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Design Process and Performance Testing of a Dynamic Seat Cushion

By Sirinant Channak, Erwin M. Speklé, Allard J. van der Beek, Sonja N. Paus-Buzink, & Prawit Janwantanakul

FEATURE AT A GLANCE:
Dynamic sitting aids, like air-filled cushions, encourage postural shifts and activate trunk muscles, potentially mitigating musculoskeletal discomfort and preventing the onset of low back pain. However, evidence on optimal design and pressure is lacking. This project addresses these gaps by developing a portable cushion to reduce discomfort in high-risk office workers. A systematic, four-phase iterative approach optimized the cushion's diameter, construction, and air fill. The resulting round cushion, with two layers of chambers at 21–25 kPa, promotes postural shifts and trunk muscle activation while maintaining comfort. Future research should evaluate its application and sustained benefits in diverse office environments.

KEYWORDS:
dynamic sitting, postural shift, discomfort, prolonged sitting, muscle activation, low back pain

INTRODUCTION

Low back pain (LBP) is a common health problem and a significant global contributor to years lived with disability (Wu et al., 2020). Work-related LBP is highly prevalent, with a point prevalence of 60% (Bin Ahmed et al., 2023). Office work is predominantly sedentary, characterized by prolonged periods of sitting for tasks such as computer use, attending meetings, giving presentations, reading, and making phone calls (IJmker et al., 2006). Among healthy office workers, the 1-year incidence rate of LBP is 20% (Sihawong et al., 2014), and up to 27% of those with new-onset LBP progressed to chronic LBP (Sihawong et al., 2016). After recovering from LBP, 69% of the patients in a cohort study experienced recurrence within 1 year (da Silva et al., 2019). Therefore, effective interventions should be developed to reduce LBP and specifically for the working population to also improve work ability and reduce sickness absence due to LBP (Rasmussen et al., 2016).

Dynamic sitting approaches have been proposed as one of interventions aimed at promoting movements or postural shifts during prolonged sitting (Akkarakittichoke et al., 2021; O'Sullivan et al., 2006; Pynt, 2015; Wang et al., 2014; Waongenngarm et al., 2021), effectively reducing new-onset neck pain and LBP among office workers (Waongenngarm et al., 2021). A single postural shift can enhance subcutaneous oxygen saturation by an average of 2.2%, suggesting a positive impact on tissue viability (Reenalda et al., 2009). Frequent postural shifts, specifically 20–30 times per hour, effectively reduce bodily discomfort and lower the risk of LBP (Akkarakittichoke et al., 2023). Sitting on a gym ball improves spine motion and activates trunk muscles (Holmes et al., 2015), and replacing an office chair with a gym ball for 8 weeks improved core muscle endurance (Elliott et al., 2016). However, sitting on a gym ball may induce discomfort, especially without a backrest (Gregory et al., 2006; Kingma & van Dieen, 2009). To minimize discomfort, combining an air-filled cushion with a chair that has a backrest could be crucial in optimizing the effectiveness of postural shift interventions (Akkarakittichoke et al., 2022).

Developing a dynamic air-filled seat cushion intervention may help prevent LBP among office workers by enhancing postural shifts and facilitating core muscle activation, thus reducing bodily discomfort during prolonged sitting. This intervention should integrate elements such as air cushions (Waongenngarm et al., 2021), gym balls (Elliott et al., 2016), and an unstable surface attached to a hemisphere (a dome-shaped structure) (Alshehri et al., 2024), which induce postural shifts and activate trunk muscles to mitigate the detrimental effects of prolonged sitting (Liu, 2020). The design should carefully consider the diameter, inflation levels, and postural movement patterns of the seat cushion (Kuster et al., 2020; Liu, 2020), as these factors significantly impact postural shifts and trunk muscle activation while maintaining comfort. Specifically, the diameter of the chair relative to the hip breadth of users is crucial for ergonomic fit and comfort (Yuan et al., 2020). However, there is a lack of specific information on the hip breadth of Thai individuals when sitting. This data is important for tailoring cushions to Thai office workers, to ensure comfort and effectiveness in reducing discomfort during prolonged sitting.

Optimizing seat cushions is crucial for even pressure distribution and minimizing peak pressure on the buttocks (Kim et al., 2017), and several studies have explored innovative dynamic air-filled seat cushions design. Robinson et al. (2023) used a user-centered design to create pneumatic bladders, redistributing pressure to prevent wheelchair user sores. A fuzzy multi-criteria decision-making approaches (Mistarihi et al., 2023) led to the development of a chair attachment cushion with air-blowing techniques to reduce the negative effects of prolonged sitting. Dynamic air cushions with inflation–deflation sequences relieve pressure, reduce interface pressure, and enhance blood perfusion (Arias et al., 2015; Fadil et al., 2022). However, only Waongenngarm et al. (2021) have investigated interventions using an automatic air-pumping cushion to prevent neck pain and LBP in office workers. The optimal cushion size and air fill required to promote postural movement, trunk muscle activation, and comfort remain unclear (Kingma & van Dieen, 2009; O'Sullivan et al., 2006; Yuan et al., 2020).

To address these gaps, in the present study, we developed a new portable, dynamic air-filled seat cushion to reduce discomfort during prolonged sitting, by encouraging postural shifts and facilitating trunk muscle activation, while still providing comfort. Therefore, the purpose of the present design project was to determine the optimal diameter, construction, and air pressure of the cushion, as well as to test usability to ensure user needs and preferences.

Project Phases of the Design Process

Healthy office workers who are at risk of LBP from Bangkok, Thailand, participated in this project. Phase 1 included 50 workers, while Phases 2–4 involved the same group of 10 workers to control for individual variation in postural shifts and trunk muscle activity. Participants in all phases were eligible if they met the following criteria: (1) at least had 5 years of experience in their current office position; (2) aged 23–55 years; (3) had a normal BMI (18.5–22.9 kg/m^2 for Thailand); and (4) had a BROW score ≥53, indicating high risk of future non-specific LBP (Janwantanakul et al., 2015). Participants were excluded if they met the following criteria: (1) reported neck or low back pain within the past 6 months; (2) had a history of injury or accidents in the spinal region; (3) had undergone spinal, abdominal, pelvic, or thigh surgery within the past 12 months; (4) exhibited signs of neurological deficits (weakness or abnormal sensation); (5) were diagnosed with specific neck and low back pain, inflammatory arthritis, infections, cancer, benign, or kidney disease; (6) had wounds, hemorrhoids, contusions, or keloid scar in the buttocks or posterior thigh region; or (7) engaged in regular exercise. A new portable, dynamic air-filled seat cushion was developed using an iterative human-centered design approach, structured into four phases (Figure 1).

Phase 1 aimed to determine the optimal diameter of the seat cushion that provides the most comfort, suitability, and overall satisfaction to its user. Hip breadth measurement is a critical step in designing comfortable seating (Taifa & Desai, 2017; Teo Chuun et al., 2018). Variations in hip breadth influence pressure distribution on the cushion, significantly affecting comfort levels, which is a key factor in evaluating the suitability of different cushion sizes (Hu et al., 2020). Fifty office workers had their hip breadth measured three times, defined as the maximum horizontal distance across the hips, while sitting upright on a stool with knees at a 90-degree angle and thighs parallel to the floor (Taifa & Desai, 2017). Participants sat on office chairs with round seat cushions of six sizes, ranging from 30 to 40 cm in diameter (Ø 30, Ø 32, Ø 34, Ø 36, Ø 38, and Ø 40 cm). The seat cushions were in the same shape, with the amount of air fill varying proportionally with the diameter. The researcher adjusted the chair height for each participant, ensuring 90° hip and knee flexion, with feet fully contacting the floor (Figure 2 and see Supplemental Appendix B). Participants were instructed to sit naturally on each seat cushion, with arms resting on their laps, until they felt comfortable, and not to cross or lift their legs. Afterward, participants rated comfort, suitability, and overall satisfaction for each seat size using a 5-point Likert scale and had the opportunity to provide product design feedback (see Supplemental Appendix A for the questionnaire). The scores had verbal anchors as follows: 1 = very uncomfortable/unsuitable/dissatisfied, 2 = uncomfortable/unsuitable/dissatisfied, 3 = neutral, 4 = comfortable/suitable/satisfied, and 5 = very comfortable/suitable/satisfied. After determining the optimal diameter of the seat cushion that offers the highest comfort, suitability, and overall satisfaction in Phase 1, we utilized that diameter for testing in the subsequent phase.

Phase 2 aimed to investigate the construction of the seat cushion that provides the most postural shifts during a 10-minute sitting period. Five seat cushion constructions (A, B, C, D, and E) were designed based on a mix of unstable sitting characteristics—air cushions (O'Sullivan et al., 2006; Waongenngarm et al., 2021), gym balls (Elliott et al., 2016; Kingma & van Dieen, 2009), and hemisphere unstable sitting (Reeves et al., 2006; Voglar et al., 2022). Prototype-A: a round air sac; Prototype-B: a ring-shaped air sac; and Prototype-C, -D, and -E: air sacs combining elements of Prototype-A and -B, offering a balance between dynamic and stable seating experiences (Figure 3). A researcher measured participants' hip breadth in the same process as in Phase 1 to select the appropriate size of the dynamic seat cushion. Ten office workers meeting the criteria tested all five prototypes (Prototype-A, -B, -C, -D, and -E) in random order. The researcher adjusted each participant's workstation and chair to standard ergonomic guidelines (Sanders, 2004), with additional individual adjustments for comfort (see Supplemental Appendix B). Each participant sat in the assigned posture without crossing their legs or lifting their

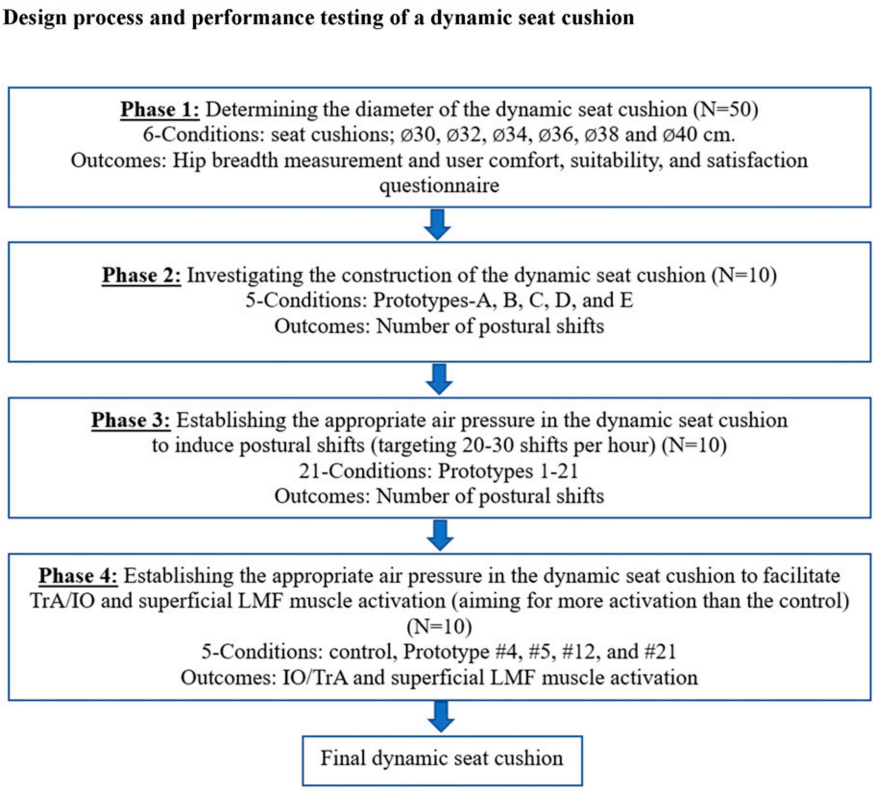

Figure 1. The four phases of the iterative human-centered research through design approach.

Figure 2. The office chair with a dynamic seat cushion used in Phase 1.

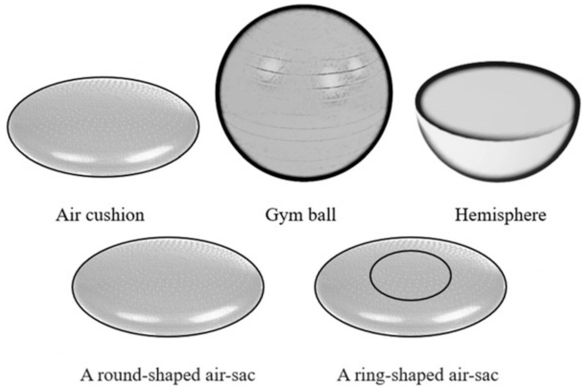

Figure 3. Five seat cushion prototypes (A–E): round-shaped and ring-shaped air sacs incorporating air cushions, gym balls, and hemisphere unstable sitting characteristics.

buttocks, sitting naturally on the chair while maintaining balance on each of the dynamic seat cushions. A seat pressure mat device (see Supplemental Appendix C) was placed on top of the dynamic seat cushion to detect the number of postural shifts (Reenalda et al., 2009) throughout 10 minutes. Each condition involved a 10-minute typing task using a standardized text passage at their own normal pace, followed by a 10-minute break (standing or lying down to prevent prolonged sitting). At the end, participants rated comfort, suitability, and overall satisfaction for each condition on a 5-point Likert scale. The seat cushion construction that was identified in Phase 2 to encourage most postural shifts in 10 minutes was selected for Phase 3.

Phase 3 established the appropriate air fill in the dynamic seat cushion to induce postural shifts, targeting 20–30 shifts per hour. Prototype-E with two horizontal layers of air-filled chambers was selected, based on the results from Phase 2. The first layer contains one chamber, while the second layer contains two chambers. Prototype-E was adapted to create 21 cushions with varying air amounts in each chamber. Each adjustment added 5 mm of air, resulting in inflation heights ranging from 20 to 60 mm. A researcher measured participants' hip breadth to select the appropriate size of the cushion. Ten office workers who met the criteria were randomly assigned to varying conditions. Data collection occurred over two consecutive days, with 10–11 conditions each day. Participants sat on office chairs with cushions, as in Phase 2 (see Supplemental Appendix B for workstation setup). Each condition involved a 10-minute typing task followed by a 10-minute break. After every three conditions, participants took a 30-minute to 1-hour break to prevent muscle fatigue. Postural shifts were recorded using a seat pressure mat during each 10-minute typing test. Participants rated comfort, suitability, and overall satisfaction for each condition. Out of the 21 prototypes from Phase 3, those encouraging more than 3.5 postural shifts in 10 minutes (equivalent to 21 shifts per hour, targeting in the range of 20–30 shifts per hour) were selected for testing in Phase 4 to assess trunk muscle activity.

Phase 4 established the appropriate air fill in the dynamic seat cushion to facilitate transversus abdominis/internal oblique muscle (TrA/IO) and superficial lumbar multifidus (LMF) muscle activation, aiming for more activation than the control. The TrA and LMF muscles are key to spinal stability, supporting the spine during activities (Hodges & Moseley, 2003; Panjabi, 1992). Ten office workers were randomly assigned to a sequence of four intervention and control conditions: sitting on a seat cushion Prototype #4, #5, #12, and #21 and control (sitting without seat cushion). A researcher measured participants' hip breadth to select the appropriate size of the cushion prototype. In Phase 4, EMG signals from the TrA/IO and LMF muscles were collected during 10-minute typing tasks, with muscle activities averaged across the left and right sides. The EMG signals were sampled at 2000 Hz, filtered (20–450 Hz band-pass) using a fourth-order zero-lag Butterworth filter, full-wave rectified, and smoothed with a 50 ms window to calculate root mean square (RMS). Surface sensors were placed bilaterally 2 cm medial to the anterior superior iliac spine for TrA/IO and 2 cm lateral to the L5 spinous process for LMF. Maximum voluntary isometric contraction (MVIC) tests were conducted to normalize EMG data. Processed signals were normalized to %MVIC and analyzed using EMGworks 4.7.9 (Delsys Analysis Software). Each condition included a 10-minute typing task followed by a break, with EMG recording muscle activation during the task. Seat cushion prototypes that promoted greater trunk muscle activity than the control were selected for final testing for 1 hour (Channak et al., 2024). Participants then rated comfort, suitability, and overall satisfaction for each condition.

Statistical Analysis

Descriptive statistics were calculated for all variables. Shapiro–Wilk tests were conducted to assess the normal distribution of study variables. The results indicated that the study variables followed a normal distribution. All statistical analyses were performed using SPSS Statistics software (version 29.0 for Windows, SPSS Inc, Chicago, IL, USA). A one-way repeated measures ANOVA was used to compare the differences in the number of postural shifts, trunk muscle activation, comfort, and overall satisfaction scores among sitting conditions during the 10-minute period. The post-hoc LSD procedure was used to compare means and determine statistically significant differences between selected means. Statistical significance was determined at the 0.05 level for all tests.

RESULTS

Participants in Phase 1, 50 office workers (52% female) aged 24–54 years, with an average age of 33, were assessed. Hip breadth while sitting ranged from 35 to 43 cm (5^{th}–95^{th} percentile), with an average of 39 cm. The participants in Phases 2, 3, and 4 were the same 10 full-time office workers, comprising 5 men and 5 women aged 25–37 years, with an average age of 31. They had an average BMI of 21 kg/m^2 and an average hip breadth of 37 cm (see Supplemental Appendix D).

Phase 1

Comfort, suitability, and overall satisfaction scores showed that the 38 cm seat cushion had the highest average scores (4.1 and 4 out of 5, respectively), followed by the 40 cm and 36 cm cushions (3.9 and 3.8 out of 5, respectively). There was no statistically significant difference between the 36, 38, and 40 cm sizes ($p > .05$).

A subgroup analysis ($N = 300$) was conducted based on observations in 50 participants using six different seat cushion sizes relative to participants' hip breadth and included situations where the participant sat on a seat cushion with the same size as their hip breadth ($N = 22$), a size larger than their hip breadth ($N = 52$), and a size smaller than their hip breadth ($N = 226$) (Figure 4). Most participants (46%–50%) reported the highest comfort, suitability, and satisfaction (5 points) when using a seat cushion of the same size as their hip breadth, though differences between groups were not significant ($p > .05$). About 33%–38% of participants reported comfort, suitability, and overall satisfaction (4 points) when using cushions larger than their hip breadth. However, 38%–39% of participants reported neutral (3 points), while 10%–12% reported very uncomfortable, unsuitable, and dissatisfied (1 point) with using cushions smaller than their hip breadth. Thus, the dynamic seat cushion should be at least as wide as the user's hip breadth to ensure optimal comfort, suitability, and overall satisfaction while sitting.

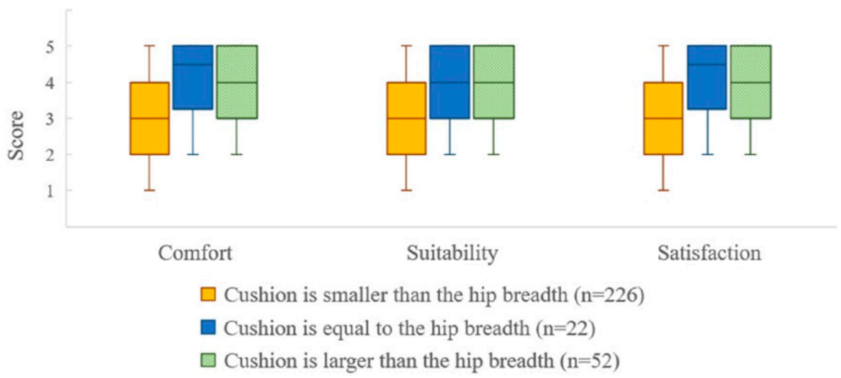

Figure 4. Scores of user comfort, suitability, and overall satisfaction, with SD.

Table 1. Number of Postural Shifts in 10 Minutes and Comfort, Suitability, and Overall Satisfaction Scores.

	Number of postural shifts (times per 10 minutes)			5-point Likert scale			
Construction	**Mean ± SD**	**Range**	**Significant difference of other prototypes ($p < .05$)**	**Comfort**	**Suitability**	**Satisfaction**	**Significant difference of other prototypes ($p < .05$)**
Prototype-A	0.50 ± 0.71	0–2	C, D, E	3.6 ± 0.7	3.3 ± 1.1	3.4 ± 1.1	-
Prototype-B	0.70 ± 0.67	0–2	C, D, E	2.8 ± 0.8	2.8 ± 0.8	2.7 ± 0.8	D, E
Prototype-C	1.80 ± 1.23	0–4	A, B	3.6 ± 1.4	3.5 ± 1.4	3.6 ± 1.4	-
Prototype-D	1.90 ± 1.66	0–5	A, B	4.0 ± 1.1	4.0 ± 1.1	4.0 ± 1.1	B
Prototype-E	2.50 ± 2.32	0–6	A, B	4.1 ± 1.0	4.0 ± 0.9	4.1 ± 1.0	B

Phase 2

A one-way ANOVA revealed a statistically significant difference in the mean number of postural shifts between the five conditions (Prototype-A, -B, -C, -D, and -E) ($F_{(1.96,17.65)} = 5.61$, $p = .01$). Post-hoc analyses using the LSD test showed that in 10 minutes, Prototype-E exhibited the highest number of postural shifts (3 shifts), followed by Prototype-C and -D (2 shifts each), and Prototype-A and -B (1 shift each). However, there was no statistically significant difference ($p > .05$) between Prototype-A and -B, nor among Prototype-C, -D, and -E (Table 1). Prototype-E had the highest average scores for comfort (4.1), suitability (4.0), and overall satisfaction (4.1). Prototype-E showed a statistically significant difference ($p < .05$) compared to Prototype-B. However, no statistically significant differences were observed between Prototype-E and Prototype-A, -C, or -D.

Phase 3

Twenty-one prototypes had the number of postural shifts ranging from 2 to 4.2 times per 10 minutes. Prototype #4 averaged 3.6 ± 1.3 shifts, Prototype #5 averaged 3.9 ± 1.8 shifts, Prototype #12 averaged 4.2 ± 2.4 shifts, and Prototype #21 averaged 3.7 ± 1.3 shifts, all exceeding the target of 3.5 shifts per 10 minutes (Figure 5). However, a one-way ANOVA revealed no significant differences in the mean number of postural shifts between conditions ($F_{(6.23,\ 56.04)} = 1.42$, $p = .22$). Post-hoc analyses using the LSD test revealed no significant differences between any pairs of conditions. Thus, we chose Prototype #4, #5, #12, and #21 for Phase 4 due to their number of postural shifts exceeding 3.5 times per 10 minutes. Twenty-one prototypes had comfort, suitability, and overall satisfaction scores ranging from 2.8 to 4.1. The comfort scores were as follows: Prototype #4: 4.1 ± 0.8, Prototype #5: 3.8 ± 0.6, Prototype #12: 4.1 ± 0.7, and Prototype #21: 3.9 ± 0.7.

Phase 4

Prototype #4, #5, #12, and #21 had average TrA/IO activation ranging from 3.1 to 3.5 %MVIC, while the control condition had 1.3 %MVIC. One-way ANOVA revealed a statistically significant difference in the average activation between conditions ($F_{(2.07,18.67)} = 13.19$ $p < .001$). Post-hoc analyses using the LSD test indicated that Prototype #4, #5, #12, and #21 were significantly different from the control condition ($p < .001$), but no significant

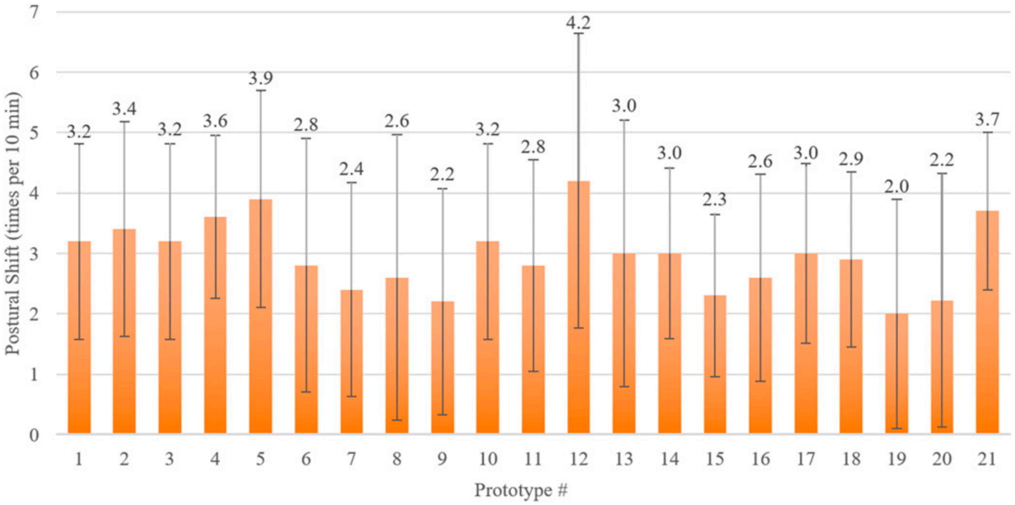

Figure 5. Number of postural shifts, with SD, among the 21 conditions (Prototype #1 to #21) in Phase 3.

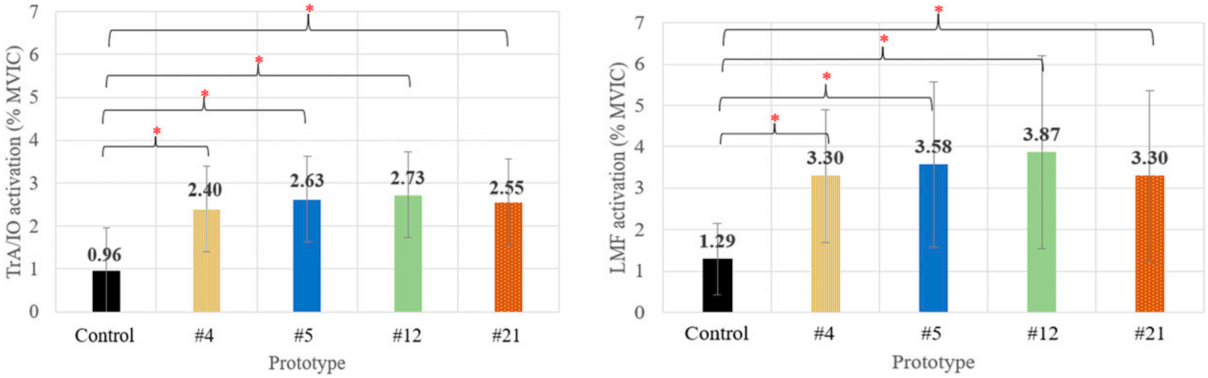

Figure 6. Average TrA/IO and superficial LMF activation, with SD, across conditions (*$p < .05$).

differences were found among Prototype #4, #5, #12, and #21 ($p > .05$) (Figure 6).

Prototype #4, #5, #12, and #21 had average superficial LMF activation ranging from 2.4 to 2.6 %MVIC, while the control condition had 1 %MVIC ($F_{(2.18,19.57)} = 17.58$ $p < .001$). Post-hoc analyses using the LSD test revealed that the superficial LMF activation of Prototype #4, #5, #12, and #21 were significantly different when compared with the control condition ($p < .001$), but there were no significant differences between cushion prototypes ($p > .05$) (Figure 6). Thus, we chose Prototype #5 and #12 designs (Figure 7) for their highest % MVIC values, indicating their effectiveness in promoting trunk muscle activation compared to the control, evaluated over a 1-hour period. The comfort scores were as follows: Prototype #4: 3.8 ± 0.9, Prototype #5: 4.0 ± 0.6, Prototype #12: 4.0 ± 0.6, and Prototype #21: 3.5 ± 0. 8 and control: 2.5 ± 0.8.

DISCUSSION

This project used four-phase iterative human-centered research through design approach for developing a dynamic seat cushion that induces postural shifts and trunk muscle activities while maintaining comfort in office workers.

Phase 1

The results suggest that the dynamic seat cushion should be at least as wide as the user's hip breadth to ensure optimal comfort, suitability, and overall satisfaction. This aligns with a previous study by Sydor and Hitka (2023) recommending that the seat width of ergonomic office chairs should match the hip width of the largest anticipated user, with a small excess on both sides for added comfort (Abdulkadir et al., 2018). Generally, chair designs often follow a percentile-based approach for the target population. For instance, the seat width of an office chair should be designed to the 95th percentile of female hip width, plus movement and clothing (Gupta et al., 2018). Our results recommend using a subject-based approach to achieve a more personalized fit by choosing a seat cushion that matches the user's hip breadth, ensuring optimal user comfort, suitability, and overall satisfaction

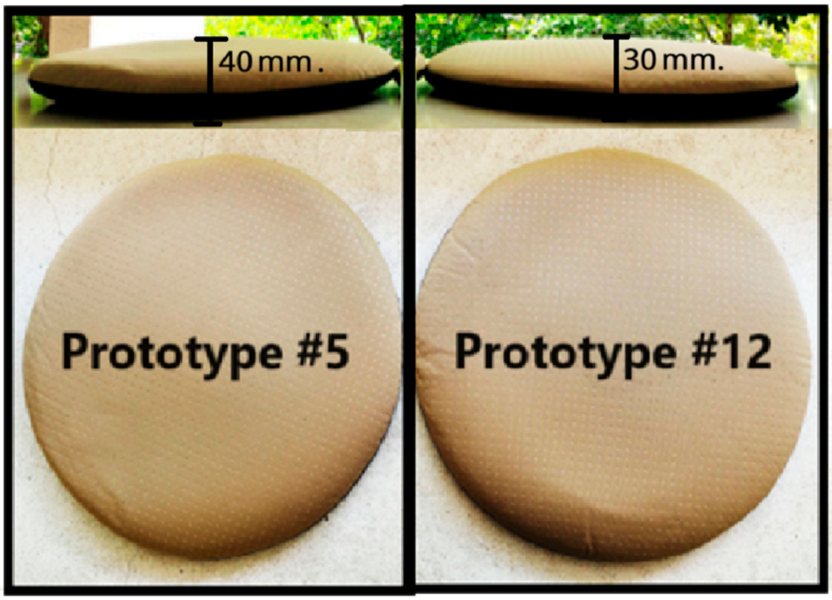

Figure 7. Prototype #5, with a height of 40 mm and greater air volume, differs by 10 mm in height from Prototype #12, which is 30 mm.

when sitting. However, practical challenges associated with customization must be considered. Therefore, we recommend offering three cushion sizes (36 cm, 39 cm, and 42 cm), with the most suitable option being the one closest to the user's hip breadth. The next best option would be a cushion slightly larger than the user's hip breadth, as it also offers favorable comfort, suitability, and satisfaction.

Phase 2

Prototype-E proved to encourage the highest number of postural shifts during 10 minutes. This result may be due to the air sac design of the air-filled cushion in Prototype-E. This construction is based on the concept of unstable sitting on an air cushion (O'Sullivan et al., 2006), which is comparable with sitting on a gym ball (Elliott et al., 2016; Kingma & van Dieen, 2009) or an unstable hemisphere (Reeves et al., 2006; Voglar et al., 2022), encouraging movement while sitting. According to Aissaoui et al. (2001), air-filled cushions behave elastically, creating a sense of instability during body movement and transmitting dynamic load energy through the gluteal tissues. Howard and Kumar (1996) have stated that the center of gravity (CG) plays a crucial role in determining stability of an object. A lower CG increases stability by distributing weight closer to the base, reducing the likelihood of tipping or becoming imbalanced. Conversely, a higher CG makes an object less stable, resulting in facilitated shifting or movement. Therefore, the elevated CG in air-filled cushions can lead to increased instability, encouraging postural shifts during sitting.

Phase 3

Prototype #4, #5, #12, and #21 stood out among the 21 cushions with their design characteristics likely contributing to their effectiveness in facilitating postural shifts and trunk muscle activation. Previous research by Zhang and Li (2022) emphasized that optimal air fill and pressure must be carefully balanced for optimal cushion performance. Park et al. (2013) demonstrated that higher inflation levels significantly increased muscle activation, aligning with our findings. Yu et al. (2022) further highlighted that air-cell-based cushions with an inner pressure range of 100–500 Pa enhanced movement during sitting, which is relevant to our findings as we explored optimal pressure ranges for dynamic cushions. The role of the CG in stability was also critical; the higher CG created by the specific air sac design in Prototype #4, #5, #12, and #21 facilitated greater instability, encouraging postural shifts. Cushions that promote 3.5 shifts in 10 minutes, as identified in our study, align with the goal of achieving 21 shifts per hour, which has been shown to benefit lower back health (Akkarakittichoke et al., 2023; Waongenngarm et al., 2021). Dynamic sitting that encourages body movement has shown to minimize low back discomfort during prolonged sitting by engaging different parts of the trunk muscles (van Dieen et al., 2001). Sitting on a gym ball has indicated increased trunk muscle activation (ranging from 0.51 to 5.56 %MVIC) (Gregory et al., 2006; Jackson et al., 2013; Kingma & van Dieen, 2009; Sakulsriprasert et al., 2015). However, the wide range of %MVIC is influenced by various factors, such as tasks and duration, affecting EMG interpretation. Therefore, these earlier findings cannot be directly applied to our study.

Phase 4

Results from Phase 4 showed that all dynamic seat cushions facilitated greater activation of the TrA/IO (2.4–2.7 %MVIC) and superficial LMF muscles (3.3–3.8 %MVIC) compared to the control condition (TrA/IO = 1.0 %MVIC and LMF = 1.3 % MVIC), aligning with findings from previous studies (Gregory et al., 2006; Jackson et al., 2013; Kingma & van Dieen, 2009; Sakulsriprasert et al., 2015). No significant differences in % MVIC were observed during a 10-minute typing task across the four dynamic seat cushions. These positive results from the 10-minute laboratory setting may not fully be generalized to real-world scenarios. With caution, we selected the two dynamic seat cushions showing the highest %MVIC values for further evaluation in a 1-hour study (Channak et al., 2024), based on their ability to effectively promote trunk muscle activation compared to the control condition. Prototype #5 and #12 share the same design, but Prototype #5 has a greater air volume and a height difference of 10 mm compared to Prototype #12.

Strengths and Limitation of This Study

One of the major strengths is its use of an iterative human-centered research through design approach, which facilitates the rapid development of healthcare interventions and promotes user-focused innovation (Fischer et al., 2021). This creative problem-solving method can lead to the development of innovative solutions. Involving office workers in a usability study, this project emphasized the importance of user feedback in designing dynamic seat cushions, highlighting the significance of intuitive design for optimal functionality. Additionally, we used a seat pressure mat device and wireless surface EMG as primary objective measurements to assess postural shifts and muscle activation. These tools provide precise, non-invasive, real-time data, thus improving assessment reliability and validity (Zhang et al., 2023) and our understanding of the relationship between muscle activity, postural shifts, and intervention effectiveness.

However, there are limitations to this study that should be noted. First, the findings are specific to office workers in Thailand, which may limit the generalizability of the proposed solution to other geographic regions with different workplaces. Second, while implementing iterative human-centered research through design is valuable, it does not encompass a comprehensive overview of all potential challenges. Further studies are essential to incorporate additional sources and real-world experiences, thereby gaining a holistic understanding of these challenges. Third, this project did not delve into the cost implications of dynamic seat cushions, leaving uncertainties about the feasibility and scalability of the solution in low-resource settings. Further research should aim to address these aspects more comprehensively. Finally, although this project did not yield statistically significant results in the outcomes assessed, decisions regarding the intervention approach were made by the research team based on observed trends in the data and practical considerations related to evidence-based support. This underscores the need for further research to validate and build upon these preliminary findings.

CONCLUSION

This systematic, four-phase iterative human-centered research study successfully developed a portable, dynamic air-filled cushion designed to reduce discomfort during prolonged sitting. The cushion promotes postural shifts, trunk muscle activity, and comfort to reduce LBP risk among office workers. The cushion's diameter, construction, and air fill were optimized for effectiveness as well as user needs and preferences. Future studies should evaluate the cushion's practical application and long-term benefits in real-life office environments to confirm its efficacy in improving occupational health.

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Author Contributions

The authors have contributed in the following ways: SC provided the concept/research design, data collection, data analysis, and manuscript writing. AJvdB, EMS, SNPB, and PJ contributed to the concept/research design, data analysis, and manuscript writing. All authors read and approved the final manuscript.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: EMS, SNPB, and AJvdB declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The cushion being studied has currently been in the process of obtaining a patent owned by the National Research Council of Thailand (NRCT) and Chulalongkorn University. SC and PJ have been listed as inventors and may receive financial benefits from the patent.

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Ethical Statement

Ethical Approval

The project phases involving experiments with participation of human subjects were conducted at a laboratory of Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University. All participants received detailed information about the project and were asked to sign a written informed consent form, which had already been approved by the Ethics Committee at Chulalongkorn University (COA No. 015/2023).

Supplemental Material

Supplemental material for this article is available online.

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