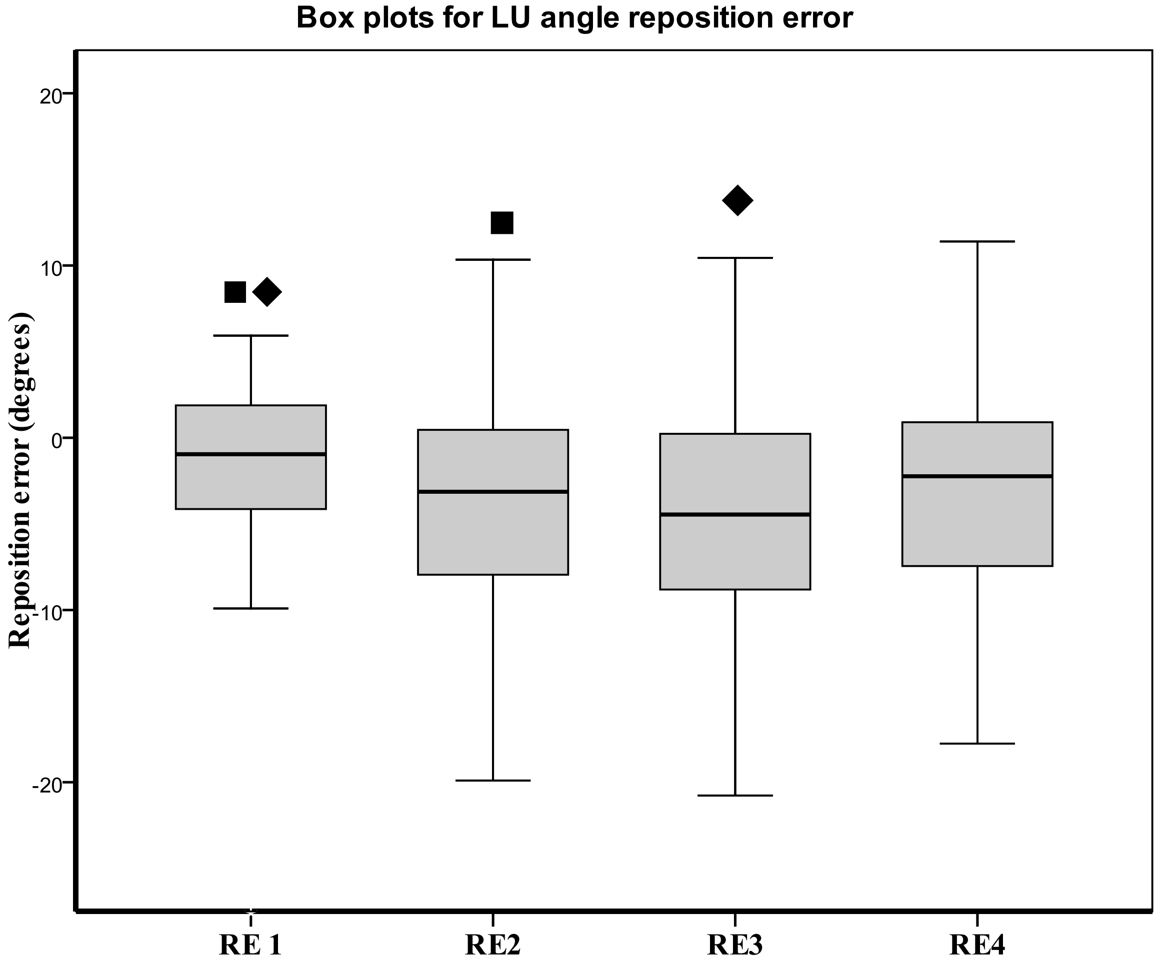

FIGURE 26: Box plots showing median values and data dispersion for LU angle reposition error in each trial.

RE1= error in immediate reposition trial to IOSP, RE2= error in reposition to IOSP after 10 minutes in FSP, RE3= error in reposition to IOSP after 30 minutes in FSP, RE4= error in reposition to IOSP after slouch overcorrect procedure.

◆■*Indicate statistical significant differences p<.05.*

TABLE 8. Angles in optimal sitting posture and the extremes of sitting posture

ANGLE	IOSP	FSP	FLSP
HE	26.5 (7.2)	28.8 (22.5)	20.5 (10.1)
NE	48.6 (4.1)	75.8 (10.8)	43.3 (5.4)
HP	155.3 (6.6)	145.6 (30.2)	153.0 (7.6)
HT	106.6 (7.9)	69.7 (26.8)	110.0 (8.5)
CT	147.4 (5.3)	145.9 (14.1)	143.4 (7.2)
TH	158.8 (4.9)	152.2 (5.6)	159.7 (6.2)
TL	174.4 (3.6)	155.1 (4.9)	172.1 (5.5)
LU	162.9 (9.2)	167.6 (6.3)	154.6 (11.1)
PEL	-2.1 (5.2)	-13.7 (7.5)	0.6 (6.8)

Values are presented as mean and SD.

IOSP= instructed optimal sitting posture, FSP= flexed spinal posture, FLSP= fully lordotic spinal posture. HE= Head Angle, NE= Neck Angle, HP= Head protraction, HT= Head tilt, CT= Cervico-thoracic angle, TH= Thoracic angle, TL= Thoraco-lumbar angle, LU= Lumbar angle, PEL= Pelvic angle.

5. DISCUSSION

Given the complex nature of human posture, this study provides the most specific measurement to date of surface spinal curves, head and pelvis position, with reference to different seated unsupported postures. In addition, this is the first study that examines the time effect of a flexed predetermined sustained posture on head, spinal and pelvic proprioception contemporaneously.

The sample of N=47 participants in the present study was adequate in order the results to be generalized, since it was bigger than previous studies examining posture (Caneiro, et al., 2010; A. Claus, Hides, Moseley, & Hodges, 2008; A. P. Claus, et al., 2009a, 2009b; K. J.

Dolan & Green, 2006; Edmondston, et al., 2007; K. O'Sullivan, et al., 2010; P. B. O'Sullivan, et al., 2003; P. B. O'Sullivan, et al., 2006; P. B. O'Sullivan, et al., 2002).

5.1. The optimal sitting posture

Several considerations were taken into account in the present study in regard the “optimal sitting posture” that the participants were instructed in. We acknowledge that the IOSP used in this study is not superior from other postures that described as optimal or correct in the literature and were used in other clinical trials.

For several years the concept of ideal sitting posture lacked consensus in the literature. The direction of the curve of the lumbar spine has been bisectional for the researchers in point of the spinal health. A review of the literature revealed that proponents of both the lordosed and kyphosed lumbar seated position have used similar arguments with contradictory conclusions (Pynt, et al., 2001). Nevertheless, based on general agreement among published studies after the mid 90s, extensive reviews have concluded that the optimal sitting posture is comprised of lumbar lordosis (Harrison, et al., 1999; Pynt, et al., 2001). Regarding the cervical spine, minimizing forward head posture and cervical flexion was associated with higher comfort ratings (Harrison, et al., 1999).

Several postures meet the criteria for the optimal sitting posture when qualitative characteristics guide the description. A diversity of spinal curves from the occiput to the pelvis met the criteria for neutral upright spinal alignment and made inexplicit, in research and clinical reality, not only the quantitative definition of neutral posture but the aims of postural education and evaluation.

In the present study we took into account all the evidence and decided to use a mid range posture as IOSP. We defined IOSP as the posture in which the lumbar spine was positioned in a moderate degree of lordosis, the thoracic spine was in slight kyphosis, while the head and shoulders were evenly and neutrally aligned over the pelvis with the chin over the chest, moderately retracted rather than protruded (Jull, 2008; Lee, 2007; R. McKenzie, & May, S, 2003; R. McKenzie, & May, S., 2006; Richardson, 2008).

5.2. Training the sitting posture

In a number of studies researchers placed or trained subjects in a predetermined posture with reported or not reliability (A. P. Claus, et al., 2009b; Falla, Jull, et al., 2007; P. B. O'Sullivan, et al., 2006; P. B. O'Sullivan, et al., 2002). Furthermore, lumbar lordosis could be attained during sitting posture in trained subjects (A. P. Claus, et al., 2009b; P. B. O'Sullivan, et al., 2006; Scannell & McGill, 2003). Educating individuals in terms of spinal posture was proved to be a specific and demanding procedure when lumbar lordosis was related to thoracic kyphosis as prescribed in the literature and used in this study the optimal “short lordosis” sitting posture (A. P. Claus, et al., 2009b). The demands of such a procedure were reinforced by evidence showing that most of the subjects needed facilitation and feedback to achieve a lumbar angle more lordotic than the flat/upright posture (A. P. Claus, et al., 2009b) and specific rotation of the pelvis in order to accomplish lordotic posture (Dunk, et al., 2009).

Moreover, positioning of the head in a retracted rather than protruded position found to be technically and educationally demanding in the majority of the participants. The former procedure was used in this study in order the instructed posture to be easily achievable and repeatable by the participants.

5.3. Intra-tester reliability of positioning individuals into a predetermined sitting posture

The reliability study was conducted in order to assess the ability of the instructor to place reliably individuals into the IOSP. Ten individuals were manually placed in IOSP ten repeated times by the same investigator with intervals of 3 minutes. The IOSP was defined as the criterion posture in this study, a fact accentuating the importance of this assessment. The obtained ICC $_{(3,1)}$ values for all the angles were bigger than .89.

Also, coefficients of variation (CV) with standard deviation (SD) were calculated for all angles examined in the study with accepted (%) percentages. In the case of PEL angle that the CV has a high value, the SD revealed that the difference of 1.28^{0} was not significant in a small measured angle.

5.4. Differences among angles and sitting postures (HSP, FSP, FLSP, SPOP, IOSP)

Several statistically significant differences were revealed among postures and angles obtained in the present study, but a considerable observation was related to HT and TH angles. Both angles showed no significant differences ($p>.05$) between all postures measured, but only for FSP.

Head tilt angle in FSP was expected to differ ($p<.05$) from all the other postures, as in FSP the participant’s head and gaze were turned in different direction. The lack of significant differences of HT angle between all other postures could be attributed to the instruction of the participants to fix their gaze on a wall-marker ahead. We acknowledge that the specification of the point in the wall ahead at eye level was an error in procedure, despite we placed the participants in 5-meter distance from the wall-marker in order to avoid their head posture to be directed by that mark.

In all postures measured the TH angle was kyphotic. In FSP, that was close to slouch or slump sitting in regard the thoracic, the lumbar spine and the pelvis, TH angle was significantly more kyphotic than all the other postures, as previously established in the literature (Caneiro, et al., 2010; A. P. Claus, et al., 2009b). Moreover, the 26^{0} that could approximately be estimated (from figure 3) for the TH angle from Claus et al., (2009b) was comparable with the $27.8^{0}\pm6$ (mean ±SD) obtained in the present study. The reason for absence of significant differences for this angle could be explained from the small distribution of degrees among postures. Thoracic angles in end-range postures ranged from (mean ±SD) 152.2 ± 6^{0} in FSP to 159.7 ± 6^{0} in FLSP. Additionally, in all the other postures examined ranged from (mean ±SD) 158.4 ± 5.1^{0} in HSP to 159.7 ± 5.1^{0} in REP1. A difference less than 2^{0} in the thoracic spine that generally exhibits greater available range of motion in flexion than in extension , probably could not demonstrate statistically significant differences in our sample of N=47 subjects.

5.4.1. Habitual sitting posture

Sitting posture in general agreement has shown to involve more flexion than standing (Dunk, et al., 2009; Harrison, et al., 1999). The widely accepted generalization that the physiologic position of the spine is kyphotic between T1 and T12 and lordotic between L1 and L5 has been characterized as overly simplistic, since the sagittal alignment of the human spine and pelvis in standing position was highly variable among individuals (Roussouly, Gollogly, Berthonnaud, & Dimnet, 2005).

Habitual sitting posture has been described as a mid-range position, despite that was more flexed than other postures (Dankaerts, O'Sullivan, Burnett, & Straker, 2006; K. O'Sullivan, et al., 2010). In the present study HSP was significantly different than the FSP in all angles except PEL angle. Results that were partly in agreement with other studies (Dunk, et al., 2009; K. O'Sullivan, et al., 2010) argued that pain free individuals do not habitually sit in end range postures in point of angles measured. We found that the PEL angle revealed no statistically significant differences between HSP and FSP, a fact that placed the pelvis at an end range posture, as could be evident from the means of PEL angles (mean ±SD in degrees, HSP -13.3º±7.2, FSP -13.7º±7.5). Furthermore, when subjects adopting slouched sitting has been revealed that their lower three intervertebral joints approached their total flexion as measured in flexion from standing, by using X-ray images (Dunk, et al., 2009). The end range pelvic posture in the present study that carried along some of the lumbar intervertebral joints to their relative end range flexion was in contrast with previous findings (Dankaerts, et al., 2006; K. O'Sullivan, et al., 2010). It is debatable whether this difference could be attributed to methodology used, as in this study we used markers on the pelvic segment to derive sagittal angles for the pelvis. Upright or slouched sitting posture was demonstrated that occurred mainly by rotation of the pelvis and the three lower lumbar intervertebral joints (Dunk, et al., 2009), while few to no angular changes were found between L1/2 and L2/3 intervertebral segments, findings supported from previous studies (Andersson, et al., 1979; Lin, et al., 2006; Makhsous, Lin, Hendrix, Hepler, & Zhang, 2003). Habitual sitting posture involved end-range posture at the pelvis as estimated by our results, a finding that might explain the reason for more flexion presented in HSP than in other postures evaluated. Moreover, this should be taken into account when postural spinal pain is considered, as end range postures increase the load on supporting structures and may develop pain symptoms (R. McKenzie, & May, S, 2003; R. McKenzie, & May, S., 2006).

In point of head and cervical spine, HSP has been argued to vary notably between healthy individuals (Edmondston, et al., 2011; Grimmer-Somers, Milanese, & Louw, 2008; Johnson, 1998; Raine & Twomey, 1997). We found HSP’s angles to be associated with increased flexion/anterior translation in contrast with other postures evaluated except FSP. Evidence suggested that flexed sitting when compared with upright, thoracic or lumbar sitting, showed significant greater head/neck flexion and anterior translation (Caneiro, et al., 2010). The results of our study were in accordance with evidence supporting that HSP involves increased head/neck flexion, which in turn could be attributed to increased pelvis posterior tilt and lumbar relative kyphosis (Caneiro, et al., 2010; Grimmer, 1996; L. M. Straker, O'Sullivan, Smith, & Perry, 2007; L. M. Straker, Smitha, Bear, O'Sullivan, & de Klerk, 2011; Szeto, et al., 2002).

5.4.2. Self perceived optimal posture

Self perceived optimal posture was generally less kyphotic / flexed than HSP. Head angle, NE, TL and PEL angle have been moved towards extension. Only the CT angle demonstrated a trend for less flexion. The LU interestingly did not showed significant differences between SPOP and HSP. The significant difference in pelvic rotation, towards increased anterior tilt in SPOP, might give a possible explanation for this observation. The effect of pelvic rotation on lumbar position particularly and spinal posture generally (Dunk, et al., 2009) could has been differentiated in subjects perception the two postures and despite that lumbar segments moved to a relatively more lordotic posture this shift could not be evident and demonstrate significant differences.

Generally the statistically significant differences between SPOP and HSP demonstrated that all individuals do not habitually use more neutral or less kyphotic sitting postures, despite their apprehension that the optimal sitting posture is different than their HSP. In accordance with the present study were results from other studies showing that HSP is more flexed than SPOP (Edmondston, et al., 2007; K. O'Sullivan, et al., 2010). Adopting a more upright sitting posture requires increased muscle activity than a kyphosed one, both in cervico-thoracic and lumbar spine (P. O'Sullivan, et al., 2006). Slump sitting when compared to a more neutral posture was associated with significantly greater muscle activity in thoracic and lumbar region (Caneiro, et al., 2010; A. P. Claus, et al., 2009a) and this might explain the difference between, which subjects consider as optimal posture and which they use in their daily sitting.

Research is limited in SPOP and pain populations, but in a study with postural pain subjects and healthy controls, SPOP differed significantly between groups (Edmondston, et al., 2007). It remains to be evaluated whether this difference in perception is constant among patient population and the clinical implications of such an observation.

5.4.3. The instructed optimal sitting posture

The IOSP that was the criterion posture in the study found to differ significantly from HSP and SPOP in all angles. From HSP to SPOP and IOSP the relative flexion of the head and thorax and the posterior tilt of the pelvis were decreased gradually, while the relative lordosis of the thoraco-lumbar and lumbar regions was increased respectively.

In accordance, a study, quantified muscle activation in cervico-thoracic spine, found that the SPOP was in contrast with the researchers' perception of optimal sitting posture (Falla, O'Leary, et al., 2007). Contrary to these results were the findings of a study (K. O'Sullivan, et al., 2010) reporting no differences between participants' and researcher's perception of neutral sitting posture in regard the lumbar spine. Nonetheless, the authors argued that SPOP was slightly more lordotic than the tester's perceived neutral posture. In the present study the IOSP was more lordotic than SPOP, but comparisons could not be made due to different postural definitions.

The "short lordosis" as defined in the literature (A. P. Claus, et al., 2009b) has many commonalities with the IOSP in this study. For the former reason, comparisons could be made between angles that were defined identically, such as TH, TL and LU angles. For TH angle the values obtained revealed a kyphotic configuration and the means were 22.0º (95% CI, 17.1-26.9) from Claus et al., 2009 and 21.2º (95% CI, 19.7-22.6 as calculated) in the present study. Also, for TL and LU angles the configuration was lordotic for both, means were for TL 3.8º (95% CI, 0.3-7.3) and 5.6º (95%CI, 4.5-6.7) respectively and for LU 15.0º

(95% CI, 11.7-18.3) and 17.1º (95% CI, 14.3-19.9) respectively. The presented results from both studies showed values closely related, confirming the reliability of the methodology that was used and the relative congruency of postures that were used and facilitated.

The exported angular values, as presented in **Table 8**, for IOSP and the limits of sitting posture (FSP and FLSP) were elucidated that IOSP was generally a mid-range posture for most of the angles that were measured. Mid-range postures are controlled by proprioceptive neuromuscular reflexes (Panjabi, 1992a, 1992b), a fact that stresses the importance and the necessity of the neuromuscular proprioceptive system in application of stabilizing function to the spine in IOSP. The stabilizing and controlling role of the muscles in IOSP supports the methodology that was used in the present study, regarding the effect of flexed posture on neuromuscular proprioceptive function.

5.5. Repositioning trials to the optimal sitting posture

The four different repositioning trials in this study were used in order to assess the proprioceptive ability of the spine and head. Each of these was used, in one hand to expose proprioceptive deficits and in the other hand to evaluate the effect of specific procedures on spinal proprioception. More specifically, the immediate repositioning to IOSP after postural education and the “slouch-overcorrect” procedure after prolonged spinal flexion, were evaluated in regard their effect on proprioception. What is more, the two repositioning trials to IOSP after 10 and 30 minutes in spinal flexion were used to assess any possible proprioceptive deficit.

5.5.1. Immediate repositioning to the instructed optimal sitting posture

During the REP1 trial was assessed the ability of the individuals to replicate the criterion reference posture. This procedure evaluated the effect of postural instruction on healthy individuals that did not have any former postural education by a clinician or an expert. On top of that, we examined the head and spine position sense as a substance of proprioception.

In the present study, comparison between IOSP and REP1 revealed no statistically significant differences (p>.05) for all angles that were measured. The participants could accurately replicate the IOSP immediately after less than 60 seconds in postural flexion (the means and SD are presented in Table 3). This result confirmed the statistical hypothesis that IOSP and REP1 would reveal no differences. Moreover, studies supported this finding with measurements for position sense in lumbar spine (K. J. Dolan & Green, 2006; P. B. O'Sullivan, et al., 2003) and cervico-thoracic spine and head (Edmondston, et al., 2007). On the one hand, the accurate repositioning in IOSP established that clinically the postural education is achievable in healthy individuals, as previously reported (A. P. Claus, et al., 2009b; Falla, Jull, et al., 2007; P. B. O'Sullivan, et al., 2006; P. B. O'Sullivan, et al., 2002; Scannell & McGill, 2003). The manual, optical and verbal facilitation as proposed in postural education (A. P. Claus, et al., 2009b)found to be essential in this procedure and lasted about 5 to 10 minutes. The time frame of 5 to 10 minutes is more suggestive than restrictive for clinical practice, while we cannot rule out the fact that some individuals might need further facilitation and guidance. On the other hand, the repositioning revealed and confirmed the accurate postural kinesthetic sense of the head and spine in immediate repositioning in healthy individuals (K. J. Dolan & Green, 2006; Edmondston, et al., 2007).

The range of reposition error in healthy individuals generally has been measured below 5° in head and neck (Armstrong, et al., 2008; Edmondston, et al., 2007), while in the lumbar spine the range has been reported below 3° in most of the studies (K. J. Dolan & Green, 2006; Newcomer, et al., 2000; P. B. O'Sullivan, et al., 2003). In this study immediate reposition error for all angles was less than 2°, ranging from 1.9° in LU to 0.1° in HP angle. The means revealed that the subjects slightly overestimated the NE, HP, HT, CT, TH angles and the pelvic tilt, while slightly underestimated the HE and TL angles and the lumbar lordosis, but not in a statistically significant way.

Proprioceptive input and specifically reflex control of spinal movements derive from mechanoreceptor afferents that are found in a variety of spinal tissues including muscles, joints, fascia and skin (Gandevia, et al., 1992; Strimpakos, 2011). Several studies have proposed that the muscle spindles were the primary responsible receptors for joint position sense (Armstrong, et al., 2008; Gandevia, et al., 1992; Sánchez-Zuriaga, et al., 2010). Joint articular receptors are suggested to play a complementary role to muscle receptors in the mediation of position sense (Armstrong, et al., 2008) and proposed to be activated near the end of the range, in contrast with the muscle spindles that have been assumed to be activated throughout the physiologic range . High concentrations of muscle spindles arranged in highly structured arrays have been noted within deep spinal muscles (Boyd-Clark, et al., 2002) and sensory receptors have been found in spinal ligaments (Yahia, et al., 1992).

In the present study, the accurate reposition ability of the subjects could be attributed to both muscle spindles and reflexive muscle activity. It has been proposed that the spinal ligaments are appropriately situated in key locations sensitive to relative motion of the vertebrae in various planes, such that the receptors within them can monitor the movement and reflexively activate the musculature via spinal neurons, providing proprioceptive input and maintain or restore stability (Solomonow, Zhou, Harris, Lu, & Baratta, 1998). The proprioceptive function of the muscles in order to relocate the IOSP in this study could have been reinforced by the reflexive function of the spinal ligaments, as the subjects were instructed to adopt a FSP before the repositioning trial. From another perspective, muscular reflexive activity was found to be reduced in cat spines by 50% when flexion – extension cycle was increased from 1 second to 10 seconds (Solomonow, et al., 2001). Conclusively, increased time frame to reposition in a posture could have decreased the potency and the impact of reflexive muscular activation. In agreement with our assumption was the argument in another study (K. J. Dolan & Green, 2006), stated that the immediate repositioning accuracy in REP1, if this could be regarded as a flexion-extension cycle, may be therefore due to reflexive muscle activity.

The present study was in accordance with most of the studies examining spinal kinaesthesia, as subjects were required to replicate a posture selected and defined by the investigator. Edmondston et al., (2007) while examining cervical spine, used a self-selected posture to be replicated by the individuals and argued that this option would be relatively easier for the individuals to reproduce. While we used an unfamiliar posture selected by the investigator the posture reposition error revealed no significant differences from IOSP. These results were in congruency with previous studies (Armstrong, et al., 2008), showing that the reference posture has no effect on immediate proprioceptive ability in healthy individuals.

5.5.2. Repositioning to instructed optimal sitting posture after prolonged spinal flexion.

The repositioning trials (REP2, REP3) after prolonged flexed sitting showed significant differences only for HE, CT and LU angles and not for all the examined test occasions. The ten minutes of spinal and head flexion found to affect only the lumbar spine, while the 30 minutes affected the head, the cervico-thoracic and the lumbar spine. These results ruled out, but partially, our statistical hypotheses, that FSP will not affect the reposition accuracy of the subjects.

The subjects were found to underestimate the lumbar lordosis after 10 minutes spent in flexed posture, since the LU angle was estimated bigger in REP2, findings supported by a previous study in the same setting (K. J. Dolan & Green, 2006).

Regarding prolonged sustained flexion for 30 minutes, was proved by the results that the effect on spinal proprioception was more extensive than in the REP2 trial. The HE angle that represented the relative position of the thoracic and head segments, was disclosed to be significantly underestimated by the participants (Table 6). Furthermore, the cervico-thoracic angle found significantly bigger in REP3, a fact indicated that the individuals overshot the CT angle in their attempt to replicate the IOSP (Table 6). Finally, the lumbar lordosis was further underestimated when compared with the REP2 trial, as the LU angle in REP3 was measured greater than in the repositioning trial after 10 minutes in FSP (Table 6).

The results showed that while 10 minutes in flexed posture were not enough to reveal significant differences, but only for LU angle, the 30 minutes in FSP established that the proprioceptive ability of the spine was affected in a time dependent manner and the effect was spread in more spinal regions. These results could be attributed to the effect of flexed posture on proprioception.

5.5.2.1 The effect of flexed posture on muscles' proprioceptive reflexive activation

5.5.2.1.1. Lumbar and thoraco-lumbar spine

Flexed posture has been proposed to compromise the neutral zone and the spinal stability, as well as the reflexive activation of the muscles that were dependent on the creep developed in the viscoelastic tissues during static load (Youssef, et al., 2008).

Soft tissue creep occurred in human spines after only a short period of sustained flexion and produced impaired reflex activation of back muscles (McGill & Brown, 1992). In the present study, 10 and 30 minutes that the subjects remained in FSP were judged as capable of producing soft tissue creep. The first study examining the effect of sustained posture on soft tissues has revealed that prolonged flexion moment in sitting posture for 20 minutes resulted in viscoelastic tissues creep that did not fully recover the following 30 minutes of rest (McGill & Brown, 1992). The time spent in FSP in the present study can be compared and can be assumed that the creep developed didn't fully recover until the end of the testing

A recent, in vivo study gave direct evidence that physiologic levels of creep in human spines can impair reflex activation of the back muscles (Sánchez-Zuriaga, et al., 2010). In this study reflex activation of the back muscles was delayed significantly after one hour in flexed sitting. More specifically, muscle activation after creep was delayed by 36 milliseconds on average, which represented a 60% increase in onset latency (Sánchez-Zuriaga, et al., 2010). These results suggested that sustained flexed posture have a direct effect on neuromuscular control of the human spine and furthermore on spinal proprioception.

Conclusively, most of the flexed/kyphotic posture effects on the spine are long lasting, and contrary to clinical beliefs and advice, are not reduced by rest (Pynt, et al., 2001). On the contrary, in the regions that the compensating strategies were more effective and potent the proprioceptive deficit was not evident.

Comparisons in regard the proprioceptive deficit after flexed sitting could be made with two previous studies (Brumagne, Lysens, Swinnen, & Verschueren, 1999; K. J. Dolan & Green, 2006). Both studies reported that following prolonged slouch the majority of the subjects undershot the target position. Dolan & Green, (2006) reported an underestimation of the target position by a mean of -4.12⁰ (SD 4.2), after 5 minutes in slouched posture, similar to results of the study of Brumagne et al., (1999). In the present study the underestimation of lumbar lordosis was estimated -4.78⁰ (SD 7.5) after 10 minutes in FSP and -5.49⁰ (SD 8.5) after 30 minutes in FSP. It was evident that the proprioceptive deficit in regard the LU angle was time dependent as the degrees of underestimation were increased over time. According to Dolan & Green, (2006) the increased variability in reposition sense with prolonged flexed posture may reflect the variation on stress on proprioceptive structures displayed by the wide range of flexed postures adopted by the subjects, 13.71⁰ (SD 11.30). That assumption could be applicable for the interpretation of the results in the present study, as 12.4⁰ (SD6.3) was the range adopted by our participants. The divergence of degrees measured could be attributed to differences in methodology used in point of markers to export angles in degrees.

5.5.2.1.2. Head and Cervico-thoracic spine

Flexed neck and head posture research in terms of muscles' reflective activity has been absent. However, extreme positions of cervical spine have been shown to occur in sitting postures and the levels of muscular activity in such positions were low. In addition, experimental maintained relaxed flexed position causing extreme position at the cervico-thoracic junction (C7/T1) has been pain provocative in healthy subjects (Harms-Ringdahl & Ekholm, 1986).

Upright posture in comparison with flexed posture, found to be associated with increased thoracic flexion and head/neck flexion with a greater anterior translation of the head (Caneiro, et al., 2010), a posture commonly adopted during note-book computer use and office work (L. Straker, Jones, & Miller, 1997; Szeto, et al., 2002). Same findings were revealed by the present study, since both FSP and HSP when compared to IOSP presented increased flexion in head, neck and thoracic spine. Evidence supported that as the neck and head were in flexed position the load moments were increased at the base of cervical spine with concomitant increase in cervical extensor muscle strain (L. Straker, Skoss, Burnett, & Burgess-Limerick, 2009). What's more, in contrast to neutral posture, slouched posture increased the cervical extensor activity by 40% and neck protraction (upper cervical spine in extension and lower cervical spine in flexion) has developed increased load moment around the low cervical spine similar as neck and head flexed posture in a pain-free cohort (Edmondston, et al., 2011).

In cervical spine, stretching of the muscles does not seem to be the case. In the flexed neck and protracted head position, the activation of the thoracic extensors has been associated with a significant increase in cervical extensor activity (Edmondston, et al., 2011). The increased activation of cervical extensors may lead to muscle fatigue, as these muscles were found to have smaller cross-sectional area compared to the extensors with a thoracic origin. The cervico-thoracic load moment in slouched posture increased by 57.2% compared with the habitual posture (Edmondston, et al., 2011).

The activation observed may result in decreased oxygenation and decreased force output in the low threshold motor units of these muscles (Flodgren, Crenshaw, Gref, & Fahlström, 2009). The deep dorsal and occipital muscles show a high density of muscle spindles that are providing the main contribution to neck proprioception (Rix & Bagust, 2001). On top of that, fatigue in these muscles imply that the proprioception of this spinal region might be disrupted due to stimulation of tonic gamma motor neurons (the system by which the central nervous system controls and modifies muscle spindle sensitivity) secondary to accumulation of muscle contraction metabolites (Djupsjöbacka, Johansson, Bergenheim, & Wenngren, 1995).

In addition to these assumptions a recent study (Pinsault & Vuillerme, 2010) revealed a connection between muscle fatigue and cervical proprioception. This study shed light on the effect of muscle fatigue in cervical joint position sense and showed that cervical proprioception was degraded by muscular fatigue. However, this was the only study examining this association and therefore, the results should be interpreted with caution.

In the present study the HE and CT angles showed to differ significantly in REP3 trial. The experimental design used in this study has never been used in cervical and thoracic spine as a result data for comparisons were not available. In contrast with the LU angle differences for these two angles were not revealed in the 10 minutes reposition trial. Given the assumption that muscle fatigue induced the head and cervico-thoracic proprioception the time effect found to play a major role. Only prolonged flexed unsupported sitting posture that has affected muscle performance and environment was efficient to reveal proprioceptive deficiencies. However, the small means and the bigger distribution of standard deviation as presented in Table 6 impoverishes the power and the generalizabilty of these results. Furthermore, a possible explanation for these results could be attributed to the position of the pelvis that did not present significant differences in REP3 and we formerly argued that governs the whole spine.

5.5.3. Repositioning and “slouch-overcorrect” procedure

This MDT procedure used in the end of prolonged flexed sitting in order to evaluate its effect on reposition accuracy and proprioceptive deficits. The results of the study showed that the “slouch-overcorrect” procedure increased reposition accuracy in all angles that were found to present significant differences. In other words, after the repetition of the procedure for 10 times all angles showed no significant differences between IOSP posture and REP4 posture. However, the effect of this process changed the position sense for HE, CT and LU angles, since these were the angles showed reposition deficiency.

Evidence is strong that activation of muscles spindles is influenced by their recent load history (Sánchez-Zuriaga, et al., 2010). Shortening of muscle before proprioceptive performance increased spindle sensitivity resulting in increased firing in response to a subsequent stretch (Sánchez-Zuriaga, et al., 2010). According to the procedure that was used most of the postural muscles were activated during the movement of the body and subsequently stretched from one extreme of posture to the other. In the present study, prolonged FSP stretched and/or load postural muscles, a fact that may have caused desensitization on the spindles located within them. In this perspective the “slouch-overcorrect” procedure increased the proprioceptive performance and accuracy.

Moreover, cutaneous receptors when activated found to influence joint position sense (Strimpakos, 2011). The contribution of clothes can be excluded, since the female participants wore only undergarments and males nothing at the upper part of the body. The effect of cutaneous receptors on proprioception after the “slouch-overcorrect” procedure can be regarded significant as during the repetitions towards the extremes of posture the skin was stretched and relaxed several times. Stretching of the skin or a combination of stretch with relaxation has been proposed to increase cutaneous influence on proprioception (Strimpakos, 2011).

5.6. Reposition error among replicated postures

Reposition error reflects in a more distinct way the joint position sense in terms of proprioception (Armstrong, et al., 2008). In the present study reposition error was calculated for all the angles that revealed significant differences among postures. Evident differences were displayed with further testing using pair-wise comparisons for HE and LU angles regarding RE1 and RE3 and for LU angle regarding RE1 and RE2 (IOSP-REP2). In contrast, CT angle showed only a trend RE1to be significantly smaller than RE3.

The relative accuracy of immediate repositioning in REP1 for all these angles, mean for HE 1.18º, CT 0.76º, LU 1.89º, was decreased in REP3 after 30 minutes of prolonged FSP, mean for HE 5.34º, CT 2.88º and LU 5.49º (Table 6). These data suggested that the majority of the participants underestimated the relative position of head and thoracic segments, overestimated the cervico-thoracic angle and undershot the lumbar lordosis.

The distribution of these differences among three levels (head, cervico-thoracic and lumbar spine) of the upper part of the body indicated a widespread than a segmental deficit in proprioception after prolonged FSP. However, the intrinsic characteristics and the size of the sample or the angles used could not reveal congruent results for other sub-parts that were examined.

The mean difference of reposition error (HE 4.17º, CT 2.11º and LU 3.6º) and the range of angles measured (95% CI, HE 0.87-7.47, CT -0.076-4.3 and LU 1.16-6.04) after 30 minutes in FSP challenged the stability and control of neutral zone of the spine. It has been proposed that the lack of position sense and control of neutral zone may result in increased passive system end-range loading of the spine during static or dynamic postures and activity (P. B. O'Sullivan, et al., 2003). In addition, the study by Dolan & Green, (2006) also argued that proprioceptive accuracy was reduced in lumbar spine and therefore the neutral zone is challenged. Comparison of the reposition error in 10 and 30 minutes with the results of Dolan & Green, (2006) indicated divergence in values obtained. The 10 minutes reposition trial could be compared with the 5 minutes repositioning of Dolan & Green, (2006). They found a mean difference of 3.92⁰ in contrast with the present study that evaluated this difference as 2.88⁰ (standard error 0.75). Despite the fact that the two studies have similar settings the contrasts could be attributed to the following observations; differences in sample characteristics, angles definition, equipment used or finally the clinical education of the participants in the present study regarding the IOSP.

We expected to discover bigger proprioceptive deficiencies over time in prolonged FSP. The mean difference of reposition errors between RE1 and RE3 was calculated 3.60⁰ (standard error 0.88), increased when compared to RE2 but still smaller than the one reported in Dolan & Green, (2006) study. Overall, the compromised spinal stability concept was supported by the results as reposition error was increased from immediate repositioning to REP3 (mean LU RE1 1.89⁰, RE2 4.78⁰ and RE3 5.49⁰).

Another point that we have to discuss is related to the difference in immediate reposition error between the studies. We ascribed the contrast to the time frame that was determined as “immediate repositioning” between the studies, since we used a time frame less than 60 seconds instead of 5 seconds previously used. It has been reported that less than a 12-second delay between tests significantly increases position sense accuracy (Strimpakos, 2011).

The present study in contrast with other studies was evaluated the effect of FSP on proprioception. While in other studies examining healthy individuals, impairments of kinaesthetic function were not evident, we found that prolonged FSP had a significant effect on head and thoracic segments position sense. The RE calculated for HE angle was 5.34⁰ (standard error 1.2⁰) bigger than previously reported reposition errors. Interestingly, data from the literature demonstrated no significant impairment of kinaesthesia in patients with neck pain and whiplash associated disorder with small and mild disability, but in patients with traumatic onset neck pain and patients with higher levels of pain and disability (Armstrong, et al., 2008; Treleaven, Jull, & Sterling, 2003). The results of the present study indicated that proprioception of healthy individuals was compromised because of prolonged FSP and placed these subjects in the same sub-group among patients with severe pathology.

Undoubtedly, the proprioceptive deficit in our sample was impermanent and reversible, since the “slouch-overcorrect” procedure increased the proprioceptive accuracy by decreasing the reposition error in all angles that were measured. The previous observations have several clinical, ergonomic and research implications. It remains to be elucidated whether the deficit revealed in the present population is a general characteristic of healthy individuals since this was according to our knowledge the only study implemented such a methodology in the experimental procedure.

5.7. Clinical and research implications and future directions

The present study, according to our knowledge, was the first that examined at the same time the kinaesthesia in seated posture of head, spine and pelvis with skin surface tracking. The clinical significance of this experimental protocol is reinforced by the fact that postural assessment is conducted by surface evaluation and observation. The global analysis of sitting posture extends further the implications as pelvis and lower spine govern the sagittal posture and balance of the upper body.

The general clinical observation that subjects adopt relatively flexed habitual sitting postures was confirmed, while from the results was revealed that the habitual postures attained differ significantly from the self perception of optimal sitting posture. The interpretation of this finding is raising the question whether the patients are compliant when instructed to adopt a predetermined sitting posture. On top of that stands the assumption that there is no optimal or ideal sitting posture. Consistent evidence stressed the recommendation for interruption from sustained posture, as any posture due to stress concentration, lordosed or kyphosed, when maintained could lead to discomfort and symptoms.

In point of optimal sitting posture results established that clinically, education, facilitation and instruction of posture is achievable. All the participants with the verbal and manual facilitation by the researcher could adopt and replicate accurately the instructed posture. Future research should focus on the ability of subjects to replicate the instructed predetermined posture in different occasions and days, as a measure of educational effect.

Despite that several studies have investigated the proprioception of the head and spine none have focused on the upper part of the body globally. Moreover, the experimental design of this study in terms of sustained flexed posture notwithstanding has previously used, was narrowed in one region of the spine.

Impairments of kinaesthetic function were established in this study in healthy individuals because of sustained FSP. Proprioceptive deficiency primarily is a characteristic of symptomatic populations. It remains to be elucidated whether these findings can be generalized with other studies replicate the same experimental model, and furthermore to be evaluated the effect on proprioception of FSP in patient population.

An outstanding finding of the present study was the fact that healthy individuals when attaining a relaxed flexed posture for 30 minutes developed kinaesthetic and proprioceptive deficit. The significance of this finding is reinforced when we take into account that flexed sitting postures are commonly adopted in daily sitting activities (P. Dolan, et al., 1988). The clinical and ergonomic implications of such a subsequence may lead us to reconsider the value and the necessity of postural re-education in healthy individuals.

Findings in the literature are conflicting in terms of proprioceptive ability among healthy individuals and patients (Edmondston, et al., 2007; Newcomer, et al., 2000; P. B. O'Sullivan, et al., 2003). Relevant in research perspective could be the assessment of HSP, SPIP and reposition accuracy after FSP in patients with low back and neck pain or other spinal pathology.

A general observation in the present study has to do pain symptoms in healthy individuals. Given that the aims of the study were not related with symptomatic individuals and production of symptoms, it was remarkable that all the participants were complained for pain and/or discomfort on their spine during the FSP after the 20 minutes spent in this sustained posture.

Establishing a link among FSP, proprioceptive deficiency and spinal pathology would provide clinical indications for ergonomic advice and postural re-education. Loss of proprioception, or proprioceptive deficit, is capable of producing delayed neuromuscular protective reflexes and coordination, thus loss of control of spinal movements. This deficit leads to loss of prevention of excessive loading and loss of protection of the spinal underlying tissues from injury (Sánchez-Zuriaga, et al., 2010).

Life in modern society increases the tendency for a sedentary lifestyle (Egger, et al., 2001). However, systematic reviews did not show strong evidence linking sitting postures (sustained or not) as a risk factor for spinal (lumbar generally) pain and pathology (Lis, Black, Korn, & Nordin, 2007). In contrast, regarding the cervical spine, the majority of evidence linked prolonged sedentary position in workplace with increased risk of neck pain (Côté, et al., 2008). Research relating to the thoracic spine remains limited, while a recent systematic review revealed no studies reporting risk factors associated with thoracic spinal pain in adults (Briggs, Smith, Straker, & Bragge, 2009). The cross-sectional and observational design of most of the studies made impossible the strong revealment of a cause and effect relation between spinal pathology and prorpioception. Longitudinal studies with big sample sizes are required in order to establish cause and effect relations and further bring out the role of postural reeducation against spinal pathology.

Finally, the effect of MDT “slouch-overcorrect” procedure has several clinical implications. Proprioception is reinforced by stimulation of various receptors in various body structures such as joints, muscles, tendons, capsules and skin, with muscle spindles displaying the major role in joint position sense (Strimpakos, 2011). On top of that, muscle spindle receptors’ contribution to joint position and movement sense may be augmented during even light muscle contractions (Strimpakos, 2011). The later procedure although has been described for postural education and re-education was found to play an effective proprioceptive role. A possible explanation for this effect could be attributed to the stimulation of these receptors. This is the first study to date evaluating this procedure in both postural reeducation and proprioceptive enhancement. The results established its value and effectiveness but further studies are required in order to clarify these effects and investigate the impact on other clinical populations.

5.8. Limitations

We acknowledge that there were some limitations in the study we should take under consideration for the interpretation of the results. First, the sample size might was large enough in comparison with other studies assessing posture and proprioception, but the subjects were mainly young (mean ±SD= 24.4±4.9 years) and sitting posture may vary across age. Also, we recruited subjects with similar body composition, for that reason we recognize that the findings of the study cannot be generalized in people with higher levels of BMI or obese individuals. Future studies are required with different measurement apparatus to determine whether the results of the present study can be extrapolated to these individuals.

Second, we acknowledge that the FSP varied significantly among individuals and did not represent the available end range of motion in upper cervical spine and head. The assessment of real end range postures was beyond the scope of this study and the only reason that extreme postures were examined was only for comparisons with mid range postures. Furthermore, in regard angles that were examined, the HT angle data were contaminated by the instruction to the participants to fix their gaze on a wall-marker ahead. This erroneous aspect of our protocol has to be stressed in order to be avoided in other studies since even a big distance from the wall marker was proved to affect head position.

Third, we acknowledge that it is common in measurement studies to take a mean from 3 measurements and use it as a representative measure (Caneiro, et al., 2010; A. P. Claus, et al., 2009a, 2009b; K. O'Sullivan, et al., 2010). It is possible to conduct 3 measurements and use the mean during the same session or in three different occasions. However, there are significant considerations in both options regarding the rational and the aims of the present study.

In the one hand, the first option was to take 3 measurements in each posture within the same session. However, one of the main interests of the present study was the evaluation of prolonged flexed unsupported sitting in the proprioception of spinal tissues. Given that one half of creep elongation have been regained within 2 minutes after the termination of prolonged flexion (McGill & Brown, 1992), three repeated measurements could affect the basic aim of this study in terms of tissue recovery during the extra two measurement occasions over our methodology perspective. Furthermore, taking into account the consideration of Dolan & Green (2006) each reposition trail could be a flexion extension cycle. The results of a study (Solomonow, et al., 2001) have shown that if the flexion extension cycle of cat spines was increased from 1 to 10 seconds, the reflexive multifidus muscle activity was reduced by 50%. A recent study has given direct evidence that physiologic levels of creep can impair spinal muscles activation in human (Sánchez-Zuriaga, et al., 2010). Dolan and Green (2006) argued that the accurate immediate repositioning of their test could be attributed to reflexive muscles activity. These data indicate that every extra reposition attempt can affect reflective muscle activity and have a direct impact in our measurements. In other posture measurement studies (A. P. Claus, et al., 2009a, 2009b; Edmondston, et al., 2007) that have used the mean from 3 measurements, the reposition accuracy hasn’t been evaluated in regard with the time effect in a flexed posture, but independently.

In the other hand, we could take three measurements in different occasions (days or hours). Taking into account the objectives and the sequence of the procedure conducting three measurements was not possible. The first reason has to do with the fact that the clinically optimal posture was facilitated and educated during the procedure. The learning effect could contaminate our data and results in each additional measurement. The second reason was related with the education of correct posture. The instruction of optimal sitting posture could affect both the habitual and perceived correct posture, as in one hand the subjects did not know that their habitual posture was recorded and on the other hand their perception of good posture might change in each additional measurement as a result of the clinical education. Nevertheless, three measurements could have been conducted during the four reposition trials, but this could have contaminated the results, due to the difference in measurement procedures of habitual, perceived correct and repositioned postures.

Lastly, only sagittal unsupported sitting postures in healthy young individuals were investigated in this study. It has to be evaluated whether the same results would be revealed in elderly subjects and symptomatic individuals, in other postures functional, supported or unsupported and moreover in other planes (frontal or transverse).

6. CONCLUSIONS AND TAKE HOME MESSAGES

- This is the first study examining spinal posture and proprioceptive accuracy, regarding the head, spine and pelvis, in a predetermined sitting posture after prolonged flexed spinal posture.
- In the present study in healthy individuals HPS was significantly more flexed than SPOP and IOSP.
- Although individuals do not usually attain end-range postures, in HSP the pelvic angle was near at the end range.
- All the participants were able to achieve a more upright lordotic sitting posture after postural education from an expert with manual and verbal facilitation.
- Individuals can be reliably positioned in a predetermined optimal sitting posture.
- Healthy individuals can reliably and accurately replicate the IOSP immediately
- Flexed spinal sitting posture affected spinal proprioception.
- Proprioceptive deficits point out a loss of position sense in the “neutral zone” of healthy individuals.

- The distribution of these differences among three levels (head, cervico-thoracic and lumbar spine) of the upper part of the body indicated a widespread than a segmental deficit in proprioception after prolonged FSP.
- The proprioceptive deficit was increased with a time dependent manner in the lumbar spine.
- The MDT “slouch-overcorrect” procedure reinforced spinal proprioception.

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8. Appendix

8.1. Έντυπο συναίνεσης δοκιμαζόμενου σε ερευνητική εργασία

1. Σκοπός της ερευνητικής εργασίας

Σκοπός αυτής της εργασίας είναι να αξιολογήσει την καθιστή στάση ασυμπτωματικών ατόμων. Παράλληλα, σαφείς ενδείξεις υπάρχουν και σχετίζουν τις «κακές» καθιστές θέσεις με διεργασίες που προκαλούν τις ιδιοδεκτικές δομές της σπονδυλικής στήλης και το μυικό σύστημα που είναι υπέυθυνο για την διατήρηση της στάσης του σώματος. Στόχος μας είναι να διερευνήσουμε αν η καμπτική θέση [καθιστή στάση έχοντας τη σπονδυλική στήλη σε μη ευθυτενή θέση (χαλαρή / σκυφτή / καμπουριαστή) και χωρίς υποστήριξη στην πλάτη] σε συνάρτηση με το χρόνο έχει επίδραση στον επαναπροσδιορισμό μιας προκαθορισμένης καθιστής στάσης.

2. Διαδικασία μετρήσεων

Θα χρειαστεί να έρθεις στο εργαστήριο μόνο μία φορά. Θα σου ζητηθεί να καθήσεις χωρίς υποστήριξη σε μία καρέκλα/εσκαμπώ έχοντας κάποιους ανακλαστήρες κολημένους σε κάποια καθορισμένα σημεία του σώματος σου.Στη συνέχεια θα εκπαιδευτείς για μία προκαθορισμένη καθιστή στάση. Οι διαδικασίες που θα ακολουθήσουν είναι τρείς. Κατά την πρώτη διαδικασία θα καθίσεις σε πλήρως καμπτική στάση (καθιστή στάση έχοντας τη σπονδυλική στήλη σε μη ευθυτενή θέση (χαλαρή / σκυφτή / καμπουριαστή) και χωρίς υποστήριξη στην πλάτη) και θα σου ζητηθεί άμεσσα να καθίσεις κανονικά. Στη συνέχεια θα παραμείνεις σε πλήρως καμπτική καθιστή θέση για 10 λεπτά και θα σου ζητηθεί να ξαναπροσδιορίσεις την προηγούμενη στάση. Ενώ μετά από 30 λεπτά θα επαναλάβεις την προηγούμενη διαδικασία. Με αυτές τις δοκιμασίες τελειώνει και διαδικασία των μετρήσεων. Κατά την διαδικάσία χρειάζεται να φοράς μαγιό ή κοντό παντελόνι και αθλητικό φανελάκι με ράντες.

3. Κίνδυνοι και ενοχλήσεις

Κατά την διάρκεια των διαδικασιών και των μετρήσεων της στάσης του σώματος δεν υπάρχει κανένας κίνδυνος, για το λόγο ότι όλες οι καθιστές θέσεις που θα ζητηθούν να υιοθετήσεις αποτελούν καθημερινές στάσεις στις οποίες τοποθετείς το σώμα σου. Ακόμα και η παραμονή για 30 λεπτά σε καμπτική/κακή στάση δεν απέχει πολύ από αυτήν που υιοθετείς κατά την μελέτη ή την ενασχόληση με τον ηλεκτρονικό υπολογιστή.

4. Προσδοκώμενες ωφέλειες

Τα ευρήματα από την εργασία θα σου δώσουν την δυνατότητα να αντιληφθείς ποιά είναι η σωστή στάση του σώματος στην καθιστή θέση και ποιά είναι η επίπτωση των υιοθετούμενων καμπτικών στάσεων (καθιστή στάση έχοντας τη σπονδυλική στήλη σε μη ευθυτενή θέση (χαλαρή / σκυφτή / καμπουριαστή) και χωρίς υποστήριξη στην πλάτη) στην σπονδυλική σου στήλη.

5. Δημοσίευση δεδομένων – αποτελεσμάτων

Η συμμετοχή σου στην έρευνα συνεπάγεται ότι συμφωνείς με τη δημοσίευση των δεδομένων και των αποτελεσμάτων της, με την προϋπόθεση ότι οι πληροφορίες θα είναι ανώνυμες και δε θα αποκαλυφθούν τα ονόματα των συμμετεχόντων. Τα δεδομένα που θα συγκεντρωθούν θα κωδικοποιηθούν με αριθμό, ώστε το όνομα σου δε θα φαίνεται πουθενά.

6. Πληροφορίες

Μη διστάσεις να κάνεις ερωτήσεις γύρω από το σκοπό, τον τρόπο πραγματοποίησης της εργασίας ή την αξιολόγηση της στάσης του σώματός. Αν έχεις κάποιες αμφιβολίες ή ερωτήσεις, ζήτησέ μας να σου δώσουμε πρόσθετες εξηγήσεις.

7. Ελευθερία συναίνεσης

Η άδειά σου να συμμετάσχεις στην εργασία είναι εθελοντική. Είσαι ελεύθερος να μην συναινέσεις ή να διακόψεις τη συμμετοχή σου όποτε επιθυμείς.

Διάβασα το έντυπο αυτό και κατανοώ τις διαδικασίες που θα εκτελέσω. Συναινώ να συμμετέχω στην εργασία.

Ημερομηνία: __/__/__

Ονοματεπώνυμο και υπογραφή συμμετέχοντος

Υπογραφή ερευνητή

Ονοματεπώνυμο και υπογραφή παρατηρητή

8.2. Table 9. Reposition error between IOSP and REP1

TABLE 9. Reposition error between IOSP and REP1

	HE RE1	NE RE1	HP RE1	HT RE1	CT RE1	TH RE1	TL RE1	LU RE1	PEL RE1
Mean	-1.2	0.4	-0.1	-0.5	-0.8	-0.9	0.2	-1.9	0.4
SD	5.6	3.6	3.2	4.8	3.8	2.3	3.3	5.9	2.7

8.3. Υπεύθυνη Δήλωση

Ο κάτωθι υπογεγραμμένος Κορακάκης Βασίλειος 01/09 , μεταπτυχιακός φοιτητής του Προγράμματος Μεταπτυχιακών Σπουδών «Άσκηση και Υγεία» του Τμήματος Επιστήμης Φυσικής Αγωγής και Αθλητισμού του Πανεπιστημίου Θεσσαλίας

δηλώνω υπεύθυνα ότι αποδέχομαι τους παρακάτω όρους που αφορούν

(α) στα πνευματικά δικαιώματα της Μεταπτυχιακής Διπλωματικής Εργασίας (ΜΔΕ)μου με τίτλο «Καλή και κακή καθιστή στάση. Πώς η παρατεταμένη “κακή” στάση επηρεάζει την ιδιοδεκτικότητα της σπονδυλικής στήλης.»

(β) στη διαχείριση των ερευνητικών δεδομένων που θα συλλέξω στην πορεία εκπόνησής της:

1. Τα πνευματικά δικαιώματα του τόμου της μεταπτυχιακής διατριβής που θα προκύψει θα ανήκουν σε μένα. Θα ακολουθήσω τις οδηγίες συγγραφής, εκτύπωσης και κατάθεσης αντιτύπων της διατριβής στα ανάλογα αποθετήρια (σε έντυπη ή/και σε ηλεκτρονική μορφή).

2. Η διαχείριση των δεδομένων της διατριβής ανήκει από κοινού σε εμένα και στον πρώτο επιβλέποντα καθηγητή.

3. Οποιαδήποτε επιστημονική δημοσίευση ή ανακοίνωση (αναρτημένη ή προφορική), ή αναφορά που προέρχεται από το υλικό/δεδομένα της εργασίας αυτής θα γίνεται με συγγραφείς εμένα τον ίδιο, τον κύριο επιβλέποντα ή και άλλους ερευνητές (όπως πχ μέλους –ών της τριμελούς συμβουλευτικής επιτροπής), ανάλογα με τη συμβολή τους στην έρευνα ή στη συγγραφή των ερευνητικών εργασιών.

4. Η σειρά των ονομάτων στις επιστημονικές δημοσιεύσεις ή επιστημονικές ανακοινώσεις θα αποφασίζεται από κοινού από εμένα και τον κύριο επιβλέποντα της εργασίας, πριν αρχίσει η εκπόνησή της. Η απόφαση αυτή θα πιστοποιηθεί εγγράφως μεταξύ εμού και του κ. επιβλέποντα.

Τέλος, δηλώνω ότι γνωρίζω τους κανόνες περί λογοκλοπής και πνευματικής ιδιοκτησίας και ότι θα τους τηρώ απαρέγκλιτα καθ’ όλη τη διάρκεια της φοίτησης και κάλυψης των εκπαιδευτικών υποχρεώσεων που προκύπτουν από το ΠΜΣ/τμήμα, αλλά και των διαδικασιών δημοσίευσης που θα προκύψουν μετά την ολοκλήρωση των σπουδών μου.

[03/07/2012]

Ο δηλών

Κορακάκης Βασίλειος