ANTHROS: Biomechanical Assessment of Unique Pelvic Support and Tilt Mechanisms

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EXECUTIVE SUMMARY

With the increasing prominence and duration of sedentary activities, coupled with the associated risk of back pain and injury, there is a need to evaluate how different office chairs can influence the biomechanical risk factors of prolonged sitting. The purpose of this analysis was to evaluate the ability of a chair with a unique two-part seatback, consisting of separate pelvis and upper back supports, to alter 1) postural responses and movement of the spine, 2) seat pan pressure measurements, 3) pain ratings, and 4) work productivity of individuals during seated computer work performed in the Anthros Chair and Herman Millar x Logitech Embody Gaming Chair. Data were collected on 16 participants, with an equal distribution of male and female participants. In each of the two chairs, participants completed one-hour of prolonged sitting, consisting of 15-minutes of standardized data entry, typing, and reading tasks. Seat pan pressure measurements were also collected in upright and reclined sitting at initiation and following the one hour of prolonged seated work.

Differences in low back postural responses and movements were found between Anthros and Embody. The Anthros pelvic support controlled the amount of pelvic posterior tilt at the start of sitting, indicating it has the capacity to achieve postures less deviated from neutral. Throughout prolonged sitting, static, median, and peak posterior pelvic tilt and lumbar spine flexion as well as lumbar spine shifts and fidgets were similar between Anthros and Embody. Together, these findings indicate that Anthros and Embody supported individuals in similar low back postures and provided similar opportunities for movement. Over the hour of prolonged sitting, particularly after the seated breaks between tasks, female participants in the Anthros chair exhibited increases in posterior pelvic tilt. Females may have exhibited increases in posterior pelvic tilt as most were not able to easily recline in Anthros and thus, they adjusted their postures within the chair rather than with the chair. Indeed, five of eight female participants had Anthros set to the loosest tilt tension. Reclining in a chair is important for promoting movement and redistributing load during sitting; increasing the range of tilt tension in Anthros would be beneficial for supporting smaller individuals, especially females.

Throughout prolonged sitting participants demonstrated increases in lumbar spine flexion while seated in Anthros, following the seated time between tasks. Increases in flexion following seated breaks indicates a tendency for a step-like change in postures, rather than postural drift

over time. This is an encouraging finding as it indicates that Anthros can effectively support the spine; however, additional considerations may be required for use of the chair in a work environment. **First, encouraging individuals to adjust the chair throughout the day may help restore upright trunk postures.** In this study, to control the variability potentially introduced in postures by altering chair setting, participants were not encouraged to adjust their posture following set-up or allowed to adjust the chair during the one-hour of sitting. **Second, accommodation training, for example through gradual introduction to the chair over time, may also help individuals learn to adopt and maintain the seated postures observed at the initiation of the Anthros one-hour exposure.** Nevertheless, the changes in lumbar spine postures over time were not associated with clinically relevant increases in low back pain for any participant when seated in Anthros.

Anthros facilitated decreased thoracic spine flexion compared to Embody, indicating that individuals exhibit less hunched or slouched upper back postures while seated in Anthros. Moreover, although introduction to novel devices and seated postures can lead to pain responses, the decreases in upper back flexion had no corresponding increases in upper back pain. **Decreases in thoracic flexion were facilitated by the Anthros upper back support. The upper seatback section of Anthros was more posteriorly rotated than Embody, and participants remained in contact with the seatback throughout prolonged sitting creating a more supported seating experience.**

Measures of seat pan pressure were also lower in Anthros than Embody. The peak and total pressure in both upright and reclined sitting were smaller in Anthros than Embody. While the contact area on Anthros was smaller than Embody, the dispersion index, indicating pressure distribution under the ischial tuberosities, was also smaller on Anthros, particularly for male participants. **Together, these findings indicate that Anthros effectively distributed pressure on the seat pan.** This is a positive finding as areas of high focal pressure have been linked to comfort/discomfort in sitting. In support of this, buttocks pain reporting remained low in Anthros. Only one participant reported buttocks pain, but the magnitudes were well below clinically relevant thresholds.

The centre of pressure and peak pressure were more forward in Anthros than Embody, when expressed relative to the front edge of the seat pan and the participant's hips. The current results indicate that participants likely sat further forward on Anthros and/or in more forward leaning postures (i.e., perched). The tactile feedback from the pelvic support may initially result in some participants moving forward in the seat. **Additional time in the chair (i.e., accommodation training) and the ability to move between upright and reclined sitting may assist in user repositioning.**

Overall, the Anthros chair provided equivalent or improved sitting kinematics, productivity, and seat pan pressure measurements to one of the leading ergonomic chairs in the sitting industry, with no negative outcomes related to pain or work productivity compared to the Embody chair.

INTRODUCTION

Prolonged periods of sitting are often cited as a risk factor for back pain development (Bontrup et al., 2019; Janwantanakul et al., 2012). There is considerable epidemiological and laboratory research linking prolonged sitting and low back pain (da Silva et al., 2019; De Carvalho et al., 2020; Gupta et al., 2015; Hanna et al., 2019; Levangie, 1999; Lis et al., 2007; Mendelek et al., 2011; Park et al., 2018; Schinkel-Ivy et al., 2013; Sheahan et al., 2016; Thorbjörnsson et al., 2000; Van Vuuren et al., 2005; Vergara & Page, 2002; Williams et al., 1991). Yet, many occupations continue to require seated activities, with sitting time accounting for up to 90% of office workers' days (Davidson & Callaghan, 2025a; Parry & Straker, 2013). While the cause and specific tissue source for low back pain is difficult to identify, several biomechanical factors have been recognized as risk factors for low back pain.

First, sitting elicits spine flexion, often described as a slouched or hunched posture. Flexion occurs in both the upper and lower back. In the upper back, thoracic spine angles are on average 10° more flexed than those observed in standing (Claus et al., 2016; Dunk & Callaghan, 2005). In the lower back, average lumbar flexion angles range from about 30 to 80% of maximal voluntary lumbar flexion range of motion (Callaghan & McGill, 2001; Davidson & Callaghan, 2025a; De Carvalho et al., 2016; Dunk & Callaghan, 2005; Greene et al., 2019). Spine flexion has been identified as a risk factor in the development of back pain, as it alters the distribution of loading across tissues. Where a lordotic spine posture (e.g., standing) distributes compressive load across both the facet joints and intervertebral disc, flexion increases the load borne by the intervertebral disc (Adams & Hutton, 1985; Hedman & Fernie, 1997). Additionally, there is considerable engagement of posterior passive tissues to support flexed sitting postures (Callaghan & McGill, 2001). Moreover, when these flexed postures are habitually adopted, for example in daily seated office work, there is a risk of time-dependent changes in these tissues which result in back pain or injury. Reductions in spine flexion can be achieved in two ways, termed top-down and bottom-up strategies (Breen & Breen, 2020; Dunk et al., 2009). Top-down refers to movement strategies driven by movement of the thorax, for example, by reclining on the seatback. In fact, a reduction in the amount of thorax reclination has been identified as a factor contributing to low back pain in seated office work (Davidson & Callaghan, 2025b). Alternatively, bottom-up strategies refer to changes in the pelvis posture which has the potential to allow changes up the lumbar spine. For example, decreases in posterior pelvic tilt while seated could lead to decreases in lumbar spine flexion. Overall, an effort to reduce spine flexion in sitting, through both top-down and bottom-up strategies, would be beneficial for spine health.

In addition to flexed spine postures, decreases in spine movement have also been identified as a risk factor for pain development in sitting. For example, sitting elicits less spine movements than other activities, like walking (Callaghan et al., 1999) and these decreases in spine movement may contribute to pain development through altered load, fluid, and nutrient distribution within the joint (Adams & Hutton, 1985; Huang et al., 2014; Nachemson, 1966; Wilder et al., 1988; Wilke et al., 1999). Indeed, individuals with low back pain often exhibit more frequent and/or larger spine micromovements in sitting, potentially as a mechanism to combat their pain (Davidson & Callaghan, 2025b; Dunk & Callaghan, 2010; Vergara & Page, 2002). Moreover, in prolonged standing, early static standing was associated with low back pain reporting (Gallagher & Callaghan, 2015). Chairs which allow for spine movement during sitting, through factors such as chair adjustability and recline, may assist in reducing the development of pain during prolonged sitting.

Last, alterations in seat pan pressure may also be associated with pain responses in prolonged sitting. While there is some evidence to suggest that seat pan pressure is associated with subjective measures of comfort/discomfort in sitting (De Looze et al., 2003), this relationship in office chairs specifically is less defined (Zemp et al., 2015). Nevertheless, lower seat pan pressure (typically peak pressure), and greater pressure distribution (typically redistribution away from the ischial tuberosities) are desired for user comfort, and thus, may influence pain development in prolonged office sitting. Seat pan pressure can be adjusted by altering seat pan characteristics and by altering how an individual is supported by the chair. Alterations in the shape of the seat pan, foam properties, and fabric certainly impact seat pan pressure measurements (Groenesteijn et al., 2009; Makhsous et al., 2012; Vos et al., 2006). Additionally, the use of a backrest decreased peak seat pan pressure (Dunk & Callaghan, 2005) and increasing backrest angle also decreased peak and average seat pan pressure (Vos et al., 2006). The addition of a supplementary lumbar support in an office chair also led to decreased peak and average seat pan pressure (Carcone & Keir, 2007). Further, supporting the upper body through armrest use can also decrease seat pan pressure (Vos et al., 2006). Where low seat pan pressure and high pressure distribution are the goal for mitigating pain development in prolonged seated work, both the seat pan characteristics and overall postural support provided by the chair must be considered.

With the increasing prominence and duration of seated activities, coupled with the associated risk of back pain and injury, chairs which aim to reduce the biomechanical risk factors of prolonged sitting are critical. The aim of this analysis was to evaluate the ability of a chair with a unique two-part seatback, consisting of separate pelvis and upper back supports, to alter 1) postural responses and movement of the spine, 2) seat pan pressure measurements, 3) pain ratings, and 4) work productivity of individuals during prolonged computer work. Specifically, the Anthros Chair and Herman Millar x Logitech Embody Gaming Chair were compared during standardized office work tasks.

METHODS

Participants

Sixteen participants, eight males and eight females, were recruited from the general University population (Table 1). Participants were included if they had not reported any musculoskeletal injury or low back pain in the previous 12 months which required medical attention or time off work. The University of Waterloo Research Ethics Board approved all experimental procedures, and each participant signed informed consent prior to the data collection.

Table 1: Mean (standard deviation) for participant age, height, mass, and body mass index (BMI).

	Sample size	**Age (years)**	**Height (m)**	**Mass (kg)**	**BMI (kg/m^2)**
Male	8	26.6 (3.4)	1.79 (0.05)	79.1 (6.9)	24.8 (1.9)
Female	8	24.9 (3.1)	1.69 (0.07)	63.1 (14.6)	21.9 (3.9)
Total	16	25.8 (3.3)	1.74 (0.08)	71.1 (13.8)	23.3 (3.3)

Experimental Protocol

In a single laboratory session of approximately 3 hours per participant, three seated office tasks were completed over one hour of sitting in each of an Anthros Chair and Herman Millar x Logitech Embody Gaming Chair (Figure 1).

a) At initiation, a 90-second dynamic trial consisting of three repetitions of alternating between an upright and reclined posture, holding each posture for approximately 10-seconds.

b) At initiation and after the prolonged seated work, 60-second seated trials in both an upright posture and a reclined posture, with a pressure mat on the seat pan. For both a) and b) participants were instructed to maintain their vision on a video playing on the computer monitor and rest their hands on the desk.

c) One-hour of standardized seated computer work. Within each hour, participants performed three 15-minute blocks of standardized computer work (Table 2**Table 2:** Description of the standardized computer work completed in each of the two chairs.

These tasks remained consistent between the two chairs, but the assigned material was never duplicated within each participant.), separated by 5-minute seated breaks. Participants were not permitted to cross their ankles or legs or excessively lean on the desk other than their forearms to use the mouse and keyboard. The order of the chairs was randomized, as was the order of the tasks within each chair condition.

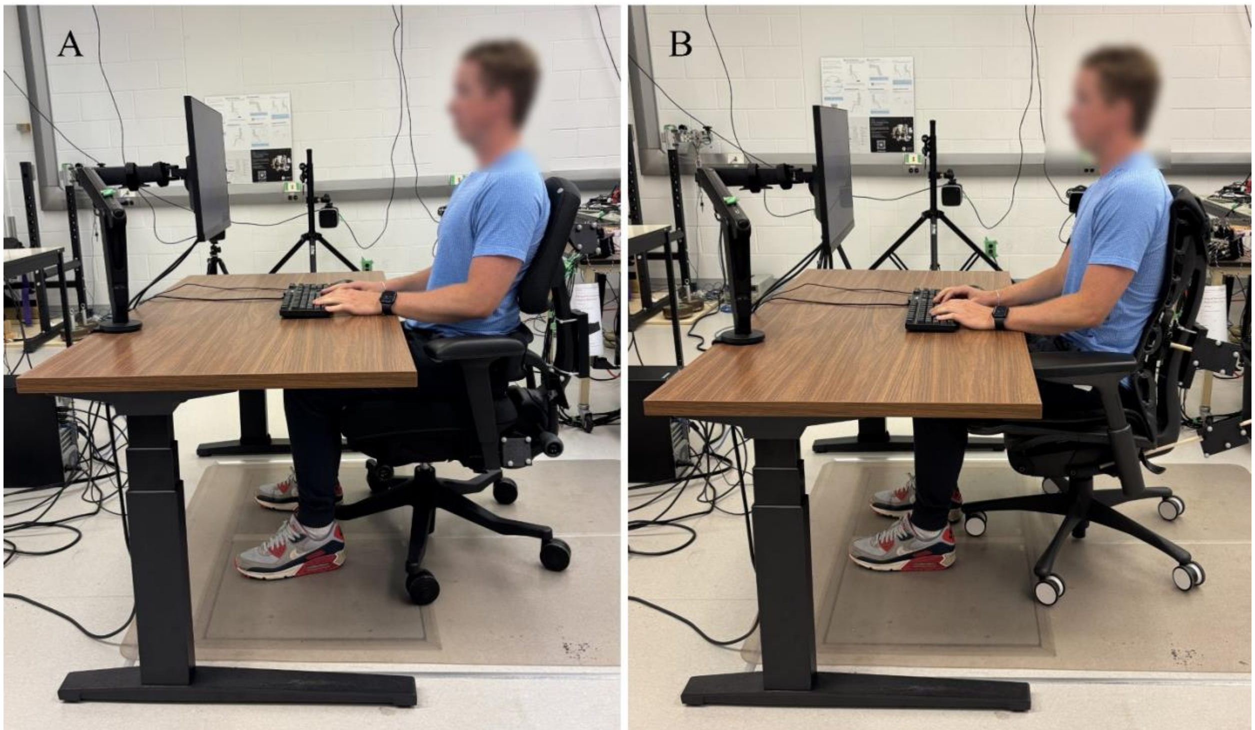

Figure 1: Image of participant in A) Anthros and B) Embody.

Table 2: Description of the standardized computer work completed in each of the two chairs. These tasks remained consistent between the two chairs, but the assigned material was never duplicated within each participant.

Task	Details
Typing	Text passages standardized to an ATOS readability level between 6.0 and 6.9 and grade 5 equivalency were copied using Mavis Beacon Teaches Typing software. Standardization of readability ensured that the text difficulty was similar across passages. Participants primarily used the keyboard.
Data Entry	Transfer of product, client, and company information from invoices into a custom developed graphic user interface. The number of entries were consistent across invoices. Participants used both the mouse and keyboard.
Reading Comprehension	Completion of a scaled version of the Qualitative Reasoning section of the standardized Graduate Record Exam (GRE). Each test contained 10 questions related to text completion and short, medium, and long passages that were extracted from previous GRE practice exams. Participants primarily used the mouse.

The Anthros and Embody chairs were adjusted to each participant's anthropometrics. Prior to the participant sitting in each chair, the chairs were locked in an upright position (i.e., tilt lock on) and the seatback(s) were situated in their most rearward position. Positioning in Anthros was always completed prior to Embody.

1) **Chair Height:** Set to facilitate a traditional 90º trunk-thigh, knee, and ankle angle.
    a) **Anthros:** Four female participants (heights ranging from 1.61 to 1.68 m) required a footstool.
    b) **Embody:** No footstool required for any participant.
2) **Seat Pan Depth:** Set to ensure 2-3 fingers widths between the front edge of the seat pan and behind the participant's knees/calf.
    a) **Anthros:** Participants were instructed to adjust their rearward position on the chair.
    b) **Embody:** Seat pan depth adjusted using the two front handles on the chair.
3) **Back Support:** Participants were instructed to adopt an "upright posture" facilitated by "anteriorly rotating their pelvis". This process was facilitated through demonstration by the

researcher, palpation and queuing rotation of the anterior superior iliac spines (ASIS), and queuing rotation of the ischial tuberosities (IT) on the seat pan.

a) **Anthros:** The lower back support was moved forward to support the pelvis, such that participants felt posterior rotation of the pelvis was restricted, but they were not being pushed forward in the chair. Next, the upper back support was moved forward to support the thorax, such that participants felt they were supported in their upright posture, but they were not being pushed forward in the chair.

b) **Embody:** The seatback was moved forward to support the participant in an upright posture.

4) **Tilt Tension**

a) **Prolonged Seated Work**

i. **Anthros**: The tilt was unlocked. Participants were familiarized with the tilt tension loosest (i.e., recline) and tightest setting. Next, the tension was adjusted such that participants could perform seated computer work. The goal was to ensure that the tension was balanced between supporting them in an upright posture and allowing movement in the chair. Five female participants had the chair at the loosest setting.

ii. **Embody:** Participants were exposed to the four "tilt limiter" levels, where 0 was no tilt and 4 was maximal recline. Most participants selected level 1, with two participants selecting level 2. The tension was then adjusted such that participants could perform seated computer work.

b) **One-Minute Upright and Reclined Posture Trials**

i. **Upright:** Tilt settings identical to above.

ii. **Recline:** The tilt tension was loosened from its position for upright computer work to enable participants to recline in each of the chairs. The goal was to ensure that the tension was just loose enough that they could maintain the reclined posture with their feet on the floor.

c) **Dynamic Upright and Reclined Posture Trials**

i. The tilt tension was adjusted to balance support in both an upright and reclined posture. The tension for these dynamic trials was typically set to somewhere between the tilt tension for the upright and reclined posture.

Following set-up in the chair, the desk height and chair arm rests were adjusted to facilitate a horizontal forearm position with the participants' hands on the keyboard. The monitor location was adjusted such that the horizontal line-of-sight aligned with the top of the monitor and was situated one arm length away.

Instrumentation

Accelerometers

Triaxial accelerometers (ADXL 335, Analog Devices, Norwood, MA) were used as inclinometers to measure cervical (neck) spine, thoracic spine, lumbar spine, and pelvis angles. The accelerometers were affixed to the participant's skin overlaying the first sacral vertebrae (S1), first lumbar vertebrae (L1), seventh cervical vertebrae (C7), and the back of the head on a head band (Figure 2). Calibration trials were performed to normalize the flexion-extension angles with respect to each participant's maximal range of motion. A total of two calibration trials were collected, including upright standing and maximum standing forward flexion. Accelerometer data were sampled at 250 Hz.

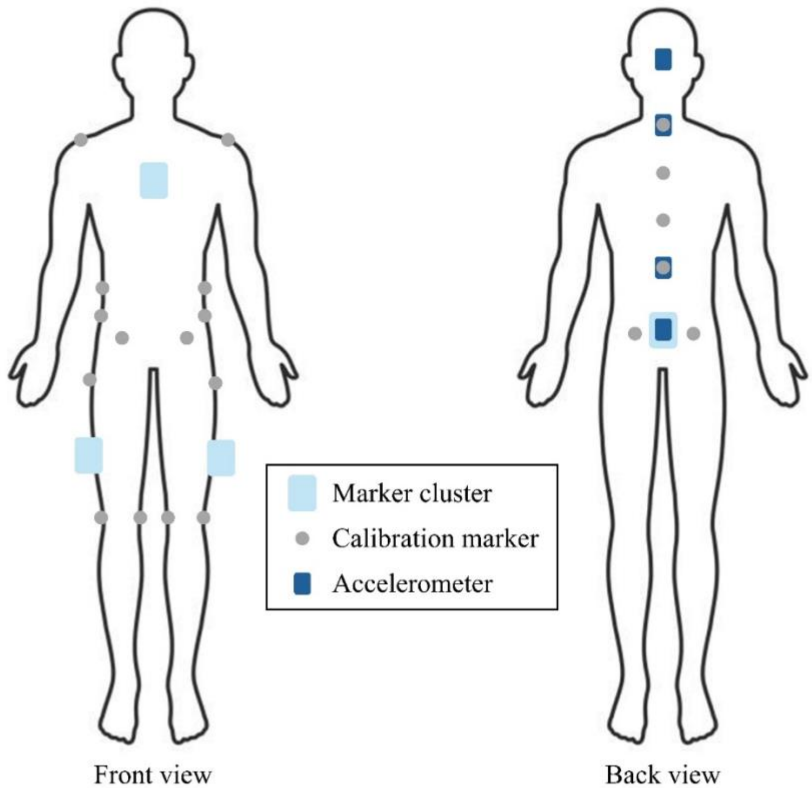

Figure 2: Accelerometer and motion capture instrumentation of the participant.

Motion Capture

Position data of the thorax and thighs were recorded from a passive motion capture system (Arqus 9, Qualysis, Gothenburg, Sweden). Marker clusters, containing four retroreflective markers, were adhered to segments (Figure 2) these remained on for the duration of the protocol. Retroreflective calibration markers were also adhered to relevant anatomical landmarks (Figure 2) to allow for calculation of joint angles. The positions of calibration markers were determined from a reference trial (i.e., 5-second quiet standing in a T-pose for participant and 5-second static trial for chairs) then reconstructed relative to their respective marker cluster during the experimental protocol. This process greatly reduced participant encumbrance during the seated trials. Participants also performed a left and right functional hip trial to locate the hip joint center (Camomilla et al., 2006). The pelvis cluster was then removed to prevent interactions with the seatback. Marker position data were sampled at 50 Hz.

Position data of the Anthros and Embody chair were also recorded with motion capture. A marker cluster coupled to the seat pan of each chair was used to reconstruct calibration markers placed on the corners of the seat pans (Figure 3). Two additional marker clusters were adhered to the seatbacks of each chair. On Anthros, marker clusters were placed on both the lower and upper back support to reconstruct the retroreflective calibration stickers adhered to each segment of the seatback (Figure 3). On Embody, the top seatback cluster was used for tracking the top three rows of calibrated markers and the bottom seatback cluster was used for tracking the bottom three rows of calibrated markers (Figure 3).

Figure 3: Motion capture instrumentation of the Anthros (A) and Embody (B) chair.

Seat Pan Pressure

For the one-minute seated trials collected at initiation and following the prolonged seated exposures, a pressure mat (X3, XSensor Technology Corporation, Calgary, AB, Canada) was situated over the seat pan. The pressure mat consisted of 1,296 sensels (36 x 36) each with an area of 2.54 cm^2. The mat was placed such that sensel (1,1) aligned with the front left corner of each seat pan. Much like the process used for tracking the seat pan of each chair, calibration markers on the pressure mat, including the four corners aligning with the seat pan and sensel (1,1), were reconstructed relative to the seat pan cluster. Pressure data were collected at 10 Hz synchronously through XSensor Pro (V7, XSensor Technology Corporation, Calgary, AB, Canada) with the motion capture and accelerometers.

Pain Responses

Participants completed a pain rating for 6 body regions using a 100 mm electronic visual analogue scale (VAS) on an iPad application (Figure 4; e-VAS, https://apps.apple.com/ca/app/evas/id6447213570). Ratings were completed bilaterally for the upper back, low back, buttocks, and thighs at the start of prolonged sitting (0 minutes), and after each 15-minute block, until the end of the one-hour prolonged sitting exposure. Thus, a total of four pain ratings were collected in each chair at 0, 15, 35, and 55 minutes.

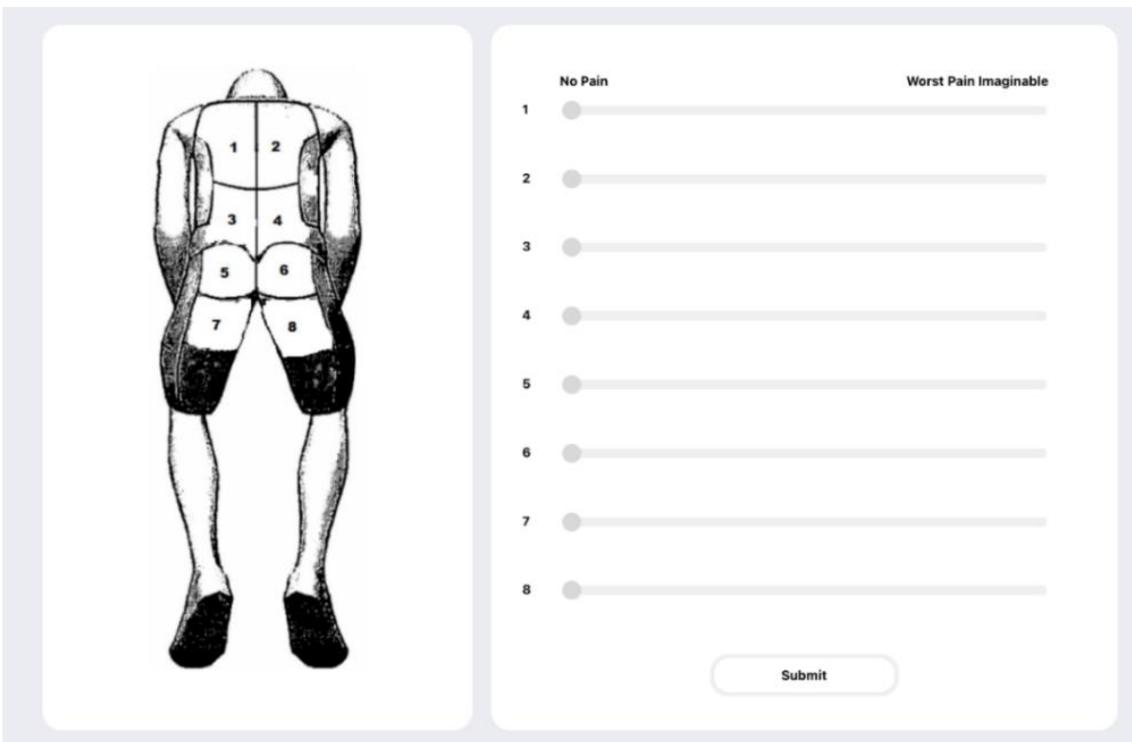

Figure 4: Electronic visual analogue scale (e-VAS) used to collect pain ratings.

Outcome Measures

Spine Postures and Movement

Raw voltage data obtained from the accelerometers were imported into a custom Python program. Voltage data were smoothed using a dual-pass second order low-pass Butterworth filter with an effective cut-off frequency of 1 Hz (Davidson & Callaghan, 2025a). Accelerometer channels were then calibrated relative to gravity and converted to angular measures (degrees) using standard four-quadrant trigonometric equations. Pelvis angles were derived from the inclination of the S1 accelerometer. Lumbar spine, thoracic spine, and cervical spine (neck) angles were derived from the relative inclination of L1 and S1, C7 and L1, and head and C7, respectively. Specifically, pelvic anterior-posterior tilt, and lumbar spine, thoracic spine and neck flexion-extension were calculated and expressed relative to the angles from the upright standing calibration trial (defined as 0°). Lumbar angles were additionally normalized to maximum flexion range of motion.

Postural data for the spine were summarized in several ways. First, to assess overall variability in angles between the chairs, an amplitude probability distribution function (APDF) was generated for the angles measured throughout the each entire one hour prolonged sitting exposure (Haoberg & Jonsson, 1975) (Figure 5). The APDF effectively sorted the angles into 0.1° or 0.1 %Max bins then summed the number of instances identified in each bin to construct a cumulative probability distribution. The angles at 10% (static), 50% (median), and 90% (peak) of the APDF were calculated. Additionally, mean angles in each 15-minute block were calculated to assess differences between tasks and over time. To further assess postural changes in the pelvis and lumbar spine over time, mean angles over 1-minute time blocks were computed. Specifically, the mean angles at 1^{st}, 2^{nd}, 4^{th}, 8^{th}, and 15^{th}-minute in the first block then the 1^{st} and 15^{th} minute in the second and third block were compared.

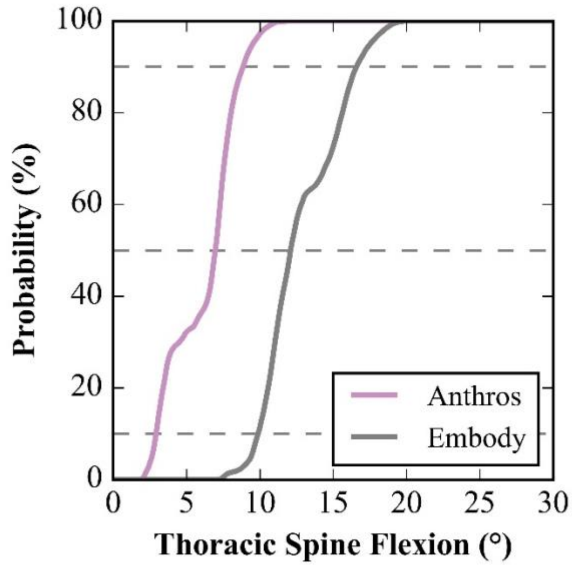

Figure 5: Example of amplitude probability distribution function (APDF) of the thoracic spine flexion for a male participant while seated in Anthros and Embody. The dashed horizontal lines indicate angles at 10% (static), 50% (median), and 90% (peak).

Dynamic movement quantified through micromovements of the lumbar spine were evaluated by calculating the shift and fidget frequencies (Dunk & Callaghan, 2010). Shifts were defined when the difference in the average lumbar angle of two 15-second sliding windows, separated by 3-seconds, exceeded 5°. Fidgets were defined when the lumbar angle at a data frame exceeds 3 standard deviations of the 60-second sliding window centered on that frame, for no longer than 3-seconds.

Trunk-Thigh Postures

Raw marker position data were imported into a custom Python program. Position data were smoothed using a dual-pass second order low-pass Butterworth filter with an effective cutoff frequency of 3 Hz (Brereton & McGill, 1998). Data acquired from the upright standing calibration trial were used to construct anatomical coordinate systems for the thorax and thighs, using their respective anatomical landmarks. Trunk-thigh (thighs relative to thorax) angles were calculated using a Z-X-Y Cardan sequence (Wu et al., 2002), then angles between the left and right leg were averaged (Wu et al., 2002). The mean trunk-thigh angle over each 15-minute block was calculated.

Chair Tracking

Position data were conditioned the same as described above in the *Trunk-Thigh Posture* section. Data acquired from a static chair calibration trial were used to construct coordinate systems for each component of both the Anthros and Embody chairs, including the seat pan, lower seatback and upper seatback, using their respective landmarks. The angles of each of the chair components were calculated using a Z-X-Y Cardan sequence. Forward-backward inclination of each chair component was calculated in the static calibration trial (i.e., chair set to participant but participant not sitting in chair) to assess baseline differences between Anthros and Embody and throughout the prolonged sitting exposure to assess differences in participant-chair interaction between Anthros and Embody. Over the prolonged sitting exposure, inclination was expressed relative to the values during the static calibration to isolate any recline of each chair.

Positioning Relative to Seatback

Additionally, the relative position of spine with the seatback were calculated (Figure 6). Specifically, the horizontal distance between the plane formed by markers on the seatback to each of C7, T4, T8, and T12 was calculated. The seatback planes were instantaneously constructed to align with the height of the respective anatomical landmark. If the anatomical landmark was above the seatback (e.g., C7), the horizontal distance from the top of the seatback and the anatomical landmark to the nearest cm was calculated.

Figure 6: Schematic diagram of the horizontal distance between the participant's spine landmarks (C7, T4, T8, and T12) and the seatback of each chair.

Seat Pan Pressure

Pressure variables capturing both magnitude and spatial distribution were computed at initiation and following one-hour of sitting in each chair (Table 3). Pressure magnitude variables included peak and total pressure, as well as contact area. Pressure spatial distribution metrics were the location of the center of pressure and peak pressure relative to the front edge of the seat pan and the hips, as well as the distribution index. Pressure variables were calculated instantaneously at each frame of data, then the average over the 1-minute trials in the upright and reclined posture were calculated.

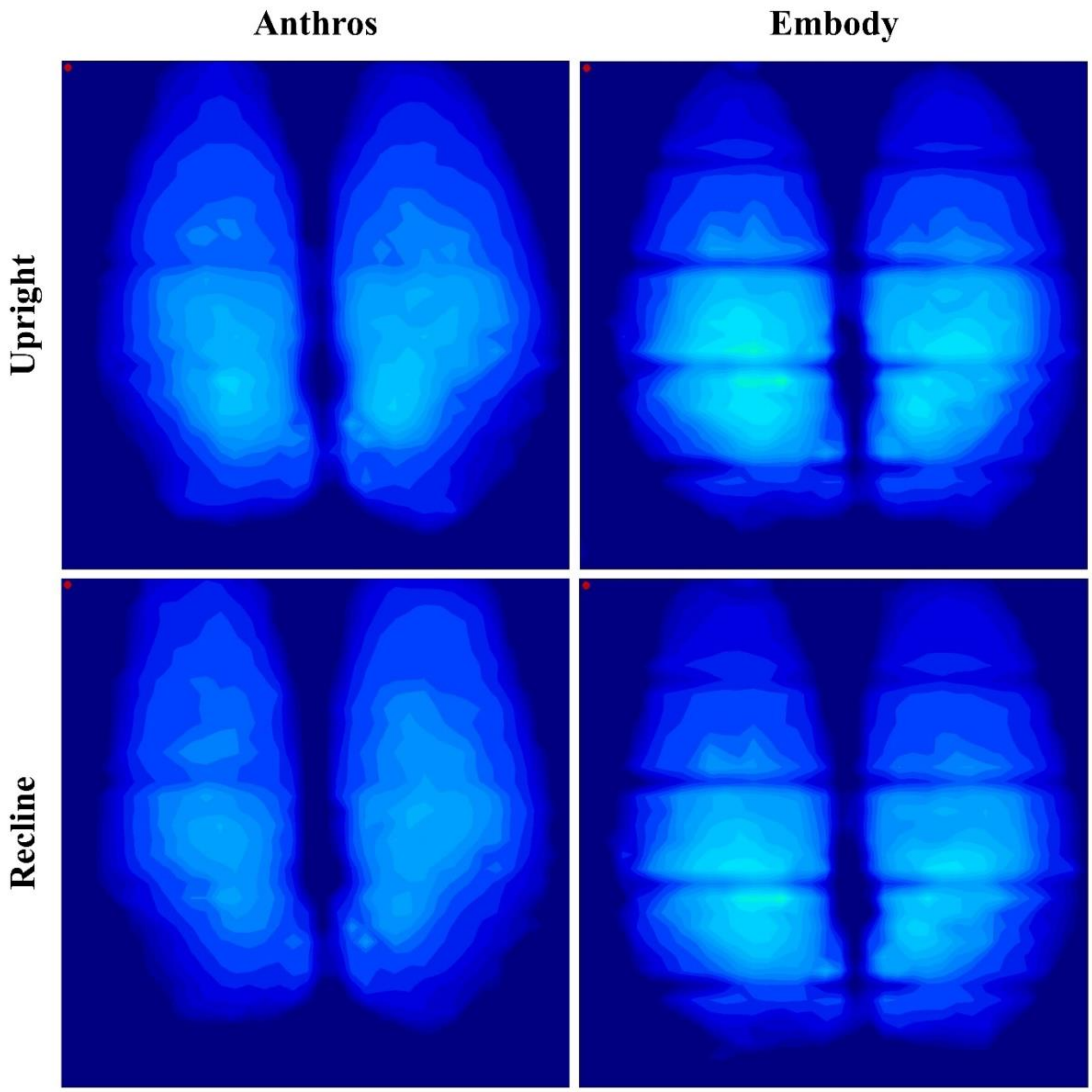

Figure 7: Example seat pan pressure data from female participant in Anthros (left) and Embody (right) during upright (top) and reclined (bottom) sitting. Note - the rigid lines in the Embody are due to seat pan cushion structure.

Table 3: Description of variables calculated from the pressure mat on the seat pan.

Variable	Description
Magnitude	
Contact Area	Estimated surface area (cm^2) in contact with mat. Exported from XSensor Pro.
Peak Pressure	Maximum pressure (mmHg) recorded from a single sensel.
Total Pressure	Sum of pressure (mmHg) recorded across all sensels.
Spatial Distribution	
Dispersion Index	The area of peak pressure under the left and right ischial tuberosities was calculated by locating the peak pressure on the left and right side of the posterior of the mat and the adjacent cells (3 x 3 box centered on the peak pressure). The pressure in the cells meeting this criterion were summed, then divided by the total pressure.
Centre of Pressure	Position on the mat where pressure is balanced in all directions. Exported from XSensor Pro as sensel (row, column) then expressed relative to a vector at the front edge of the seat pan and between the left and right hip. The horizontal distance between the center of pressure and the seat pan and hips are presented.
Focal Pressure Location	The sensel location of the peak pressure expressed relative to a vector at the front edge of the seat pan and between the left and right hip. The horizontal distance between the focal pressure location and the seat pan and hips are presented.

Pain Responses

Pain ratings for each body region were expressed relative to the baseline values collected at the start of the first block (i.e., subtract baseline) and an average value was calculated for the left and right side.

Productivity

Productivity was assessed in each of the three tasks. Typing and data entry productivity were evaluated by the speed (words or entries per minute) and accuracy (the percentage of correct words or entries). Reading comprehension was evaluated as a percentage, which represented the number of correctly selected answers.

Statistical Analysis

All statistical tests were completed with an alpha level of 0.05. Paired sample t-tests or mixed model analyses of variance (ANOVA) were performed on all kinematic, pain, and productivity variables to determine the effects of *chair* (within- subject factor: Anthros and Embody), *task* (within-subject factor: data entry, typing, and reading comprehension), *time* (within-subject factor) and/or *sex* (between- subject factor: male or female). Non-parametric equivalents were performed if data violated assumptions of normality (i.e., shifting frequency). When applicable, post hoc pairwise comparisons were performed with a Bonferroni correction.

DISCUSSION OF RESULTS

Kinematics during Upright and Reclined Sitting

Pelvis and Lumbar Spine Postures

There was a main effect of *posture* for pelvic tilt ($p < 0.001$). As expected, the pelvis was more posteriorly rotated in recline compared to upright sitting, with an average increase of 8.5° in Anthros and 10.0° in Embody (Figure 8). There were no significant effects of *chair, trial* or *sex* ($p \geq 0.155$). **The current results are promising as they demonstrate that short durations of upright sitting did not lead to increases in posterior pelvic tilt in Anthros compared to Embody. Moreover, reclining movements in Anthros did not negatively impact pelvis postures in subsequent upright sitting.** There were no significant effects of *chair, posture, trial,* or *sex* on lumbar spine flexion ($p \geq 0.062$). However, the *posture* * *trial* interaction did indicate that repetitive reclining led to small decreases in lumbar spine flexion during subsequent upright sitting (Figure 8). Lumbar spine flexion in upright sitting decreased an average 5.0 %Max in Anthros and 4.3 %Max in Embody from the first to the third upright sitting trial. It appears that the active reclining may position the user in a less flexed posture, closer to the neutral lumbar spine reference position. This is likely because the lumbar spine flexion angle in reclined sitting, resulted in an average 3.0% less spine flexion, although these differences *were more pronounced in Anthros than Embody* (Figure 8). Together, these findings imply that **reclining in Anthros could positively impact spine postures, by decreasing lumbar spine flexion during the reclined sitting, which may also transfer to better postures in subsequent upright sitting.**

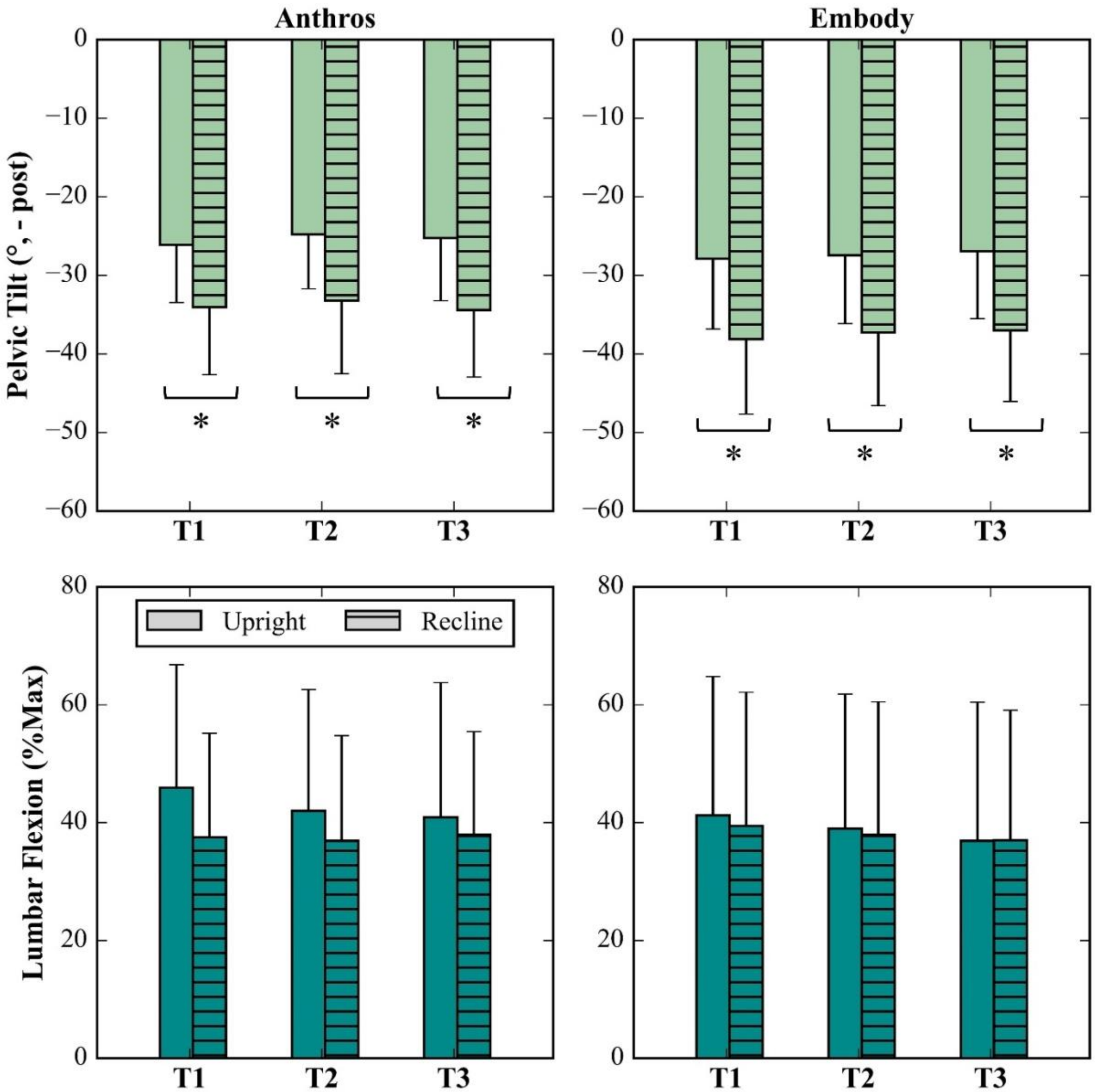

Figure 8: Mean (bar) and standard deviation (error bars) for pelvic tilt (top row) and lumbar spine flexion (bottom row) in Anthros (left column) and Embody (right column) during three repetitions of upright and reclined sitting. The asterisks (*) indicate significant differences between upright and recline sitting for pelvic tilt.

Chair Tracking

First, the results for the inclination of each chair component, including the seat pan, lower seatback, and upper seatback during the static calibration trial (i.e., chair set to participant but participant not sitting in chair) are presented, followed by the inclination during upright and reclined sitting. For the upright and reclined sitting, as well as the data presented later for prolonged sitting, inclination angles are expressed relative to the values during the static calibration, thereby representing any recline of the chair.

There were significant differences by *chair* in the baseline position of the seat pan and lower and upper seatback support during set-up. The seat pan of Anthros was rotated an average 2.4° more forward than Embody ($p < 0.001$; Figure 9). Further, the lower and upper seatback support of Anthros were rotated an average 13.1° and 4.2° more backwards than Embody ($p < 0.001$). There were no differences by *sex* in chair set-up ($p \geq 0.292$; Figure 9). With these differences in mind, **Anthros effectively provided a more open angle between the seat pan and lower seatback support** (Figure 10).

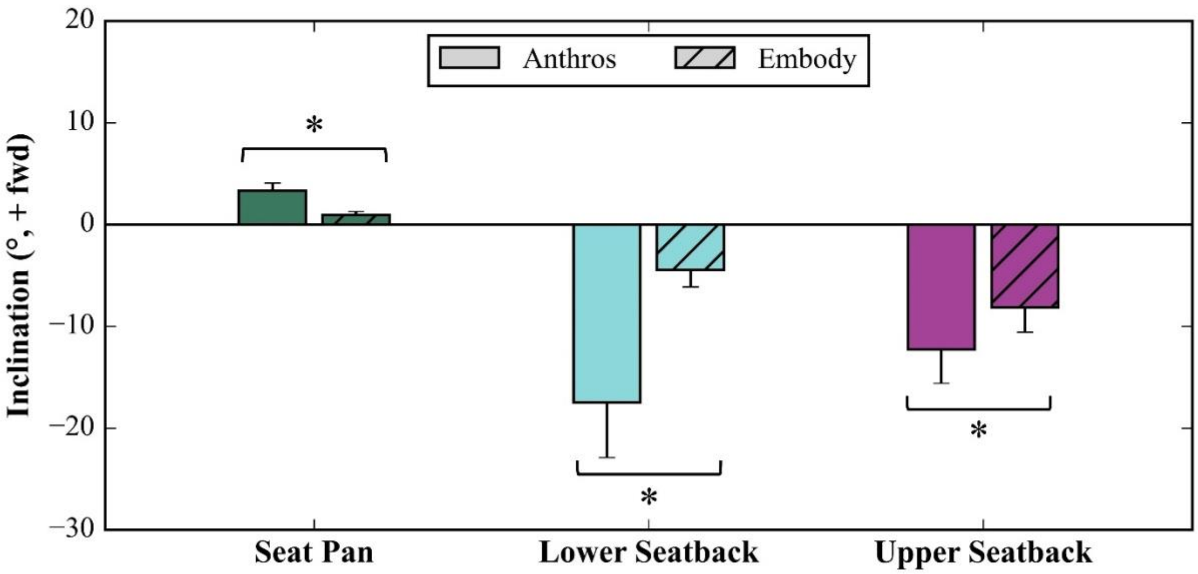

Figure 9: Mean (bar) and standard deviation (errors bars) in the forward-backward inclination of the seat pan, lower seatback, and upper seatback of Anthros and Embody following chair set-up for each participant. The asterisks (*) indicate significant differences between *chairs.*

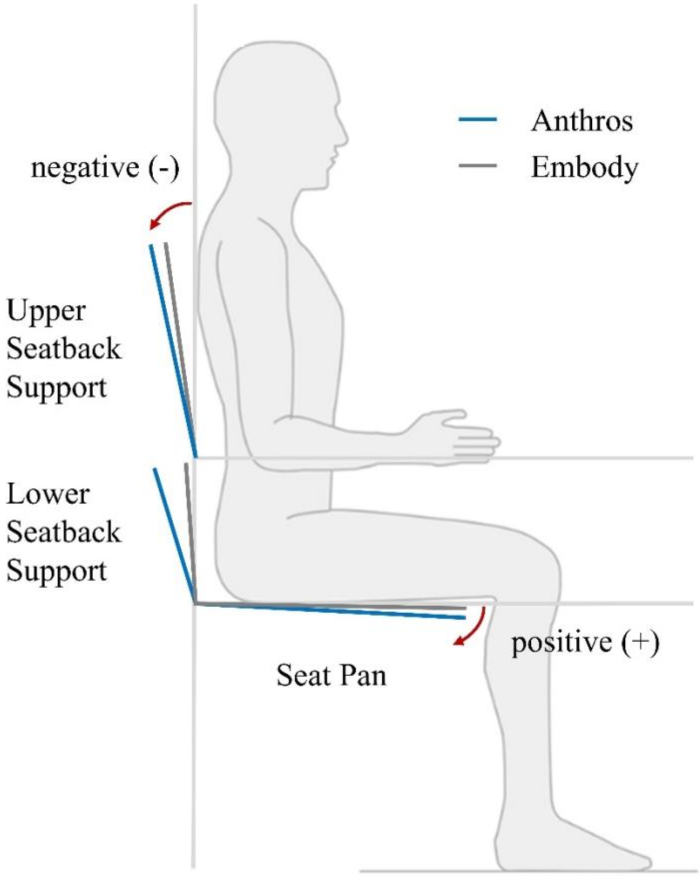

Figure 10: Angular definition and average rotation of each component of Anthros (blue) and Embody (grey) at set-up. The image of the human is strictly for context and does not represent set-up in either of the chairs.

There were significant *chair * posture* interactions for all three chair components ($p \leq 0.030$). All chair components were rotated backwards more in reclined compared to upright sitting ($p_{adj} < 0.001$), thereby confirming that participants effectively completed upright and reclined sitting (Figure 11).

The *chair * posture* interaction for seat pan inclination also indicated that **the seat pan of Anthros was an average 2.0° more reclined than Embody during upright sitting only** ($p_{adj} = 0.006$; Figure 11). Since the seat pan of Anthros was naturally more anteriorly rotated at baseline, on average by 2.0° (Figure 9), the seat pan of Anthros and Embody were reclined at similar absolute angles. There was also a main effect of *sex* for seat pan inclination ($p = 0.006$), wherein **the seat pan was more reclined for males than females** (Figure 11). **In Anthros, females tended to have more difficulty reclining.** This is likely related to differences in body mass between sexes. Males were heavier than females (Table 1), providing more body mass to assist in reclining. Moreover, five of eight females had the Anthros tilt tension at its loosest setting. **Adjustment of Anthros to facilitate looser tilt tension or providing users with the ability to adjust seat pan depth (location of pivot point) may be required to facilitate recline for smaller individuals.**

The *chair * posture* interaction indicated that lower seatback inclination increased more in Embody than Anthros during recline compared to upright sitting, albeit there were no significant differences between the chairs in either posture ($p_{adj} \geq 0.053$; Figure 11). This is likely related to differences in tilt synchronization between the seat pan and seatback, as well as seatback compliance, wherein the lower seatback of Embody was more mobile and deformable. Aligning with findings for the seat pan above, there was a main effect of *sex* for the lower seatback inclination ($p = 0.008$) that indicated that the lower seatback was more reclined for males than females (Figure 11).

The *chair * posture* interaction indicated that upper seatback inclination increased more in Anthros than Embody during reclined compared to upright sitting ($p_{adj} < 0.001$; Figure 11). Moreover, the upper seatback was more reclined in Anthros than Embody in both recline and upright sitting (Figure 11). While upper seatback inclination was within 1.0° across the trials, there was also a tendency for reclination to increase across the trials. Specifically, upper seatback backwards rotation was larger in the third compared to the first trial ($p_{adj} = 0.031$; Figure 11). **Increases in the recline of the upper seatback in Anthros may have contributed to the observed decreases in lumbar spine flexion with repetitive reclining (Figure 8), via a top-down spine movement strategy.**

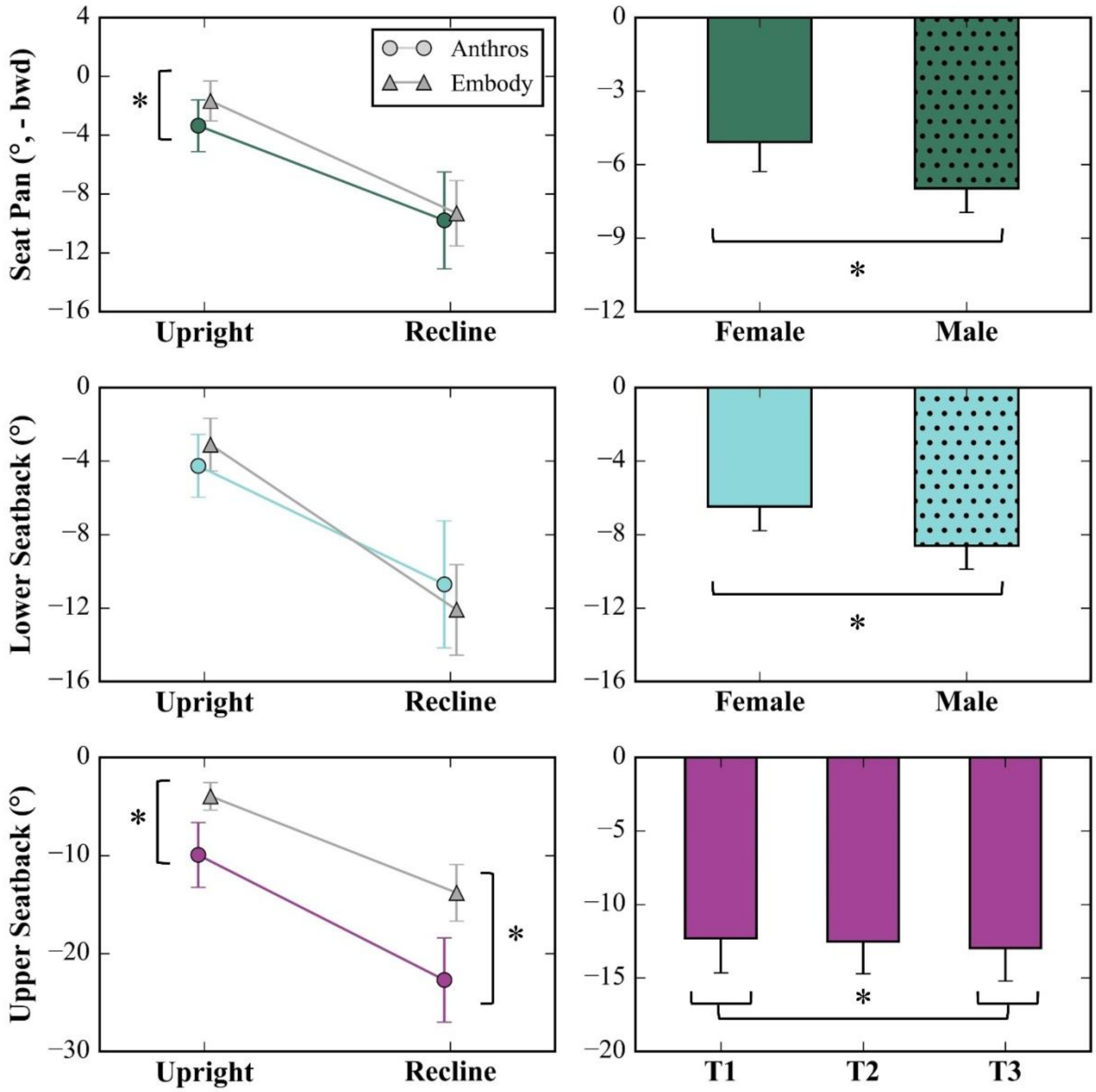

Figure 11: Mean (scatter, bar) standard deviation (error bars) for the forward-backward inclination of the seat pan (top row), lower seatback (middle row), and upper seatback (bottom row). Significant *chair * posture* interactions (left column) and main effects of *sex* or *trial* (right column) are displayed. The asterisks (*) indicate significant differences by *chair, sex,* or *trial*.

Kinematics during Prolonged Sitting

Pelvis and Lumbar Spine Postures

During the one hour of continuous sitting participants exhibited posterior pelvic tilt and lumbar spine flexion, which are both characteristic of seated computer work (Davidson et al., 2024; Davidson & Callaghan, 2025a; Dunk & Callaghan, 2005; Greene et al., 2019). There were no significant effects of *chair* or *sex* on static, median, and peak pelvis anterior-posterior tilt or lumbar spine flexion ($p \geq 0.051$; Figure 12). There were also no significant effects of *task* for pelvis anterior-posterior tilt or lumbar spine flexion ($p \geq 0.116$). Together, **the current findings indicate that average and peak pelvis and lumbar spine postures during one-hour of seated work were similar between Anthros and Embody.**

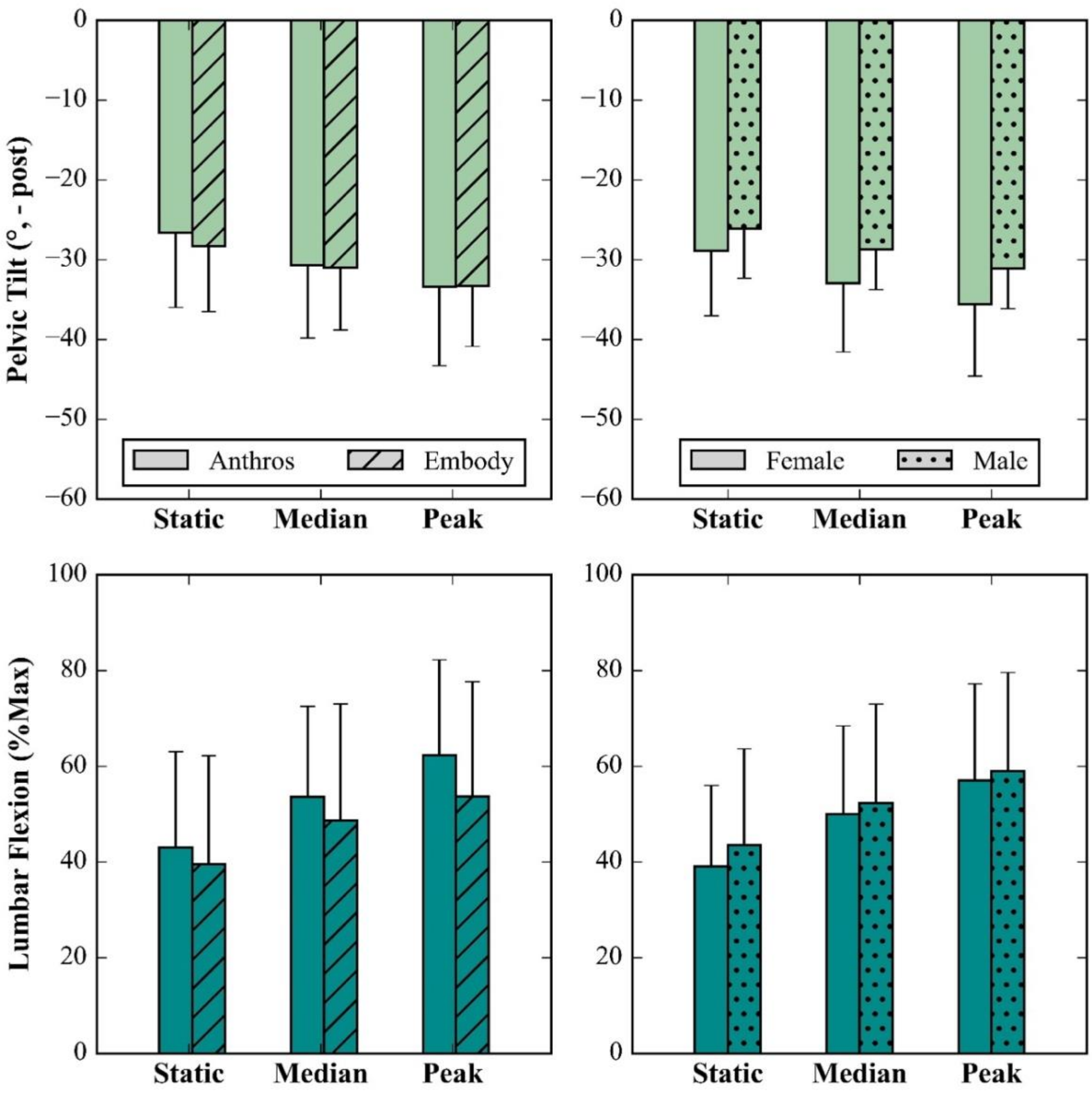

Figure 12: Mean (bar) and standard deviation (error bars) of static, median, and peak angles for pelvic anterior-posterior tilt by chair (top left) and sex (top right) and lumbar spine flexion-extension by chair (bottom left) and sex (bottom right).

Differences over time provide further insight into how individuals interact with and respond to the chair following initial set-up. A significant *chair * time * sex* interaction emerged for anterior-posterior pelvic tilt ($p = 0.027$). Throughout the first 15-minutes of sitting, pelvic tilt was not significantly different between Anthros and Embody or over time for both males and females (Figure 13). However, at the start of the sitting exposure, posterior pelvic tilt was an average 4.2° (female) and 1.6° (male) smaller in Anthros than Embody. **This is a positive finding for Anthros, as Anthros facilitated less posterior pelvic tilt in sitting than Embody.** Over time pelvis postures did not change for males when seated in Anthros or Embody, or for females when seated in Embody. However, females exhibited increases in posterior pelvic tilt over time when seated in Anthros (Figure 13). These increases in posterior pelvic tilt were up to an average 7.5°, with significant differences emerging at minute 20 (start of second block) compared to minute 1, 2, and 4, as well as between minute 15 (end of first block) and 35 (end of second block) ($p_{adj} \leq 0.039$; Figure 13).

When assessing pelvic tilt over one-hour of seated work, Anthros performed as well as Embody for male participants. However, female participants exhibited increases in posterior pelvic tilt over time when seated in Anthros. There are several possible reasons for the current findings. First, some research demonstrates that females tend to naturally adopt less posteriorly rotated pelvis postures than males and their spine postures are less impacted by a changes in chair (Dunk & Callaghan, 2005). Second, since females are smaller than males, the lower seatback support may not align as low on their pelvis, thus it may not engage the pelvis to the same extent as males who tend to have larger posterior pelvic rotation. Third, since females demonstrated larger differences in posterior pelvic tilt between the chairs at the start of prolonged sitting, females may have been less able to maintain this novel posture achieved in Anthros for a prolonged duration. Like any learned behaviour (i.e. a sitting posture ingrained over 20+ years in this sample) it is challenging to change without repetitive retraining. With repeated use, the ability to adjust the chair over time, and when combined with progressive introduction to these novel postures (i.e., accommodation training (Jackson et al., 2013)), individuals may have an easier time adopting and maintaining less posterior pelvic tilt and lumbar flexion in Anthros. **Anthros was able to control pelvis posterior rotation as a baseline posture, the ongoing challenge is to pattern this postural change, specifically in females, so it is maintained during prolonged work.**

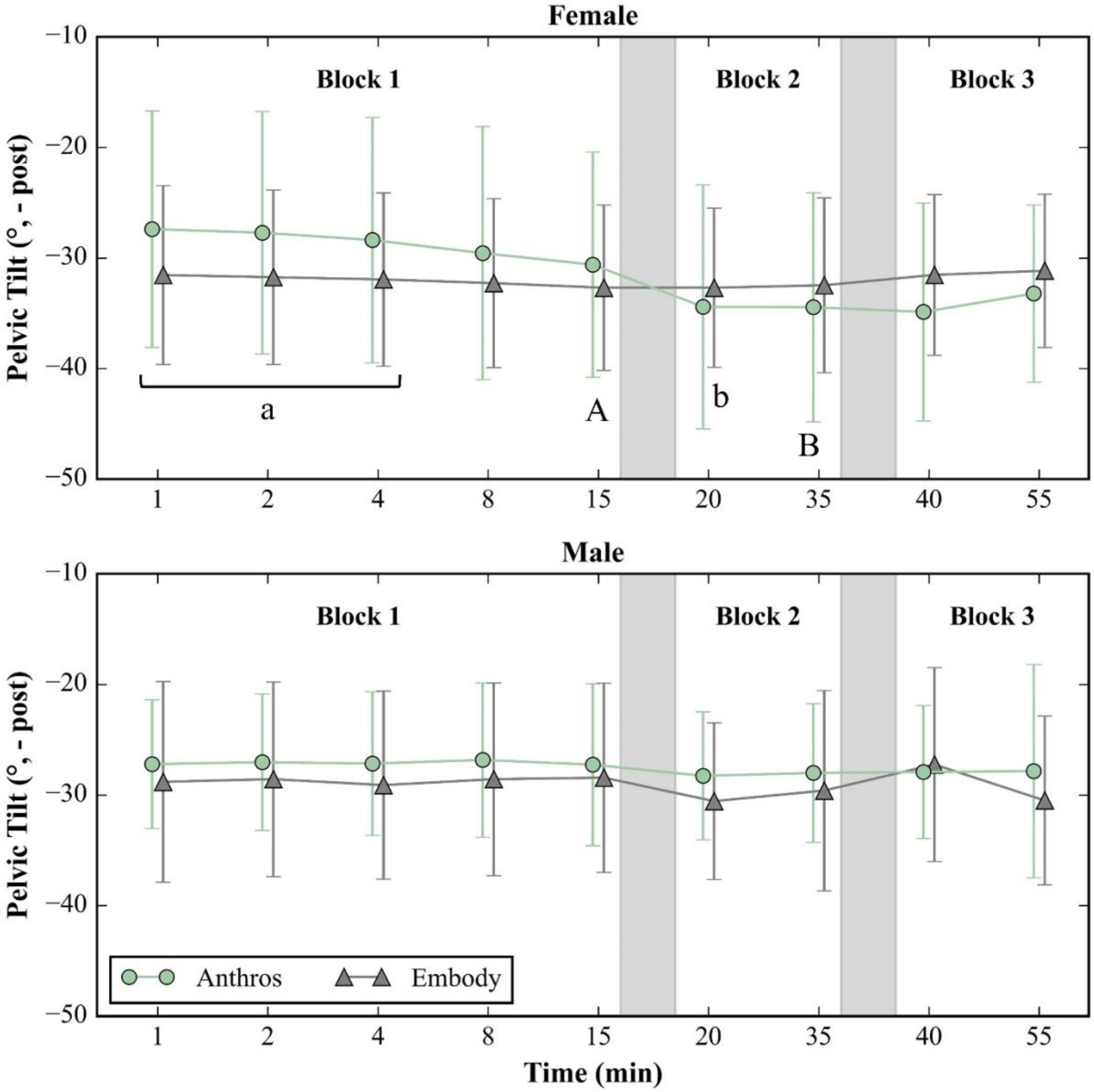

Figure 13: Mean (scatter) and standard deviation (error bars) in anterior-posterior pelvic tilt for the significant *sex * chair * time* interaction. *Chair * time* interaction plots are displayed for females (top) and males (bottom). Significant differences over time emerged for females seated in Anthros, with differences indicated by bars with different letters by case (i.e., a and b, and A and B).

Similar to the pelvis, a significant *chair * time* interaction emerged for lumbar spine flexion ($p = 0.025$). While lumbar spine flexion in Embody was not significantly different over time (on average changes within 5.8 %Max), lumbar spine flexion in Anthros modestly increased over time (Figure 14). Average increases up to 13.3 %Max occurred, with differences between chairs emerging at minute 40 (start of third block) and over time between minute 1 and 2 and minute 20 (start of second block; $p_{adj} \leq 0.033$; Figure 14). No significant effects of *sex* emerged ($p \geq 0.052$).

Collectively, the pelvic tilt and lumbar flexion angles were consistent within a block of seated work, with changes occurring following a seated break. **The increase in flexion following breaks suggests a step-like change in posture, rather than a gradual drift over time. This pattern indicates that the Anthros chair can provide effective spinal support during uninterrupted sitting; however, sustained posture maintenance over a full workday may require time to break the ingrained or existing seated postural habits.** First, encouraging users to make periodic adjustments, such as altering the seatback supports or reclining in the chair, could help restore spine postures. In the present study, participants were not reminded to change their posture or permitted to adjust the chair during the one-hour of sitting, which may have limited the opportunity to explore these benefits of the chair and correct postural accommodations over time. Second, accommodation training, for example through gradual introduction to the chair over time with non-seated breaks, may also facilitate the adoption and maintenance of novel seated postures.

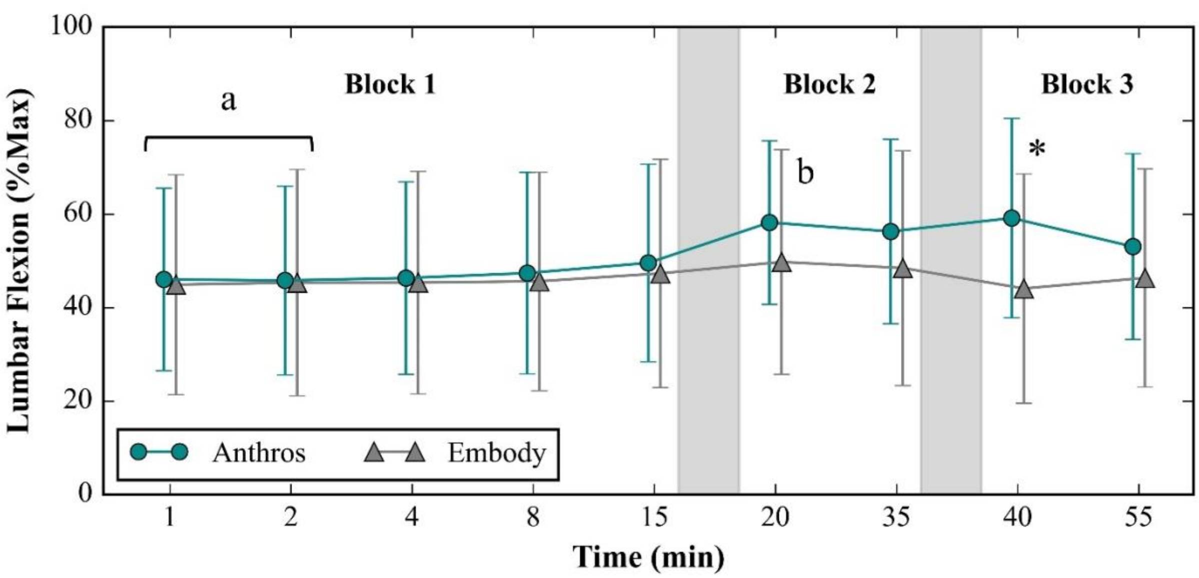

Figure 14: Mean (scatter) and standard deviation (error bars) in lumbar spine flexion-extension for the significant *chair * time* interaction. Significant differences over time emerged in Anthros, with differences indicated by bars with different letters. The asterisks (*) at minute 40 indicates a difference between chairs.

Thoracic and Cervical Spine Postures

A main effect of *chair* emerged for static, median, and peak thoracic spine flexion ($p \leq 0.031$). Throughout prolonged sitting, *participants demonstrated an average 3.9° to 5.6° less flexion of the thoracic spine when seated in Anthros compared to Embody* (Figure 15). Moreover, a significant *chair* * *task* interaction ($p = 0.028$) indicated that the differences between chairs were largest during reading comprehension ($p_{adj} < 0.001$; Figure 16). No significant effects of *sex* or *time* emerged ($p \geq 0.078$), indicating that the decreases in thoracic flexion in Anthros were consistent across males and females and throughout prolonged sitting (Figure 15). **Participants exhibited less thoracic flexion when seated in Anthros compared to Embody, indicating that Anthros promotes a more upright and supported upper back posture during sitting.**

There were no significant effects of *chair* on static, median, and peak cervical spine flexion ($p \geq 0.266$; Figure 15). **Participants adopted similar cervical spine postures when performing seated computer work in Anthros and Embody.** A main effect of *sex* emerged for cervical spine flexion across the statistical tests and indicated that males were more flexed than females ($p \leq 0.021$; Figure 15). A main effect of *task* for cervical spine flexion ($p < 0.001$) also indicated that reading comprehension (1.4 ± 7.2°) elicited less neck flexion than data entry (7.9 ± 6.8°) or typing (8.0 ± 8.0°), likely because reading comprehension did not require use of, and hence line-of-sight, on the keyboard (Figure 16). There were no significant effects of *time* on cervical spine flexion ($p \leq 0.098$).

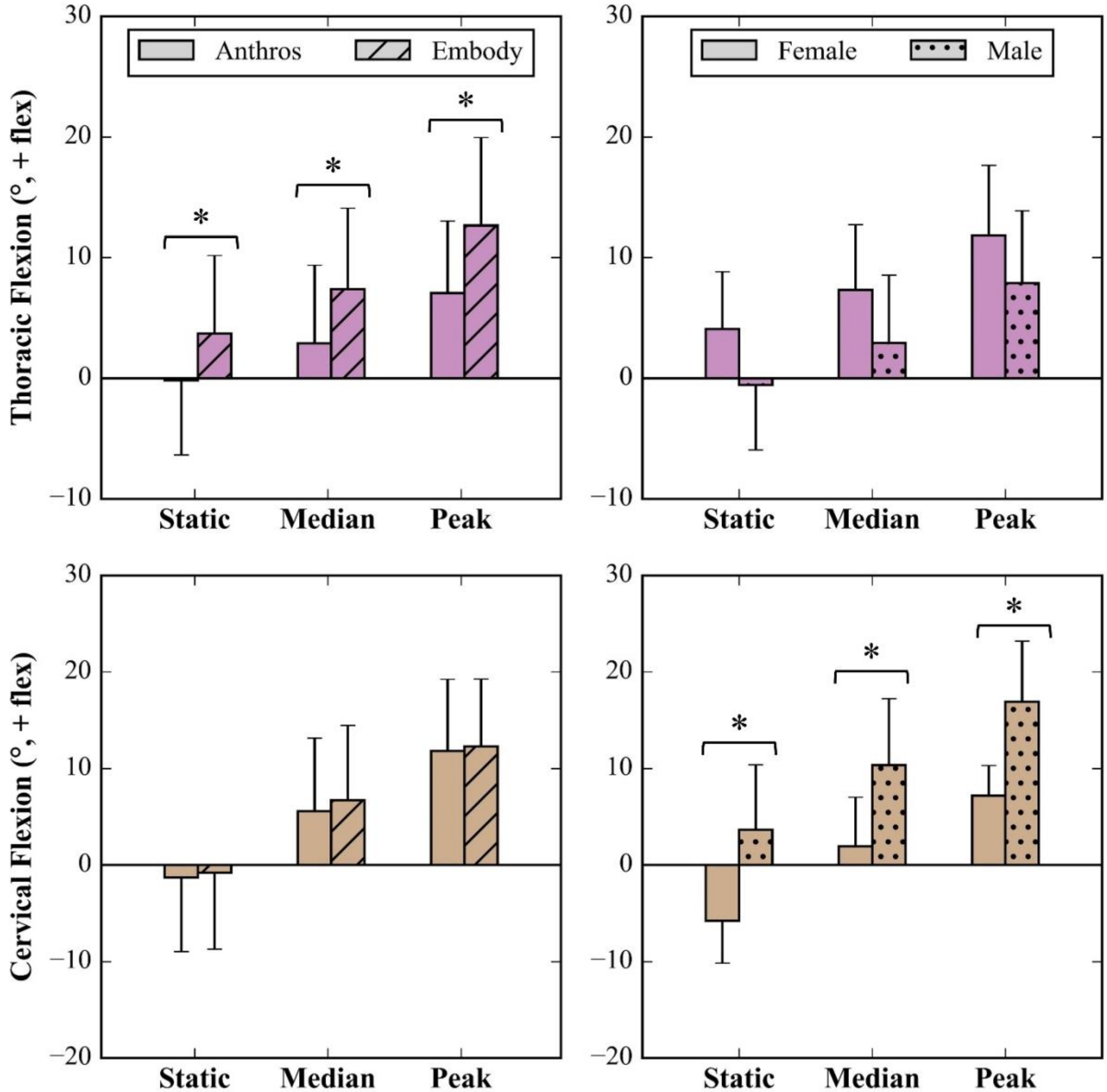

Figure 15: Mean (bar) and standard deviation (error bars) of static, median, and peak angles for thoracic spine flexion-extension by *chair* (top left) and *sex* (top right) and cervical spine flexion-extension by *chair* (bottom left) and *sex* (bottom right).

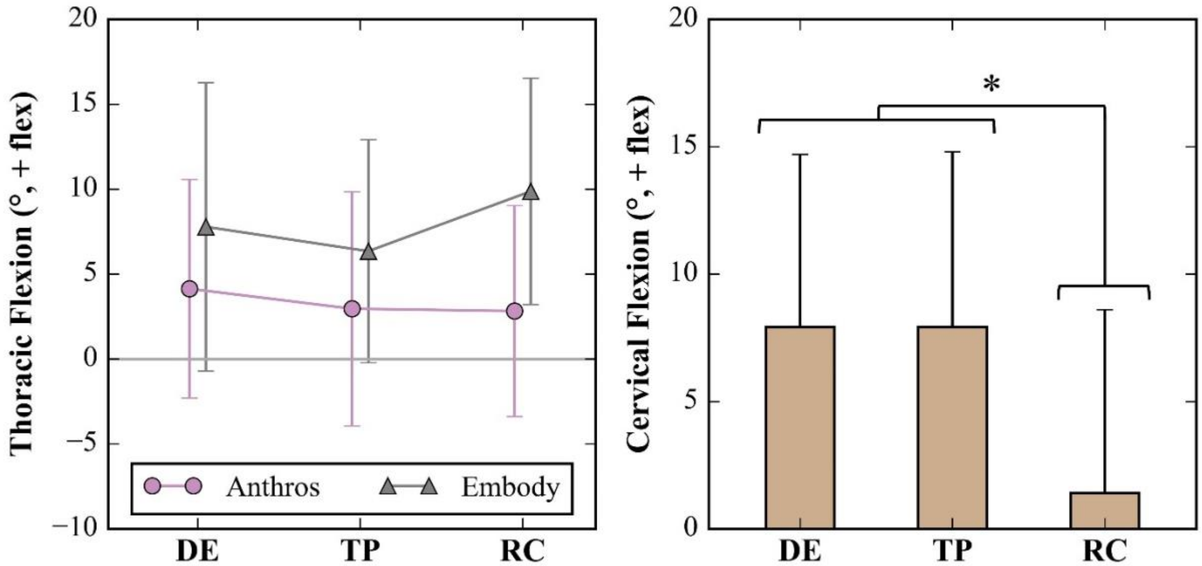

Figure 16: Mean (scatter, bar) and standard deviation (error bars) for thoracic (left) and cervical (right) spine flexion. For the *chair * task* interaction for thoracic flexion, flexion was always smaller in Anthros. For the main effect of *task* for cervical spine flexion, the asterisks (*) indicates significant differences by *task*.

Lumbar Spine Movements

Spine movements were quantified by shift and fidget frequency. The total number of shifts throughout prolonged sitting, assessed as shifts of at least 5°, tend to occur every 10 to 12 minutes (Davidson et al., 2024; Dunk & Callaghan, 2010), and thus some 15-minute blocks in both Anthros and Embody contained 0 shifts. There were no significant differences in the total number of shifts in Anthros (1.8 ± 3.1 shifts) or Embody (2.7 ± 3.4 shifts; $p = 0.321$). There were also no significant effects of *chair*, *time,* or *sex* on fidget frequency ($p \geq 0.295$; Figure 17). **Participants demonstrated similar frequency of spine movements in Anthros and Embody. While Anthros altered spine postures during prolonged sitting, particularly for the upper back, lumbar spine movements were not negatively impacted by these postural changes.** This is an encouraging finding as seated spine movement are beneficial for spine health and similar movements are occurring in the chairs, in similar or improved postures.

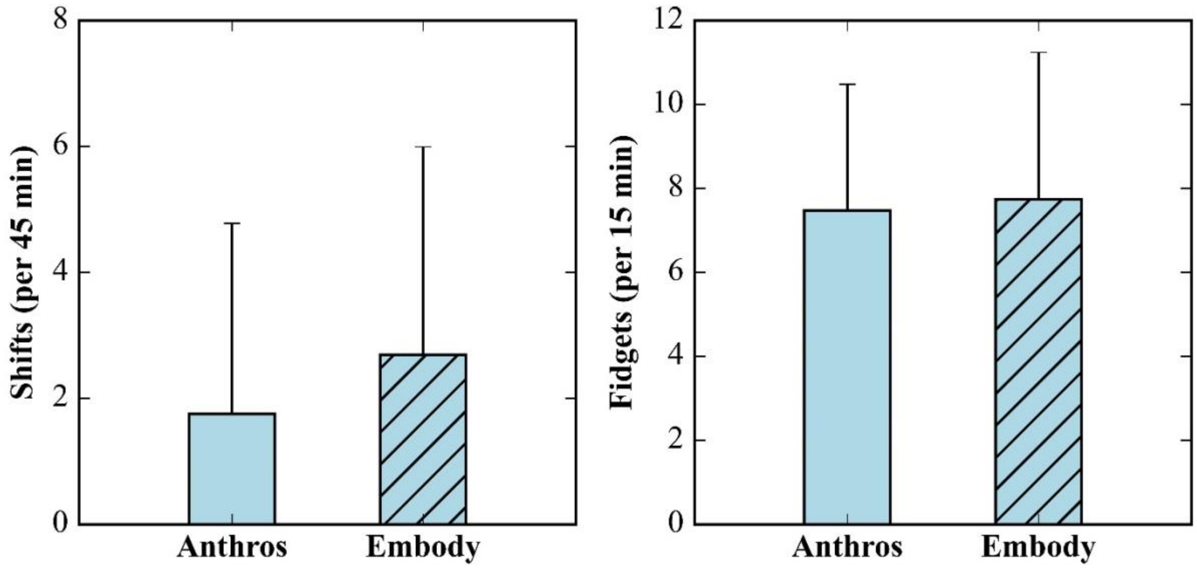

Figure 17: Mean (scatter) and standard deviation (error bars) in shift (left) and fidget (right) frequency.

Trunk-Thigh Postures

A significant *chair * sex* interaction emerged for the mean trunk-thigh angle ($p = 0.009$). While females demonstrated similar trunk-thigh angles in both Anthros and Embody, males demonstrated larger (more open) trunk-thigh angles in Anthros than Embody ($p_{adj} = 0.015$; Figure 18). Further, this resulted in males having significantly larger trunk-thigh angles than females in Anthros ($p_{adj} = 0.013$; Figure 18). **A more open trunk-thigh angle for males in Anthros aligns with them adopting more upright trunk postures when seated in Anthros compared to Embody**, as participants demonstrated less thoracic flexion in Anthros (Figure 15). There were no significant effects of *task* or *time* for the trunk-thigh angles ($p \geq 0.095$) as trunk-thigh postures were consistent throughout the sitting exposure (Anthros: static = 103.1°, peak = 111.3°; Embody: static = 102.0°, peak = 110.4°).

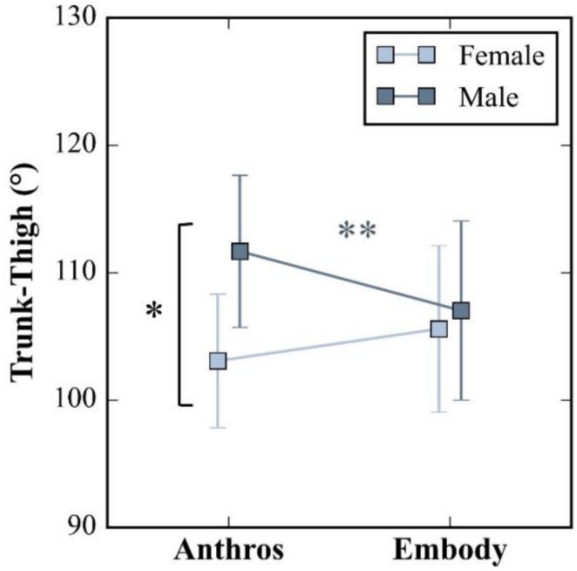

Figure 18: Mean (scatter) and standard deviation (error bars) of the trunk-thigh angle for the significant *chair * sex* interaction. The single black asterisk (*) indicates significant differences by *sex* in Anthros. The double grey asterisk (**) indicated a significant difference by *chair* for males.

Chair Tracking during Prolonged Sitting

The following results represent chair inclination relative to the initial set-up, wherein these findings are more indicative of how the participant interacts with the chair during prolonged seated work (e.g., magnitude of recline). **Inclination of the chair components were consistent throughout the sitting exposures in both Anthros and Embody.** On Anthros, average static and peak angles remained within 2° of inclination for the seat pan and lower seatback and within 4° of inclination for the upper seatback (Figure 19). There were no significant effects of *task* or *time* for any of the chair components ($p \geq 0.073$).

There was a *chair * sex* interaction for the seat pan inclination ($p = 0.006$). Seat pan inclination was consistent between Anthros and Embody for females, but males reclined the seat pan more in Anthros than Embody ($p_{adj} < 0.001$). Likewise, **when seated in Anthros, the seat pan was more reclined for males than females** ($p_{adj} = 0.002$) but recline was not significantly different between the sexes in Embody (Figure 19). **As noted earlier for short-duration upright and reclined sitting, females also tended to experience a challenge reclining in the Anthros during prolonged sitting periods.**

It is also worth considering how these differences in seat pan inclination relate to pelvic tilt (Figure 12 andFigure 13). When accounting for baseline differences between chairs, where the seat pan of Anthros was rotated an average 2.0° more forward than Embody (Figure 9), during prolonged sitting the seat pan of Anthros was an average 2.0° more posteriorly rotated than Embody for males and 2.0° more anteriorly rotated than Embody for females. Females also tended to exhibit less posterior pelvic tilt in Anthros than Embody at the start of sitting (up to an average 4.2°; Figure 13), and this may be partially related to the more anteriorly rotated seat pan in Anthros where Anthros may have facilitated more perched postures for females. Alternatively, for males, the seat pan of Anthros was more posteriorly rotated, but they still exhibited small decreases in posterior pelvic tilt in Anthros compared to Embody (up to an average 2.6°; Figure 13). *For males, the Anthros lower seatback support may more effectively engage the pelvis to control posterior rotation due to the chair's posterior pelvis support angle (Figure 9) and the more posteriorly rotated male pelvis in sitting. In other words, the angle of the support may align better with the male pelvis angle while females, who naturally tend to sit with less posterior pelvis rotation (Beach et al., 2005; Dunk & Callaghan, 2005; Gregory et al., 2006) may benefit from a more aggressive angle of the pelvis support (i.e. reducing the ~20° pelvis support angle).*

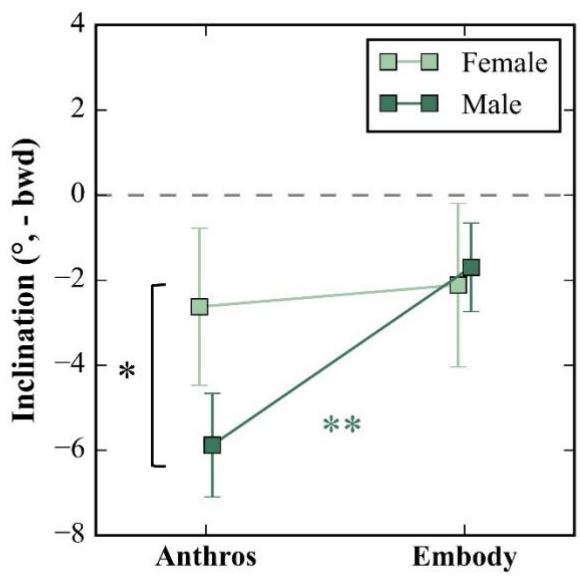

Figure 19: Mean (scatter) and standard deviation (error bar) for the seat pan *chair * sex* interaction. The single black asterisk (*) indicates significant differences by *sex* in Anthros. The double green asterisk (**) indicated a significant difference by *chair* for males.

There were main effects of *chair* for lower and upper seatback inclination ($p \leq 0.011$). **Both components of the seatback were more reclined in Anthros** (Figure 20)**. Reclining, and thus an increased tendency to use the seatback, is an encouraging finding.** Reclining on the seatback enables off loading of muscular components (Corlett & Eklund, 1984) and has been identified as a potential strategy to mitigate pain development in sitting (Davidson & Callaghan, 2025b). There was also a main effect of *sex* for lower seatback inclination ($p = 0.017$). The lower seatback was more reclined for males than females in both chairs (Figure 20). This supports that males reclined more than females in both chairs.

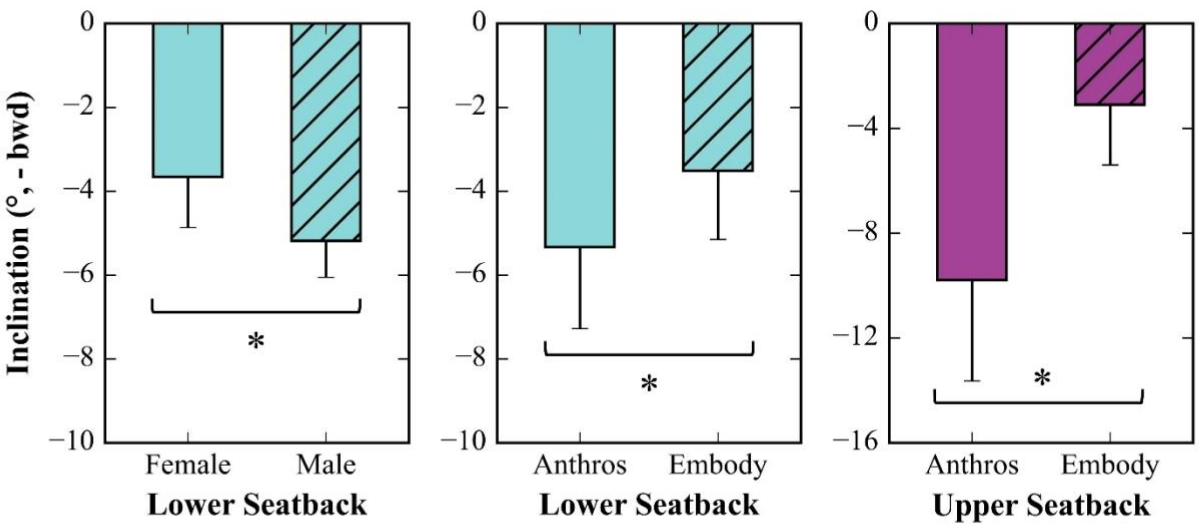

Figure 20: Mean (scatter) and standard deviation (error bar) for the lower and upper seatback in Anthros and Embody. There was a main effect of *sex* for the lower seatback (left) and a main effect of *chair* for the lower (middle) and upper (right) seatback.

Pain Responses

There were no significant effects of *chair* or *sex* on pain in any body region ($p \geq 0.066$; Figure 21). Further, pain ratings were compared to clinically relevant thresholds for transient pain development in prolonged sedentary postures (i.e., 8 mm threshold) (Hägg et al., 2003).

For the lower back in Anthros, 4 participants reported pain (2 to 4 mm), but no rating exceeded the 8 mm threshold. In Embody, 3 participants reported pain (1 to 13 mm), wherein 8 mm was exceeded by 1 participant.

For the upper back in both Anthros (1 to 15 mm) and Embody (2 to 12 mm), 5 participants reported pain. **The 8 mm threshold for transient pain development was exceeded for 2 participants in Anthros (at 40 or 60 minutes) and one of these participants also reported pain above 8 mm while seated in Embody (at 20 and 40 minutes).** When considering that participants adopted more upright postures of the thoracic spine in Anthros, thereby suggesting a change in their habitual seated behaviour, it is not surprising that some participants would report pain in this body region as initial exposures to novel sitting postures can lead to transient pain for some individuals (Jackson et al., 2013). **However, Anthros facilitated decreases in thoracic spine flexion compared to Embody, without resulting in any significant differences in reported upper back pain.**

Pain ratings for the buttocks and thighs remained low in both chairs. One participant reported buttocks pain in Anthros (2 mm) and 2 participants reported buttocks pain in Embody (2 to 8 mm), however all reported values remained below a meaningful change in pain levels. No participants reported thigh pain in either chair.

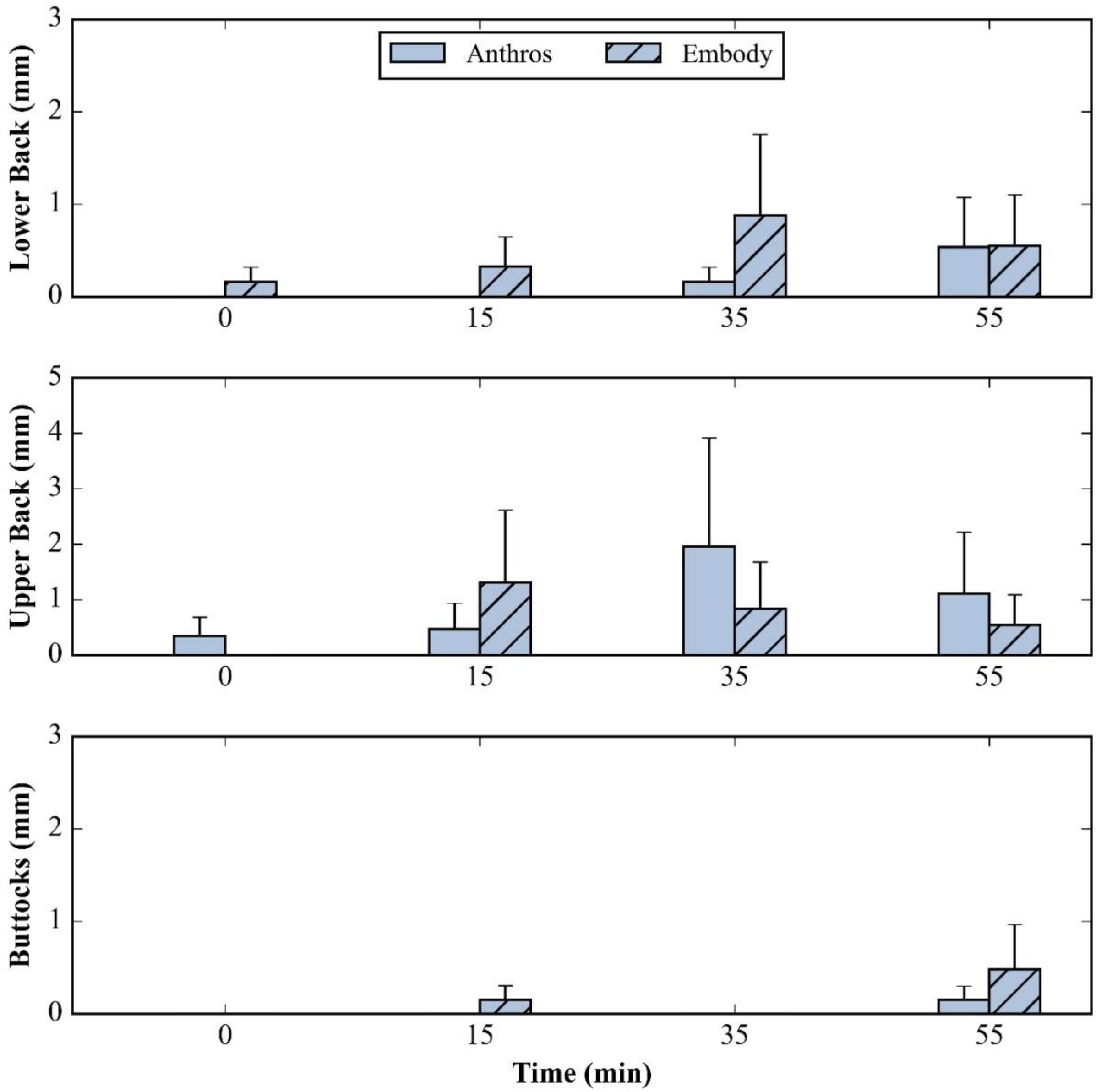

Figure 21: Mean (bar) and standard deviation (error bar) of lower back (top), upper back (middle), and buttocks (bottom) pain throughout one-hour of sitting in Anthros and Embody.

Seat Pan Pressure

Pressure Magnitude

For peak seat pan pressure, there were significant main effects of *chair* and *posture* ($p < 0.001$). **Peak pressure was an average 36 mmHg lower in Anthros than Embody**. As expected, with a change in posture, peak pressure was an average 15 mmHg higher during the upright compared to reclined sitting (Figure 22). There were no significant effects of *time* or *sex* on peak pressure ($p \geq 0.086$).

For seat pan contact area, there were significant interactions for *chair * posture* and *chair * time* ($p \leq 0.025$). **Contact area was always larger in Embody than Anthros** ($p_{adj} < 0.001$; Figure 22), **even though peak pressure was lower in Anthros**. No significant pairwise differences emerged by posture ($p_{adj} \geq 0.096$), indicating that contact area was not different between upright and reclined sitting (Figure 22). Contact area may have been lower in Anthros due to the shape of the seat pan or participant positioning on the seat pan. Where Embody provides users with a large planar seat pan, Anthros has concave sides and a waterfall front edge which may lead to decreased contact area. Participants appear to have also sat further forward in Anthros than Embody (Figure 24), potentially in response to the novel tactile feedback provided by the pelvis support. Moreover, in Anthros only, contact area increased following prolonged sitting ($p_{adj} < 0.001$; Figure 22). Changes in contact area following sitting may be indicative of time-dependent changes in the seat pan foam over time or changes in participant-chair interactions, for example moving forward on the chair. Since the location of the center or pressure and peak pressure were consistent over time, it is more likely that the increases in contact area following prolonged sitting on Anthros were due to foam deformation. Nevertheless, these changes in seat pan contact area in Anthros over time did not negatively impact pressure distribution or pain responses. There were no significant effects of *sex* for contact area ($p \geq 0.104$).

For total seat pan pressure, there was a significant *chair * posture * sex* interaction ($p = 0.041$). **Total pressure was always smaller on Anthros than Embody** ($p_{adj} \leq 0.016$; Figure 22). This is not surprising given the observed decreases in peak pressure and contact area when seated on Anthros. Moreover, total pressure remained consistent between postures for males in both chairs and females in Embody, but total pressure decreased for females when reclined in Anthros ($p_{adj} < 0.001$; Figure 22). **Decreased total seat pan pressure for females likely resulted because some females had difficulty reclining in Anthros. When attempting to recline, females exerted force on the upper seatback and through their feet, thereby offloading the seat pan.** Likewise, although total pressure was consistently larger for males than females, significant differences between sexes only occurred when reclined in Anthros ($p_{adj} = 0.029$; Figure 22). There were no significant effects of *time* on total pressure ($p > 0.096$).

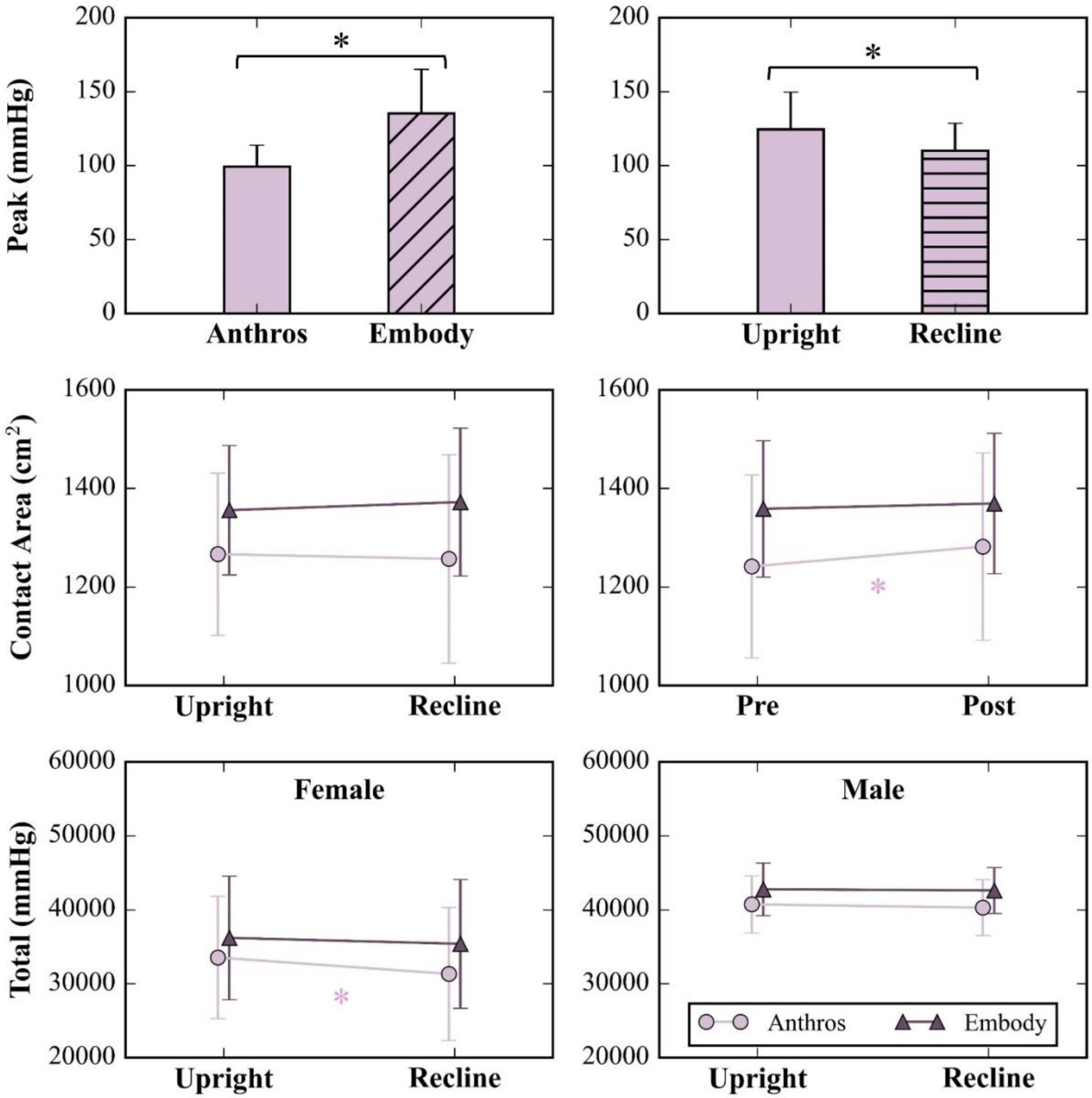

Figure 22: Statistical results for variables of seat pan pressure magnitude. Mean (bar) and standard deviation (error bars) for the peak pressure by *chair* (top left) and *posture* (top right), where the black asterisks indicate significant differences between *chairs* and *postures*. Mean (scatter) and standard deviation (error bars) for contact area for the significant *chair * posture* (middle left) and *chair * time* interaction (middle right). Mean (scatter) and standard deviation (error bars) for total pressure for the significant *chair * posture * sex* interaction. *Chair * posture* interaction plots are displayed for females (bottom left) and males (bottom right). The purple asterisks indicate a significant difference by *posture* or *time* for Anthros only.

Pressure Spatial Distribution

For the dispersion index under the ischial tuberosities, there was a significant *chair * sex* interaction and a main effect of *posture* ($p \leq 0.042$). **For male participants, the dispersion index was significantly lower in Anthros than Embody** ($p_{adj} < 0.001$; Figure 23). There were no significant differences in the dispersion index between the two chairs for females, but overall, the dispersion index was 0.2% lower in Anthros than Embody. The dispersion index was also 0.2% lower in recline compared to upright sitting (Figure 23). **A lower dispersion index on Anthros, particularly for male participants, indicates that there was better pressure redistribution away from ischial tuberosities in Anthros compared to Embody. In Anthros, seat pan pressure is more evenly distributed throughout the cushion.**

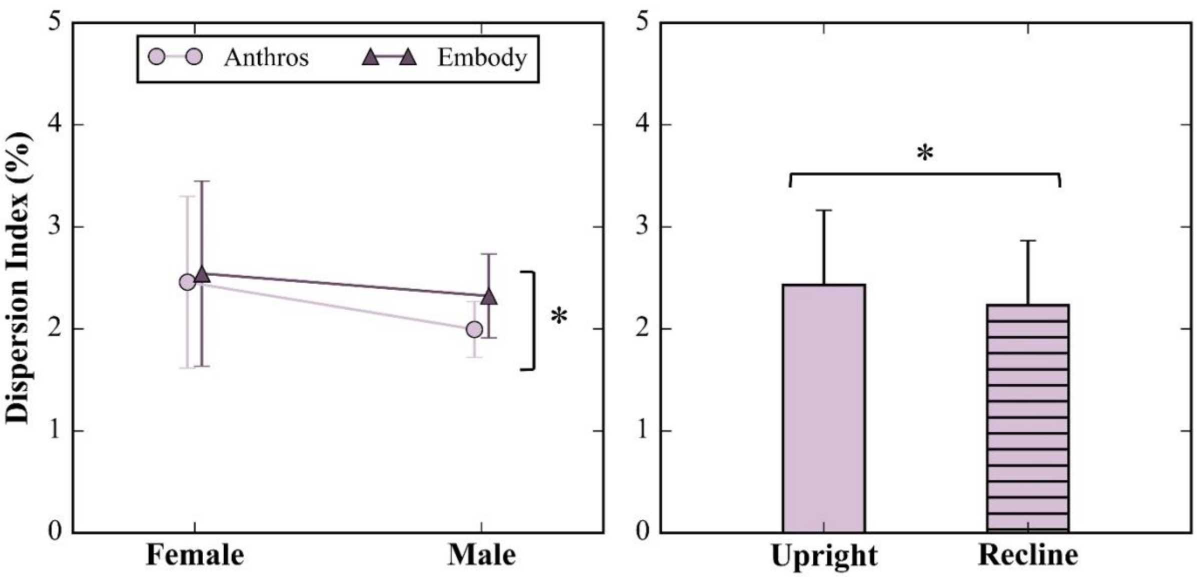

Figure 23: Mean (scatter, bar) and standard deviation (error bars) of the dispersion index for the significant *chair * sex* interaction (left) and by *posture.* The asterisks (*) indicates a significant difference between *chairs* and *postures*.

For CoP horizontal distance from the front edge of the seat pan, there were significant interactions for *chair * sex*, *chair * posture*, and *time * posture* ($p \leq 0.037$). The CoP was always closer to the front edge of the seat pan in Anthros compared to Embody ($p_{adj} < 0.001$; Figure 24). When comparing sexes in each chair, males had the CoP positioned closer to the front edge of Anthros than females whereas females had the CoP positioned closer to the front edge of Embody than males ($p_{adj} < 0.001$; Figure 24). *This sex interaction could imply differences in* *forward-backward positioning on the chair, where females sat deeper in the seat pan to engage with the Anthros seatback components for support. While the pressure measures are only pre-post 1 hour seated exposure, the reduction in pelvis posterior rotation seen at the initiation of sitting and through block 1 (Figure 13) would support this hypothesis*. Further, the CoP was closer to the front edge of the seat pan in the reclined compared to the upright posture, with slightly larger forward movement in Anthros compared to Embody ($p_{adj} < 0.001$; Figure 24). Forward movement of the CoP was likely due to offloading seat pan pressure, particularly under the ischial tuberosities, onto the seatback. The *time * posture* interaction confirmed that CoP was closer to the front edge of the seat pan in upright posture, but no pairwise differences emerged over time ($p_{adj} \geq 0.076$; Figure 24). Since the CoP tended to move forward during reclined sitting, a more forward CoP in Anthros could also have occurred because males tended to recline more during the 1-hour blocks than females in Anthros (Figure 19).

For the horizontal distance from the location of peak pressure to the front edge of the seat pan, there were main effects of *chair* and *posture* ($p \leq 0.001$). The location of the peak pressure was 3.4 cm closer to front edge of Anthros compared to Embody and 1.7 cm closer to the front edge in recline compared to upright sitting (Figure 24). There were no significant effects of *sex* or *time* ($p \geq 0.135$).

Overall, the location of the CoP and peak pressure were closer to front edge of the seat pan in Anthros. This may have occurred because participants sat further forward in the seat pan and/or in more upright trunk postures (i.e., more perched sitting posture). This is most likely attributable to the Anthros approach of "bringing the chair to the user", where the user was positioned on the seat pan and the posterior seatback components were adjusted to support the user at the seat pan location. This forward positioning of the seatback pelvic support in Anthros would support participants sitting closer to the front edge of the seat pan to provide space between the calves and front edge of the seat pan. While seat pan pressure was concentrated over a smaller contact area (Figure 22), the current results indicate that Anthros had lower peak pressures and no increases in pain (Figure 21; Figure 23). Additionally, in the context of these pressure differences, the postural responses in Anthros support that participants adopted more upright trunk postures. Notably, participants exhibited less posterior pelvic tilt, particularly at the start of the sitting, and less thoracic spine flexion.

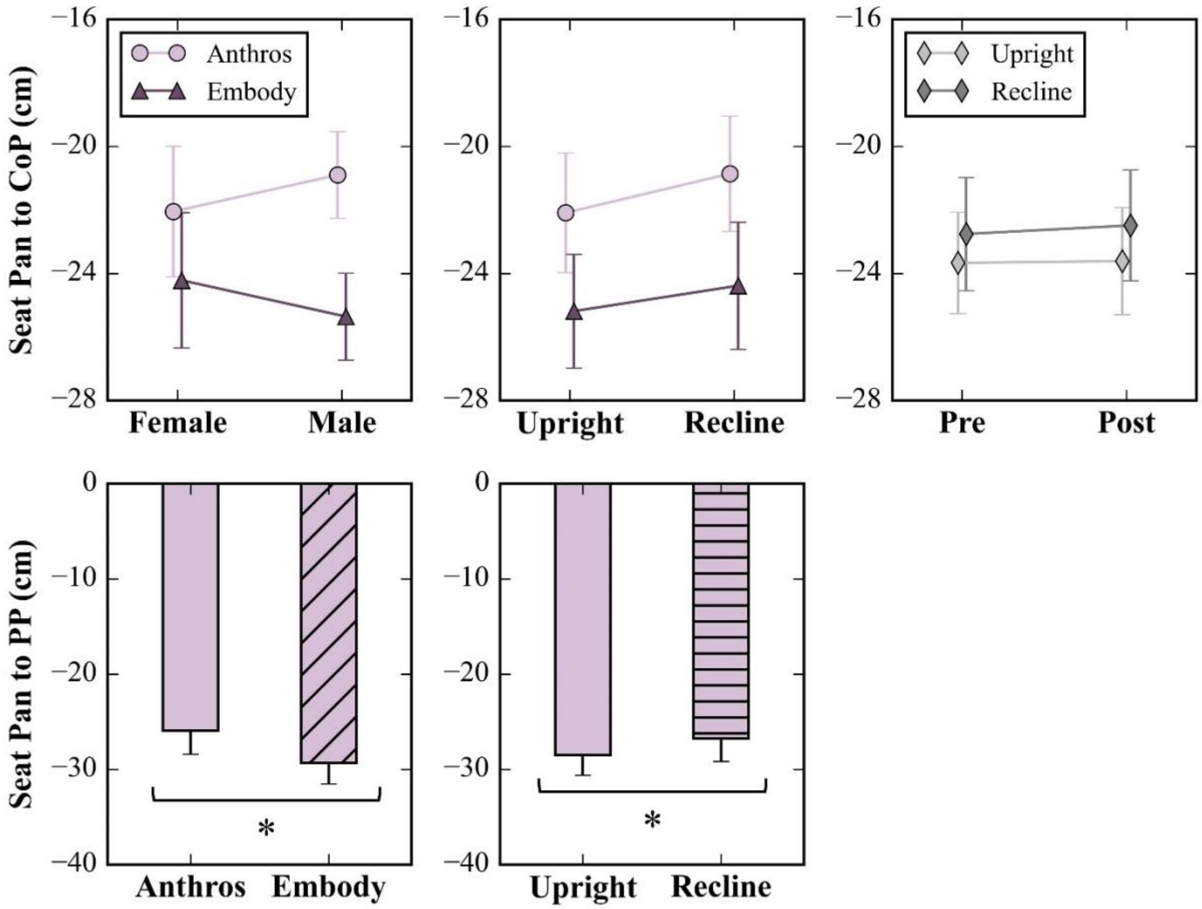

Figure 24: Statistical results for variables of seat pan centre of pressure (CoP) and peak pressure (PP) horizontal distance to the front edge of the seat pan. Mean (scatter) and standard deviation (error bars) of the centre of pressure for the significant *sex * chair* (top left), *chair * posture* (top middle), and *posture * time* interaction (top right). Mean (bar) and standard deviation (error bars) of the peak pressure by *chair* (bottom left) and *posture* (bottom middle). The asterisks (*) indicates a significant main effect of *chair* and *posture*.

For CoP horizontal distance from the hips, there were significant *chair * posture* and *posture * sex* interactions ($p \leq 0.044$). **The CoP was just in front of the hips on both chairs, but on it was further forward on Anthros than Embody in both postures** ($p_{adj} \leq 0.039$; Figure 25). Unlike expressing pressure localization relative to the seat pan, pressure localization relative to the hips eliminates any confounding from forward-backward positioning on the chair. **The current results further support that the more anterior pressure localization in Anthros is partially the result of a more perched posture, due to pelvis posture and reduced thoracic flexion.** The position of the CoP relative to the hips was not different between upright and recline in Embody or for females, but the CoP was more in front of the hips during reclined compared to upright in Anthros and for males ($p_{adj} < 0.001$; Figure 25).

For the horizontal distance from location of peak pressure to the hips, there was a significant *chair * posture* interaction. The location of peak pressure was about 3 cm behind the hips in both chairs during upright, which aligns with the location of the ischial tuberosities (Figure 25)**.** During recline, the location of peak pressure moved forward in Anthros but not Embody ($p_{adj} = 0.0005$) such that the location of peak pressure was further forward in Anthros than Embody during recline only ($p_{adj} = 0.013$; Figure 25).

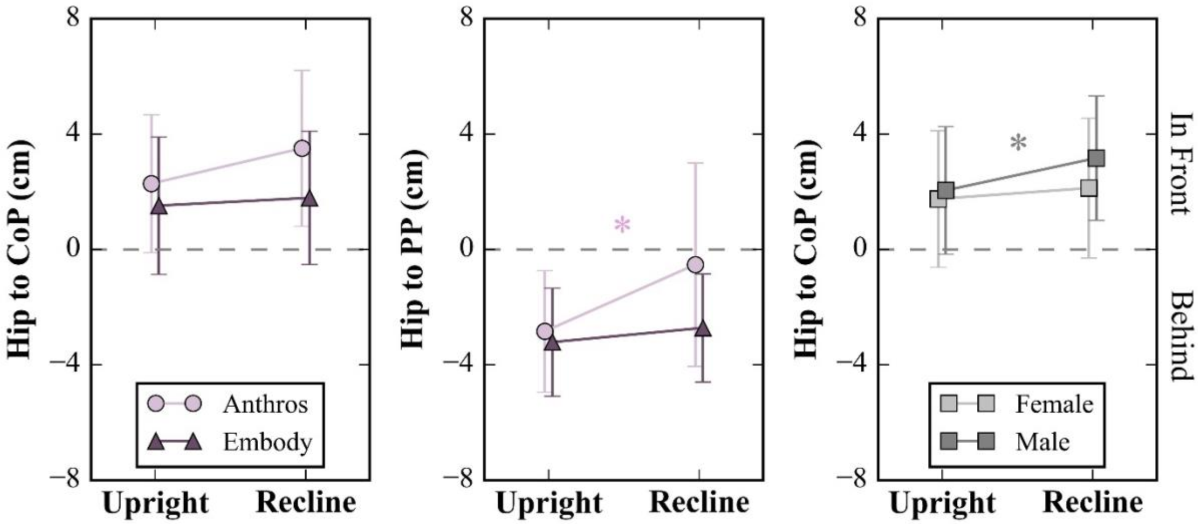

Figure 25: Statistical results for variables of seat pan centre of pressure (CoP) and peak pressure (PP) horizontal distance to the hips. Mean (scatter) and standard deviation (error bars) of the centre of pressure for the significant interactions of *chair * posture* (middle), *sex * posture* (right), and the peak pressure for the significant interaction of *chair * posture* (middle). The coloured asterisks (*) indicates a significant difference between *postures* for Anthros and males.

Seatback Distance

In both Anthros and Embody, T8 and T12 were in contact (<1 cm) with the seatback (Figure 26)**.** There were no significant effects of *chair* for C7, wherein C7 was typically above and in front of the upper seatback of both Anthros and Embody (Figure 26). There was a main effect of *chair* on the horizontal distance between T4 and the seatback ($p = 0.022$). While this significant effect indicated that T4 was 0.5 cm closer for Embody than Anthros, for both chairs, **T4 was within 2 cm of the seatback, indicating that participants were largely in contact**

with the seatback (Figure 26)**. Collectively, this analysis further confirm that Anthros supports the upper back in seated computer work.**

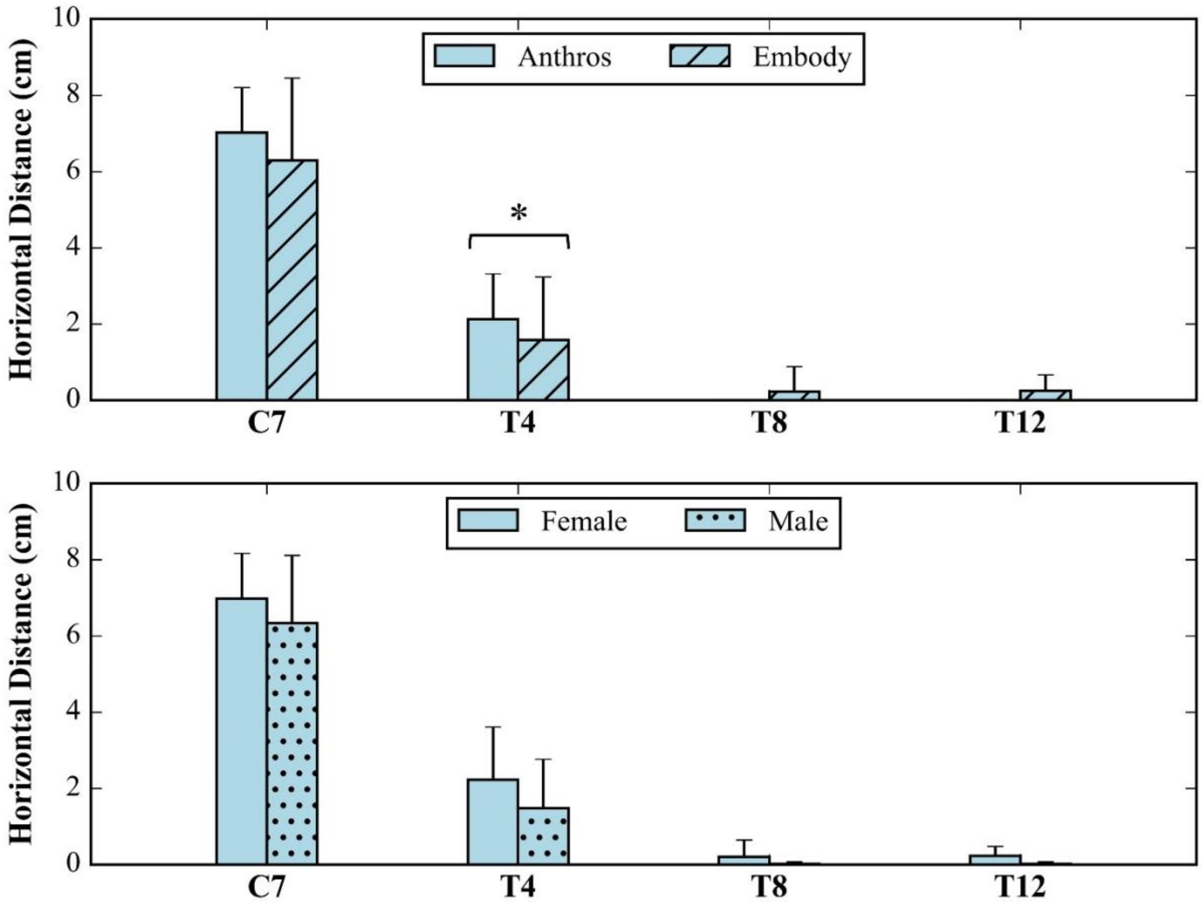

Figure 26: Mean (bar) and standard deviation (error bars) for the horizontal distance from the seatback to each spine landmark by chair (top) and sex (bottom).

Productivity

There were no significant effects of *chair* or *sex* on measures of productivity, including those for data entry (accuracy and speed), typing (accuracy and speed), and reading comprehension (score; $p \geq 0.177$; Figure 27). **The current findings indicate that introducing changes in posture while using Anthros had no negative impacts on productivity over short bouts of standardized computer work.**

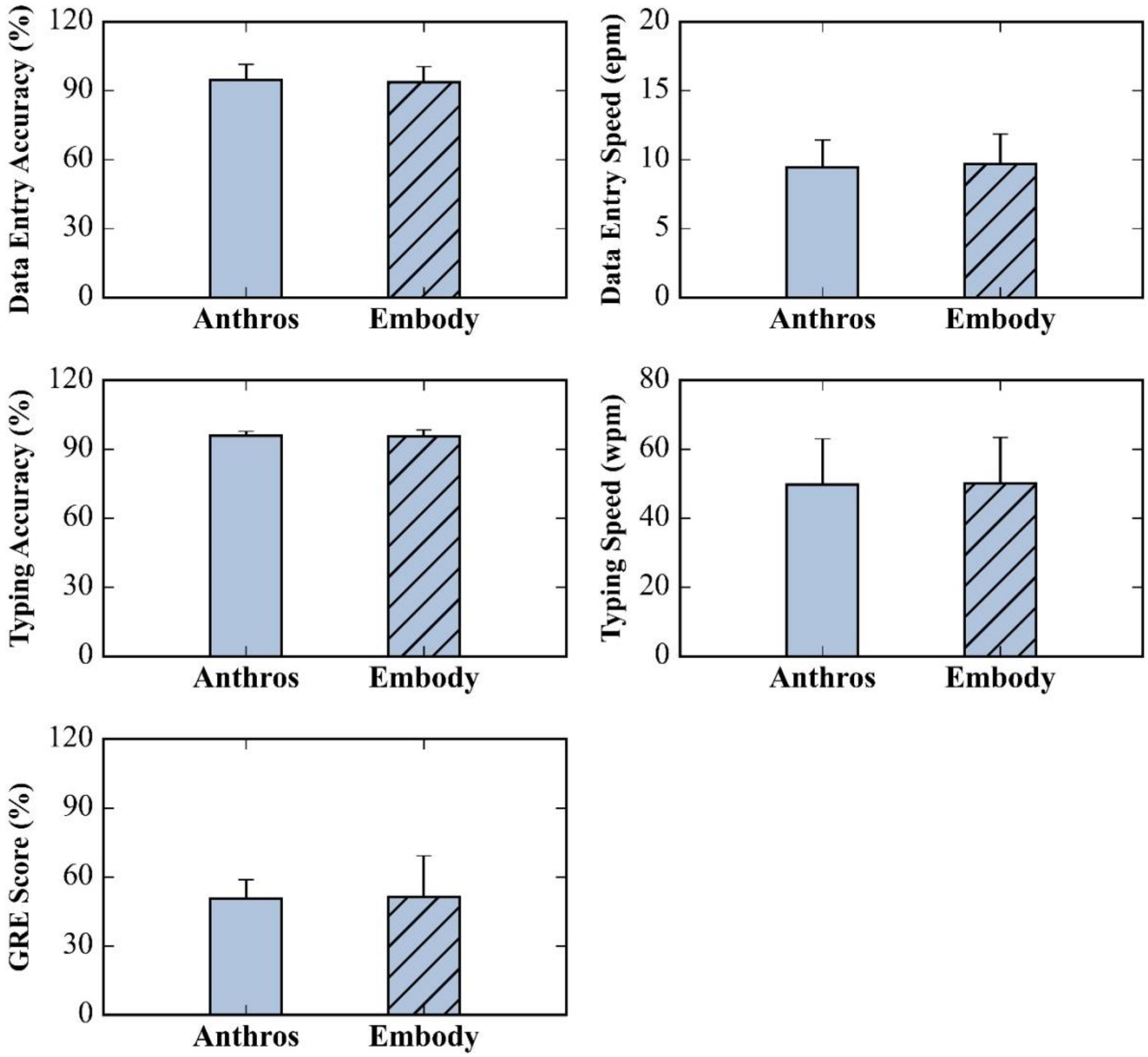

Figure 27: Mean (bar) and standard deviation (error bars) for the measures of productivity including data entry accuracy (top left) and speed (top right), typing accuracy (middle left) and speed (middle right), and reading comprehension (GRE) score (bottom left).

CONCLUSIONS

Seated behaviours of male and female participants were characterized during one-hour of seated computer work performed in the Anthros and the Herman Millar Embody chairs. Additionally, seat pan pressure measurements were performed at initiation and following prolonged sitting in each chair.

In both chairs, participants exhibited flexion of the cervical, thoracic, and lumbar spine and posterior pelvic tilt with select notable differences emerging by chair, sex, and over time. The Anthros pelvic support controlled the amount of pelvic posterior tilt at the start of sitting with reductions of 2° for males and 4° for females compared to Embody. Static, median, and peak posterior pelvic tilt and lumbar spine flexion were consistent between the chairs. Over time there was a tendency for females to exhibit increases (8°) in posterior pelvic tilt while using Anthros and while lumbar spine flexion increased over time in both chairs, the changes were larger in Anthros (13 %Max) than Embody (6 %Max). However, these changes were most pronounced after a seated break rather than during uninterrupted seated work. Throughout prolonged sitting, participants exhibited less (4° to 6°) thoracic flexion in Anthros than Embody. Cervical spine extension and lumbar spine movement behaviours, characterized by shifts and fidgets, were consistent between chairs.

There were a number of differences in the position of the chair components, including the seat pan, lower seatback, and upper seatback, both in chair set-up and in how the participants interacted with the chairs. Compared to Embody, Anthros provided users with a more open angle between the seat pan and lower seatback support as the seat pan was more anteriorly rotated and the lower seatback was more posteriorly rotated. During prolonged sitting, males tended to recline more in Anthros than females did. The upper seatback was also more posteriorly rotated in Anthros compared to Embody at set-up and during prolonged sitting and this likely contributed to the decreases in thoracic spine flexion compared to Embody.

Pain ratings remained low throughout prolonged sitting in both chairs. Four participants reported lower back pain in Anthros, but all ratings remained below clinically relevant thresholds for transient pain development in prolonged sedentary postures (i.e., 8 mm). Two participants reported upper back pain in Anthros that exceeded 8 mm, but one of these participants also had similar pain ratings in Embody. Buttocks and thigh pain remained low in both chairs.

Across seat pan pressure measurements, Anthros tended to demonstrate lower or equivalent pressure magnitudes and pressure distributions compared to Embody. In upright and reclined sitting, peak and total pressure were significantly smaller on Anthros. Contact area was also smaller on Anthros, which may be due to the differences in seat pan shape or how the participants were positioned on the Anthros seat pan. The dispersion index under the ischial tuberosities was also lower on Anthros, particularly for male participants, indicating pressure redistribution away from the ischial tuberosities in Anthros compared to Embody. The location of the centre of pressure and peak pressure relative to the front edge of the seat pan and the hips were more forward in Anthros than Embody. This finding may signify a tendency for participants to recline more, sit further forward, or perch in Anthros. However, the data on the distance between the seatback and the spinous processes (T1-12) confirms that Anthros supported the upper trunk in seated computer work.

Overall, the Anthros chair demonstrated comparable or enhanced sitting kinematics and seat pan pressure characteristics, without any negative impacts on pain levels or work productivity, relative to the Embody chair.

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