The Effect of Objectively Measured Sitting Time During Work and Leisure on Back Function and Perceived Low Back Pain: A Feasibility Study

Final Report

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1. General Introduction and Rationale

Low back pain (LBP) is one of the leading causes of disability worldwide and places a major burden on healthcare systems through frequent clinic visits and diagnostic tests [1]. It is very common: up to 84% of people in industrialized countries experience LBP at some point in their lives [2], and in Canada about one in five people has LBP at any given time [3]. Office workers are especially affected: in some studies, about one-third to half of office workers report having LBP within a one-year period [4,5]. As more jobs involve computer work and long hours sitting at a desk, people are becoming more worried about how this kind of work affects their backs and general health [6]. Sitting for long periods at work may be linked to different muscle and joint problems, including low back pain. This may be because office work often involves sitting (bending the back beyond the middle range), staying still for a long time, and experiencing both physical and mental stress [7].

Despite common beliefs that "too much sitting" causes LBP, research to determine if this is actually the case has not been consistent. Several systematic reviews have not found a clear, direct link between sitting duration alone and the onset of LBP in office workers [8–10]. There are a few reasons why the evidence is inconsistent. LBP has many causes, and the way sitting has been measured in previous studies is often not very accurate. For example, many studies simply asked people to recall how many hours they sat per day, or if it was measured, it was not in a way that could determine how they sat (their posture) or how their posture changed during the day [10,11]. These self-reported measures are affected by memory errors and may not reflect what people actually do [12]. A better way would be to measure sitting time and posture directly and objectively, using devices that record how long someone sits and how their spine and pelvis move. This would give a more precise picture of how much and how people sit, and how the posture might be related to LBP [13].

Another gap is that many studies have not looked at work sitting, leisure-time sitting, and physical activity together. Occupational and leisure-time sitting can be related, so they need to be assessed in combination to understand their overall effect on LBP [14]. Physical activity during leisure time may help offset some of the harmful effects of prolonged sitting [15], so it is important to consider what people do outside of work as well. In addition, white-collar (desk work) and blue-collar (manual) workers differ in their sitting patterns, physical demands, and movement at work [16]. For blue-collar workers, sitting may act as a recovery break from heavy physical tasks and might reduce LBP risk, whereas in sedentary jobs prolonged sitting may increase risk. Recent research has described a "physical activity paradox": high physical demands at work can increase the risk of long-lasting pain, while being active during leisure time tends to protect against pain [17]. Because white-collar workers may have high exposure to sitting and low exposure to healthy movement during the workday, it is important to study this group separately.

People who sit in one position for a long time and do not move their spine very often seem to be at greater risk of back pain than those who change positions more frequently [18]. Current public health recommendations encourage people to avoid long, uninterrupted sitting by changing posture regularly and taking short activity breaks [19]. However, there are no clear, evidence-based rules about how long it is "safe" to sit or how often people should take breaks. Because there is no data, it becomes hard for employers, employees, and occupational health workers to make decisions about sitting time at work. To answer these questions, we need strong exposure–response data that link objectively measured sitting (time, posture, and behavior) with pain and back function.

Because back pain is closely related to how well the back functions, it is important to understand if sitting affects spinal movement, muscle fatigue, and overall back function [20].

This study was designed to help fill these gaps by assessing the feasibility of using wearable devices to objectively measure sitting exposure both at work and during leisure time, as well as measuring back function in a lab a multiple time points with a population of working adults. In addition to measuring time spent sitting, this study is one of the first to quantify how the spine and pelvis move and change position over time in real-world conditions. It also combines field-based measurements (what people actually do in their normal day) with detailed laboratory tests of back function. This allows us to explore whether back function changes over the course of a workday and whether it recovers overnight. Because this type of study is complex and involves many new methods, it was important first to test whether it was practical and acceptable by conducting a feasibility study. It examines key questions such as: Can we recruit enough participants? Will participants be willing and able to wear sensors and activity monitors for long periods? Can we successfully calculate spine angles from the data collected by research-grade activity monitors? What technical issues arise, and how can we solve them? The answers to these questions will provide important information for planning a larger, more powerful study in the future.

2. Research Objectives

- Primary objective: The main goal of this study was to see whether the study design is practical and acceptable, especially the use of wearable sensors to monitor sitting over a longer period. To do this, we recorded how many participants chose to keep wearing the sensors for six extra days after the first 24 hours. This helped us understand whether participants are willing to follow a long-term monitoring protocol, which is essential for planning larger future studies.

- Secondary objective: The second goal was to objectively measure how much and how people sit, and to compare their back pain and back function before and after a period of sitting in their normal daily life, both at work and during leisure time. Back function was assessed using a set of laboratory tests done before and after a typical workday, and again after an overnight recovery period. Using these exposure (sitting and posture) and response (pain and back function) data, we also carried out a preliminary analysis to explore how sitting behavior and spine posture might affect back function and perceived back pain.

3. Research Question

- Is it practical and acceptable to use wearable devices to objectively measure how much people sit and their spine posture during sitting over several days in office workers (18 years and older) who mainly perform desk work at their job?
- Can the pilot help us to determine whether activity and posture exposures affect back function and perceived pain?

4. Methods

4.1 Study Design

An observational longitudinal study was conducted with an embedded method for assessing feasibility of procedures for future studies. As there are no specific reporting guidelines for observational feasibility studies, we followed relevant parts of the extended CONSORT (Consolidated Standards of Reporting Trials) guidelines for pilot and feasibility trials to improve clarity and transparency in reporting. Ethical approval for this study was obtained from the Health Research Ethics Board (HREB Reference #2023.097) on July 5, 2023.

4.2 Participants

A total of thirty adult office workers (18 years and older) were recruited from the local community of St. John's, including people who worked in offices and those working from home. To be included, participants had to work at least 20 hours per week in a job where sitting was their main posture—that is, they sat for more than half of their working time—and had to agree to take part in all parts of the study. This included attending all lab sessions, wearing the sensors for at least 24 hours, and completing the surveys. People who had known allergies or skin sensitivities to adhesives or medical tape were not eligible to participate.

4.3 Recruitment Strategy

Participants were recruited in two stages between July 30, 2024 and February 16, 2025. First, we used convenience sampling through posters, university email (Newsline), and social media to reach local office workers. Then we used snowball sampling, asking enrolled participants to share the study with others. Interested individuals had a short video call with the co-investigator (SAS) to review the study, check eligibility and availability, and see a brief video of the lab procedures. Those who were eligible and agreed were booked for a lab visit, where they signed informed consent; they were reminded they could withdraw at any time. All participants followed the same procedures and were part of a single study group.

4.4 Instrumentation

4.4.1 Accelerometers

Total sitting time and spine posture were measured using three small wearable sensors (ActiGraph). Using only one sensor at the hip can identify general postures such as upright vs. lying, but it cannot reliably distinguish sitting from standing, and cannot calculate the posture of the low back (the lumbar spine angle) [21,22]. We therefore used three ActiGraph GT9X devices [23]. These are small, lightweight, water-resistant sensors that attach to the body and record movement in three directions, allowing us to capture both sitting exposure and posture-related changes in the lower back [23].

4.4.2 Low Back Pain Intensity

Self-reported back pain intensity was measured at several time points using an 11-point Numerical Rating Scale (NRS), from 0 ("no pain") to 10 ("worst imaginable pain") [24]. NRS is a simple, valid, and reliable tool, widely used in research and clinical practice and recommended as a core outcome measure for pain intensity in nonspecific LBP [25]. Participants rated their pain before work (lab session 1), midway through the workday, at the end of work (lab session 2), just before sleep, and the following morning (lab session 3). The NRS score was sent by email or text, according to participant preference. Participants were classified as pain developers (PDs) if their NRS score increased by 2 or more points at the end of the workday compared with their pre-work baseline; all others (no pain, reduced pain, or ≤1-point increase) were classified as non-pain developers (NPDs). Tracking pain across the day allowed us to examine how pain changed over time in PDs and NPDs, including during leisure time and before sleep [26]. Tracking pain across the day allowed us to examine how pain changed over time in PDs and NPDs, including during leisure time and before sleep.

4.4.3 Activity Diary

To add context to the sensor data, participants completed a 24-hour activity diary (sample in **Appendix 1**). The diary was divided into 15-minute blocks, where participants recorded their main posture (e.g., sitting, standing, walking, lying) and the type of activity they were doing (e.g., computer work, cooking, resting). They were asked to update the diary about every hour to reduce recall bias. For times when this was not possible—such as overnight—participants filled it in after waking, noting when they went to bed and when they got up. The diary could be completed either online or on paper, depending on preference of participants. For the online option, an Excel version was shared via Google Docs with clear instructions on how to open, complete, and save it. Those without reliable digital access received a printed copy. At each lab session, a member of the research team reviewed the diary for completeness and clarified any missing or unclear entries. Participants' contact information was collected separately (**Appendix 2**) and used only for study-related communication, such as sending diary materials and reminders. These details were stored securely and destroyed after data collection was completed to protect participants' privacy.

4.4.4 Data Collection Procedure

A brief overview of all data collection procedures described in this section is shown in **Figure 1**.

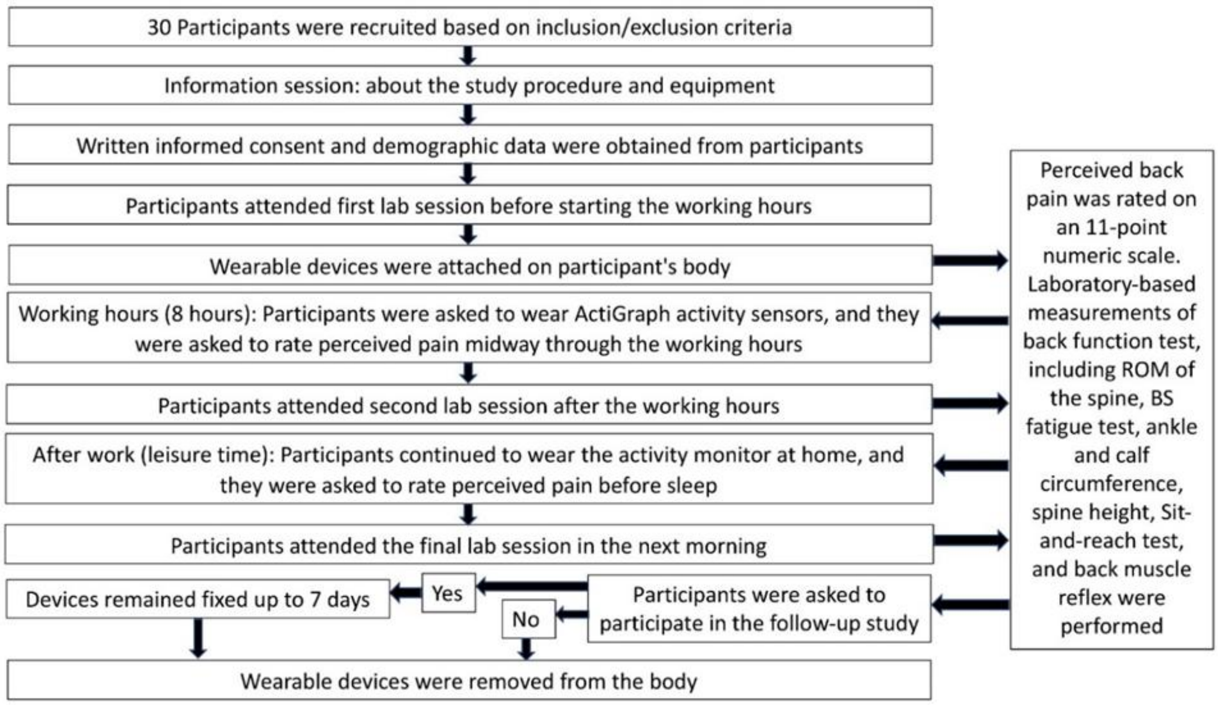

Figure 1: A brief overview of the data collection procedure.

After completing the screening interview, confirming eligibility, and obtaining written informed consent, participants were scheduled for their first laboratory session, held in the morning before their workday. At this visit, they first rated their baseline perceived back pain using the NRS. A standardized set of back function tests was then completed to establish baseline measurements. After this, three ActiGraph GT9X accelerometers were attached using Hypafix® tape and Tegaderm™ dressings (**Figure 2**). The sensors were placed over the skin of the mid and lower back, and the front of the thigh of their dominant leg. Participants then completed a brief upright standing trial to calibrate the sensors by marking a starting reference position.

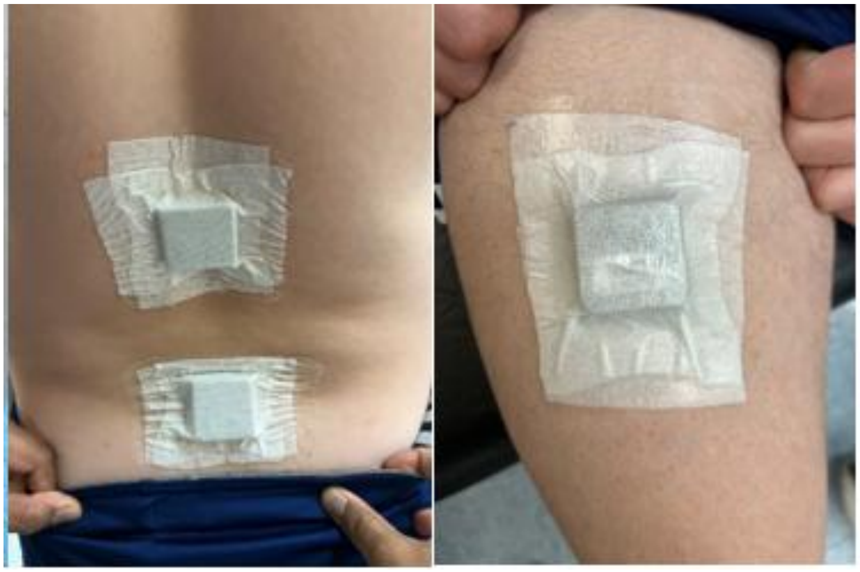

Figure 2: Sensors on the back and thigh, covered with waterproof tape.

Participants then left the lab and completed a typical workday while wearing the sensors continuously. They were asked to follow their usual schedule and behaviors. Approximately halfway through the workday, they received a text or email prompt to rate their back pain. At the end of the workday, they returned for a second lab session, repeated the pain rating, and completed the same back function tests to detect any changes relative to the morning. Sensors were inspected and adjusted if needed. Participants then went home with the devices still attached, wore them through the evening and overnight, and provided another pain rating just before going to sleep. The following morning, participants returned for a third lab session, again rated their back pain, and completed the final round of back function testing. This allowed comparison of back function at baseline, after a sitting-dominant workday, and after a night of recovery.

After the 24-hour protocol, participants were invited to join an optional extended monitoring phase, during which they continued to wear the sensors for six additional consecutive days (seven days total). This phase was designed to test the feasibility, comfort, and adherence associated with prolonged sensor use and to capture day-to-day variability in sitting behavior, posture, back function, and discomfort. Participation in this phase was entirely voluntary, and participants could withdraw at any time. Those who declined had their sensors removed at the end of the third lab session; those who agreed kept them on and returned once more to have them removed. Throughout both the 24-hour and extended phases, participants were instructed to wear the sensors continuously, including during sleep, unless significant skin irritation or discomfort occurred, in which case removal was permitted in consultation with the research team. After sensor removal, participants completed two anonymous questionnaires by answering questions about their participation experience.

4.4.5 Lab-based Measurement of Back Function

4.4.5.1 Spine Height

As an indirect measure of constant force on the spine discs, we measured seated spine height. Earlier work has shown that sitting for long periods can temporarily reduce spine height as fluid shifts out of the discs when they are squeezed [27,28]. Moving around reverses this, by pulling fluid back into the discs [29]. This pumping action, based purely on movement, is required for discs to stay healthy. In this study, we measured seated spine height using a wall-mounted digital scale. Participants sat upright on a flat wooden stool with their back against a wall and feet placed evenly (**Figure 3**). They wore goggles with a small bubble level to help keep the head looking straight forward. Spine height was taken as the distance from the top of the stool to the top of the head. Participants looked straight ahead, took a deep breath in and held it while the reading (in centimeters, to two decimal places) was taken. The measurement was repeated three times and the average was used. All measurements were performed by the same trained researcher for consistency.

Figure 3: Standardized seated posture for spine height measurement by stadiometer, with head alignment maintained using bubble-inclinometer goggles (left: from side view; right: from front view).

4.4.5.2 Calf and Ankle Circumference

Sitting for long periods can cause fluid to build up in the lower legs, leading to swelling around the calf and ankle [30]. When leg muscles are mostly inactive, gravity causes blood and fluid to pool in the lower limbs, and venous return to the heart becomes less efficient [30]. Studies showed that uninterrupted sitting for 2–4 hours causes measurable leg swelling, and brief activity breaks (e.g., three minutes of higher-intensity movement each hour) can significantly reduce this effect [31,32]. These findings support calf and ankle circumference as simple, practical markers of sitting-induced lower limb swelling and as indirect evidence of continuous versus interrupted sitting behavior. In this study, calf and ankle circumferences were measured on the dominant leg using a flexible tape measurer [33]. Participants sat at the edge of a therapy table with feet flat on the floor and the knee at approximately 90 degrees (**Figure 4**). Shoes were removed and socks lowered for accurate tape placement. Calf circumference was measured about four inches below the knee (around the widest part of the calf) [33,34]. Ankle circumference was measured one inch above the ankle (the narrowest part of the lower leg) [33,34]. The tape position was marked on the skin to allow consistent placement at repeat sessions. Each circumference was measured three times (to two decimal places in centimeters), and the average was used; if one value differed by more than 0.5 cm, a fourth reading was taken and the outlier was discarded. All measurements were performed by the same trained researcher to ensure consistency.

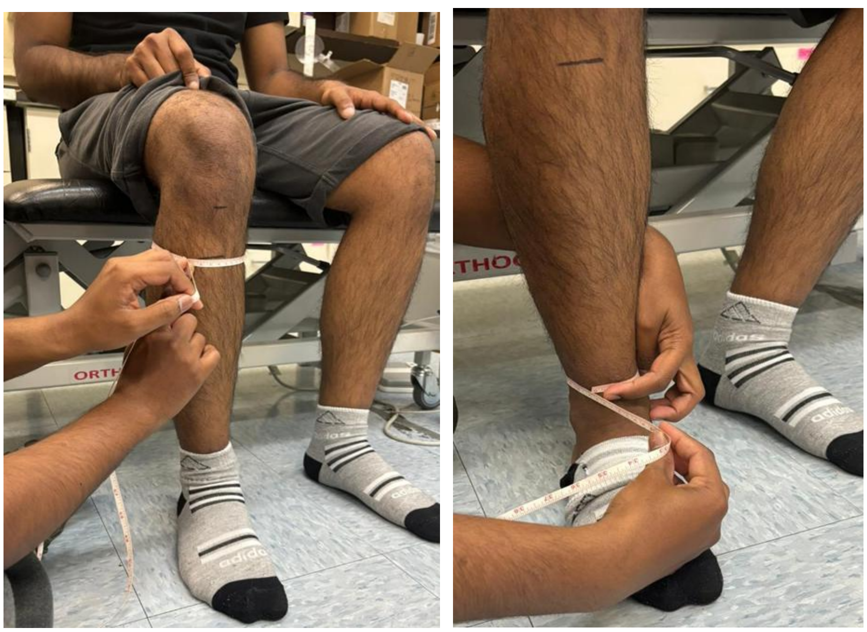

Figure 4: Measurement setup for calf (left figure) and ankle (right figure) circumferences.

4.4.5.3 Sit-and-reach Test

The sit-and-reach (SR) test was used to assess flexibility of the lower back, legs, and hips during forward bending. In this study, the test was done with participants sat on a height-adjustable therapy table with their legs straight, feet together, and bare feet pressed against the sit-and-reach box (**Figure 5**). With one hand placed on top of the other and arms straight, they slowly reached forward along the scale on top of the box, pushing a sliding marker as far as they could without bending their knees, and held that position for 2–3 seconds. The reach distance was recorded in centimeters (to one decimal place). Each person completed three trials, and the average was used for analysis. All tests were carried out by the same trained researcher (SAS) to keep the procedure consistent.

Figure 5: Sit-and-reach test performed on a therapy plinth with legs extended and feet against the box, using a fingertip slider to record maximal reach without knee flexion.

4.4.5.4 Muscle Reflex Activation Time

The muscles of the low back turn on quickly to control the back during body movements. Not turning on fast enough might play a role in how backs get hurt. We measured how fast these muscles turn on after a small, but sudden, change in balance.

Low back muscle reflex activation time was measured using a modified protocol from Gregory et al. [35]. Muscle activity electrodes were placed over a low back muscle on both sides of the back.

Then, participants stood upright holding a bin at waist level with both hands, elbows bent to about 90°, and the container not touching their body. A weight equal to 10% of each participant's body mass was dropped from a height of 2 cm into the container, this sudden weight created a tendency for the participants to tip forward, which would quickly be balanced by their back muscles turning on [36]. Participants wore noise-cancelling headphones so they could not anticipate the exact timing of the weight drop. The moment the weight hit the bottom of the bin was matched to the muscle activity recording to determine how quickly the muscles turned. Each participant completed three trials per session, and the average reflex time was used. Electrode sites were marked with permanent ink to ensure consistent placement across all three lab sessions.

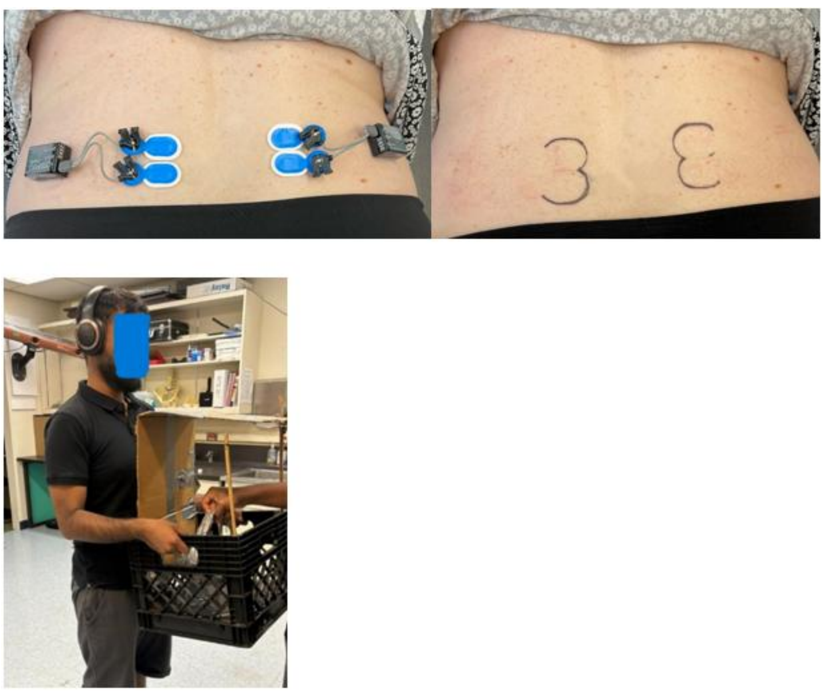

Figure 6: Experimental setup for back muscle reflex testing. Top: Muscle activity electrodes placed and marked over the low back muscles to ensure consistent placement. Bottom: Participant standing upright, holding a container at waist level and wearing noise-cancelling headphones while awaiting an unexpected weight drop.

4.4.5.5 Range of Motion

Back range of motion (ROM) was measured using a 3D motion-capture system, which is considered a gold-standard method for tracking how the trunk moves [37]. Flexible fabric braces with infrared markers attached were placed on the upper back and on the pelvis with shoulder and pelvic. Tracking these markers during movement allowed us to measure how the upper back moved relative to the hips [38]. Participants first completed a 5-second quiet standing trial, which served as the neutral reference posture (zero position) for calculations. They then moved their back in all ranges of motion: forward bending, extension, bending to each side, and twisting to each side, each repeated three times. Movements were performed with feet shoulder-width apart and standardized instructions to control foot position, arm placement, and pacing, as these factors can affect motion [39,40]. Flexion was paced by an audio cue to standardize speed; the other tasks followed a consistent pattern of starting upright, moving to the maximum comfortable range, holding briefly, and returning to neutral. All movements were recorded at 60 frames per second, and the three trials for each movement were averaged to give one representative ROM value per direction for each participant.

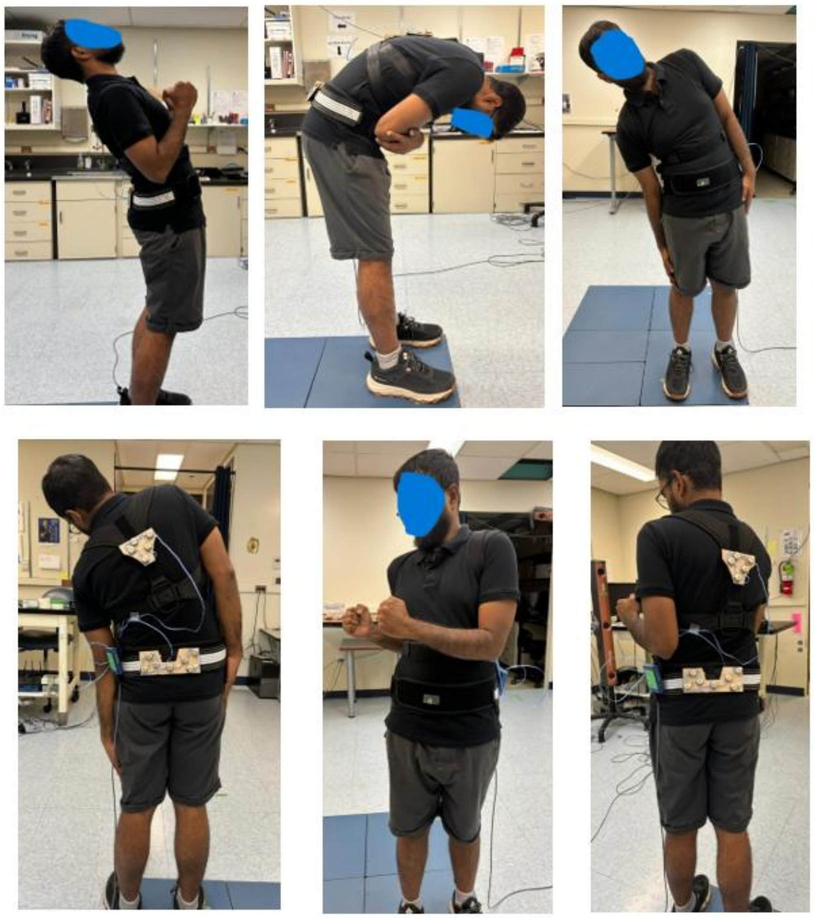

Figure 7: Examples of motion tasks performed by participants. Top row (left to right): (A) Forward bending, (B) Extension, and (C) Right side bending. Bottom row (left to right): (D) Left side bending, (E) Twist to the right, and (F) Twist to the left.

4.4.5.6 Back Muscle Endurance

How long muscles could stay on (endurance) was measured using the Biering-Sørensen fatigue test, a widely accepted and validated method for assessing how long the trunk extensor muscles can work before tiring in both healthy people and those with LBP [41]. In this test, participants lay face down on a therapy table with the front of their hip bones in line with the edge. Their pelvis and legs were secured with straps so that the back muscles, rather than the hips or legs, did most of the work. Before the test started, they supported their upper body with their hands. At the beginning of the trial, they crossed their arms over their chest and lifted their upper body so it was parallel to the floor, then held this position as long as possible. A researcher watched carefully, gave gentle cues if the posture started to drift, and stopped the test when the participant could no longer keep the correct position. The holding time was recorded with a stopwatch to the nearest second.

Figure 8: Standardized setup for the Biering-Sørensen fatigue test.

4.4.6 Feasibility and acceptability assessment of the study

To assess feasibility, we tracked several indicators throughout the study: how many people agreed to take part (recruitment rate), how many completed 24-hour study period and attended all lab sessions (retention rate), how well participants wore the sensors as instructed, and whether any adverse events occurred. We also noted any technical problems experienced by participants or staff, and the reasons why eligible participants chose not to participate or did not complete the study, to help improve future recruitment and retention. Adverse events included any problems caused by wearing the devices (such as discomfort or skin irritation), difficulties completing lab sessions, or disruptions to regular work tasks. Participants were asked to self-report adverse events using a simple yes/no checklist, and lab staff recorded any events they observed on a standard form (including date, severity, location, duration, actions taken, and outcome). Events were classified as minimal, mild, moderate, severe, or life-threatening using the Common Terminology Criteria for Adverse Events [42]. Targets for each feasibility measure (**Table 1**) were set ahead of time based on previous studies and standard guidance for feasibility/pilot studies [43].

Table 1: Criteria for evaluating feasibility outcomes and corresponding thresholds for determining whether to proceed to a full trial.

Outcomes	**Major revision prior to full trial and monitoring closely**	**Continue to full trial with modifications**	**Continue to full trial without modifications**
Enrollment rate	< 70%	70% - 90%	> 90%
Retention rate	< 70%	70% - 80%	> 80%
Adherence to wearing the sensors	< 70%	70% - 80%	> 80%
Attendance at lab sessions	< 70%	70% - 80%	> 80%
Adverse events	Minimal and mild adverse events in > 10% of participants	Minimal and mild adverse events in < 10% of participants	No adverse events

After the final lab session, participants completed a short questionnaire about how acceptable and satisfactory they found the study. They were asked about wearing the devices for 24 hours, attending three lab sessions, and their overall experience with the assessments and procedures. The questionnaire included six items (**Appendix 3**) rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The average score on these items was used as the main measure of acceptability, with an average of 4 or higher considered acceptable [44]. Participants also answered several open-ended questions (**Appendix 4**) about the study design and protocol. These written comments were analyzed qualitatively to identify ways to improve the methods for future studies. All questionnaire responses were anonymous.

4.5 Data Processing

4.5.1 Sensor Data Processing

Data from the three sensors were first downloaded using the manufacturer's software and exported as time-stamped files. These files were then imported into MATLAB, where custom scripts developed and tested in an earlier pilot phase of the project, were used to clean and analyze the data. In the first step, the script used standard filtering methods to remove noise and then calculated the orientation of each sensor. Based on angle cut-offs defined in controlled posture trials from the pilot work, each second of data was classified as sitting, standing/walking, or lying. The script then summed the total time spent in each posture and calculated the percentage of work time and leisure time spent in each posture, using the work and leisure periods reported in the activity diary. Time spent in the lab, travelling, or in unclear postures (for example, leaning or kneeling) was left unclassified and excluded from these summaries.

A second script focused only on the periods classified as sitting. It calculated how many separate sitting bouts occurred, how long they lasted on average, and the longest single sitting bout. It also estimated back posture during sitting by calculating the angle between the sensors on the upper and lower back, used as an indicator of how flexed or upright the spine was over the workday. A third script described how much the spine moved throughout the day. Very small angle changes (likely due to breathing or sensor noise) were removed, and the remaining movements were summarized using percentiles (for example, 50th, 90th, and 99th). Lower percentiles described the small, frequent movements that made up most of the sitting time, while higher percentiles captured larger and less frequent movements.

4.5.2 Muscle Activity Data Processing

Muscle activity signals were processed using custom scripts in MATLAB. The goal was to find out how quickly the muscles turned on after the weight dropped, resulting in a brief loss of balance. First, the signal from the small sensor on the bottom of the box was used to detect exactly when the weight hit the bin and the balance loss began. All muscle data were then aligned to this time point. Next, the muscle activity signals were cleaned and prepared with a series of digital filters. Quiet "resting" muscle recordings were used to remove offsets, and the data were filtered to remove noise and heart activity [45]. The signals were then rectified and smoothed to create a clear envelope of muscle activity [46]. The same processing steps were applied to the reflex trials, and the quiet-trial signal was subtracted to reduce background noise, similar to the approach used by Mackey et al. [47]. Reflex onset was identified using a simple threshold rule: the first time point after the balance loss where the muscle signal rose more than three times above the baseline variability [35]. The delay between the balance loss and this turn on point was expressed in milliseconds. Trials where muscles turned on too early or very late were removed, as these were likely not true reflexes [48]. For each participant and each lab session, valid trials were then averaged to produce a single reflex value.

4.5.3 Range of Movement Data Processing

The motion capture data were smoothed with a standard filter to remove small, high-frequency noise while keeping the main movement pattern [49]. Using the landmarks recorded in the calibration trial, we defined two body segments: the upper back and the pelvis. The low back angle was then calculated as the angle of the upper back to the pelvis in three directions: bending forward/backward, side bending, and twisting. The quiet standing posture was set as 0°, and all movement angles were given relative to this position. For each movement task (flexion, extension, right/left side bend, and right/left twist), we identified the maximum angle reached. Trials with missing markers or obvious errors were discarded and repeated. For each direction and session, the three maximum angles were averaged to give one value per movement for analysis.

4.6 Statistical Analysis

All data were analyzed with statistical software (SPSS, IBM, version 21.0). We first summarized the sample using averages and standard deviations for numerical data and counts and percentages for categorical data. Differences in posture duration and sitting behavior between groups were tested using independent-samples t-tests. Changes in back function across the three lab sessions (all 30 participants combined) were examined using repeated-measures ANOVA with Bonferroni-adjusted pairwise comparisons (Session 1 vs 2, 1 vs 3, and 2 vs 3). Effect sizes (partial eta squared and Cohen's d) were reported to show how large any changes were. All tests were two-tailed with $p < 0.05$, but given the feasibility and exploratory nature of the study, we focused mainly on the pattern and size of effects. For the six-item Likert questionnaire, responses (1–5) were grouped into "agree" (4–5), "neutral" (3), and "disagree" (1–2), and the percentage in each category was calculated for each item. Open-ended comments were reviewed to identify common themes and suggestions to improve the study design.

5. Results

5.1 Participant Characteristics

Descriptive information for the 30 participants is shown in **Table 2**. Based on changes in back pain after the workday, 19 were classified as NPD and 11 as pain developers PD. Given the small sample size, no formal statistical tests were conducted for between-group demographic comparisons, and these data are presented descriptively.

Table 2: Demographic Characteristics of Study Participants.

	Mean ± SD	Between Groups	
		Groups	Mean (SD)
Age (years)	32.8 ± 8.8	NPD	33.2 ± 9.5
		PD	32.1 ± 7.9
Height (cm)	166.5 ± 7.4	NPD	168.0 ± 8.0
		PD	164 ± 5.9
Body Mass (kg)	77.2 ± 21.7	NPD	78.4 ± 23.2
		PD	75.2 ± 19.7
BMI (kg/m^2)	27.8 ± 7.4	NPD	27.7 ± 7.9
		PD	27.9 ± 7.0

5.2 Feasibility Outcomes

Feasibility results for recruitment, adherence, retention, and safety are summarized in **Table 3**. The enrollment rate was 86%; five eligible people who were interested did not continue, mainly because they could not attend early-morning lab sessions. Once enrolled, all 30 participants completed the study (100% retention) and attended all scheduled lab visits. Everyone wore the sensors as required during the first 24 hours (100% adherence), but only 20% chose to keep them on for the longer, optional period beyond 24 hours. Adverse events were minor: 80% of participants reported mild skin irritation at the sensor sites, and no serious adverse events occurred.

Table 3: Feasibility Outcomes and Trial Continuation Recommendations.

Outcomes	Findings	Fulfilled targets and final recommendation
Enrollment rate	86%	Continue to full study with modifications
Retention rate	100%	Continue to full study without modifications
Adherence to wearing sensors	24 hours: 100% Beyond 24 hours: 20%	24 hours: Continue to full study without modifications Beyond 24 hours: Major revision prior to full trial
Attendance at lab sessions	100%	Continue to full study without modifications
Adverse events	80% reported mild skin irritation	Major revision prior to full study

5.3 Acceptability Outcomes

Participant feedback on the study protocol (Questionnaire 1) is shown in **Table 4**. All participants agreed or strongly agreed that they did not mind attending the lab sessions, suggesting the in-person procedures were fully acceptable. Most felt the wearable sensors had little impact on daily life: 93% said the devices did not interfere with tasks at home, and 83% said they did not interfere with tasks at work. In terms of comfort, 87% agreed the devices were not bothersome, with a few neutral responses and one person disagreeing. All participants agreed that the study instructions and information were easy to understand. Finally, 97% said they would recommend using the same procedures in future studies of sitting at work, with only one neutral response and no disagreement. Overall, these results show a high level of acceptability for the study protocol.

Table 4: Participant Feedback Summary from Questionnaire 1.

Question	Agree (n, %)	Neutral (n, %)	Disagree (n, %)
Did not mind attending lab sessions	30 (100%)	0 (0%)	0 (0%)
Wearables did not interfere at home	28 (93%)	2 (7%)	0 (0%)
Wearables did not interfere at work	25 (83%)	4 (13%)	1 (3%)
Wearables were not bothersome	26 (87%)	3 (10.0%)	1 (3%)
Instructions were easy to understand	30 (100%)	0 (0%)	0 (0%)
Would recommend the same protocol	29 (97%)	1 (3%)	0 (0%)

Open-ended feedback from Questionnaire 2 was grouped into five main themes: reasons for taking part, challenges, things that helped participation, experiences with the devices, and suggestions for improvement (**Table 5**). Seven participants enrolled because they were interested in research, while five participants cited concern about LBP as a motivating factor and three participants were curious about their own health and monitoring. The most common challenges were mild discomfort or itchiness from the sensors (n = 9), early-morning lab sessions (n = 4), and issues with transport or parking (n = 3). Facilitators included supportive research staff (n = 9), a convenient lab location (n = 6), clear instructions (n = 5), and flexible scheduling (n = 3). Some participants said the devices felt itchy (n = 7), while others found them unobtrusive (n = 4); a few mentioned interferences with clothing or sleep (n = 4) or that the devices felt bulky (n = 3). For future studies, participants suggested stronger recruitment efforts (n = 6), better incentives (n = 4), more flexible scheduling (n = 3), and smaller sensors to improve comfort (n = 2).

Table 5: Summary of Thematic Analysis of Open-Ended Participant Feedback.

Themes	Sub-themes	Description	Count (n)
Reasons for Participation	Interest in research	Participants expressed a desire to contribute to scientific studies	7
	Concern about back pain	Participants joined due to personal experiences or concerns about LBP	5
	Curiosity	Participants were curious about the research process or personal health	3
Challenges Faced	Mild discomfort from sensors	Mentioned itching, pressure, or irritation from the wearable devices	9
	Early morning sessions	Identified early morning timing as a challenge or barrier	4
	Transportation and parking	Issues or convenience related to commuting and parking	3
Facilitators of Participation	Supportive research staff	Praised the friendliness or professionalism of staff	9
	Convenient lab location	Found the lab location easily accessible, often located near work	6
	Clear instructions	Reported receiving well-structured, understandable guidance	5
	Flexible scheduling	Appreciated the ability to adjust lab timing to fit their schedule	3
Experience with Wearable devices	Itchiness at the attachment sites	Mentioned mild itchiness at the attachment sites of the sensors	7
	Unobtrusive wearable devices	Mentioned that the devices were not intrusive	4

	Clothing and sleep interference	Reported some challenges with dressing or sleeping while wearing sensors	4
	Bulkiness of the device	Specifically mentioned the size or texture of sensors as problematic	3
Key Suggestions for Improvement	Recruitment efforts	Suggestions for improving awareness and outreach	6
	Incentives	Commentary on financial or motivational rewards	4
	Scheduling adjustments	Suggested improvements to timing and duration of lab sessions	3
	Smaller sensors	Requested smaller or more comfortable sensors for wear-ability	2

5.4 Group Comparison (PD vs NPD) Outcomes

5.4.1 Pain Intensity Over Time

Figure 9 shows how back pain changed over time for PDs and NPDs. In the PD group, pain increased progressively during the workday, was highest right after work, and then dropped a bit before sleep and again the next morning. However, their pain never fully returned to baseline, meaning they still had more pain than at the start of the day. In contrast, the NPD group showed very little change in pain at any time point, with scores staying close to—or slightly below—their baseline values.

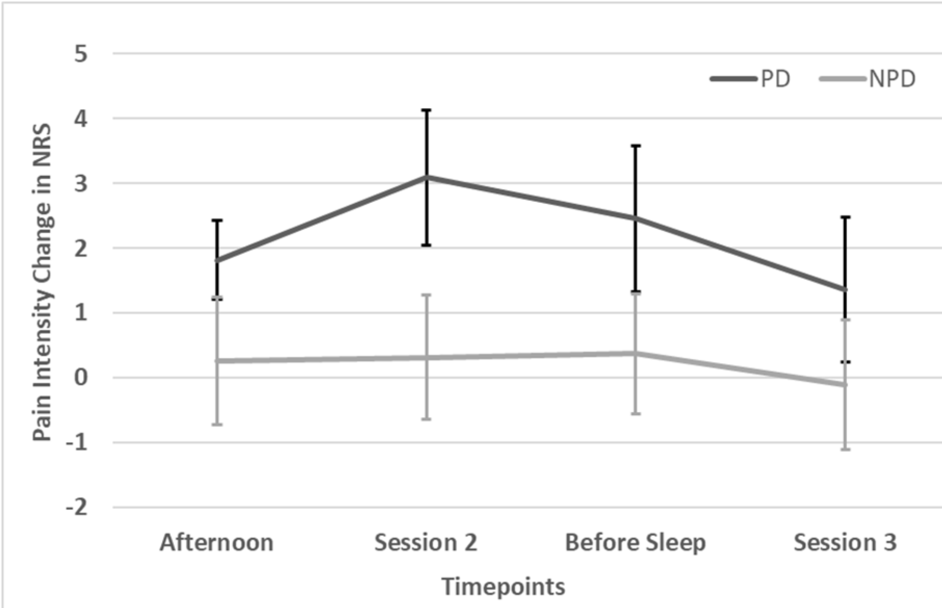

Figure 9: Change in perceived LBP (NRS) from baseline across timepoints for PD and NPD.

5.4.2 Posture Duration

On average, PDs and NPDs reported similar total working hours. During work, PDs spent more time sitting than NPDs—about 71 minutes more per day—and spent a larger percentage of their workday sitting. Time spent standing or walking at work was similar between groups. During leisure time, PDs spent less time standing or walking than NPDs and more of their leisure time lying down. While the total minutes spent lying were slightly higher for PDs, this difference was not statistically significant; however, the proportion of leisure time spent lying was significantly greater. Leisure sitting time was similar in both groups. Full results are summarized in **Table 6**.

Table 6: Comparison of Time Spent (in minutes and percentage) in Different Postures Between PDs and NPDs During Work and Leisure Periods (Mean ± SD).

Postures		Duration Spent (mins) Mean ± SD		p-value	Duration Spent (%): Mean ± SD		p-value
		NPD	PD		NPD	PD	
Work	Sitting	264 ± 109	335 ± 59	0.028*	64.7 ± 20.7	78.1 ± 11.7	0.030*
	Stand/walking	116 ± 82	88 ± 48	0.442	26.4 ± 14.8	20.2 ± 10.6	0.235
Leisure	Sitting	123 ± 101	94 ± 53	0.386	14.7 ± 10.2	12.4 ± 6.4	0.497
	Stand/walking	131 ± 88	69 ± 26	0.009*	16.1 ± 9.5	9.4 ± 3.8	0.012*
	Lying	524 ± 85	565 ± 67	0.174	67.5 ± 14.3	76.4 ± 7.6	0.035*

Note. The total minutes and percentages do not always add up to 24 hours or 100%. As some periods—such as lab sessions, travel to and from work, brief lying during work, and short or unclear movements—were not included in the posture categories.

5.4.3 Sitting Behaviors During Work Hours

To better understand how people sat during work, we looked at patterns such as how many sitting bouts they had, how often these bouts occurred per hour, the average length of each bout, and the longest single sitting period (**Table 7**). Overall, PDs and NPDs showed very similar sitting patterns. The total number of sitting bouts and the number of bouts per hour were almost the same in both groups. The average length of an uninterrupted sitting bout was only about 2 minutes longer in PDs than NPDs, and the longest single sitting bout was about 17 minutes longer in PDs, but none of these differences were statistically significant.

Table 7: Comparisons of Temporal Sitting Behavior Metrics During Work Hours Between Groups

Variables	**NPD (Mean ± SD)**	**PD (Mean ± SD)**	**p-value**
Total bouts count	16 ± 9	18 ± 9	0.613
Bout count/hour	2.3 ± 1.0	2.5 ± 1.2	0.628
Avg. sitting duration (min)	18 ± 10	20 ± 10	0.517
Max. sitting duration (min)	58 ± 30	75 ± 26	0.137

5.4.4 Back Angles During Sitting

We compared how much people bent their lower back while sitting across the full range of angles, using different percentiles (**Table 8**). At the low end (10th percentile), mid-range (25th and 50th), and high end (90th, 95th, and 99th), there were no statistically significant differences between PDs and NPDs. In other words, across small, typical, and larger bending positions, both groups sat in broadly similar postures, suggesting that differences in pain were not explained by clear differences in average sitting posture.

Table 8: Back angles (mean ± SD) across percentiles during sitting at work in PDs and NPDs, with corresponding p-values for between-group comparisons.

Percentiles	Back angle while sitting (in degree): Mean ± SD		p-value
	NPD	PD	
10th	1.9 ± 1.2	1.9 ± 0.8	0.866

25th	4.5 ± 2.4	4.1 ± 1.7	0.593
50th	8.1 ± 3.3	7.0 ± 2.5	0.347
75th	11.8 ± 3.6	10.8 ± 3.2	0.425
90th	15.8 ± 4.9	14.8 ± 4.8	0.597
95th	17.8 ± 5.3	17.0 ± 4.6	0.684
99th	22.2 ± 4.8	22.8 ± 4.7	0.725

5.5 Back Function Changes Across Sessions

Spine height decreased from morning to the end of the workday and then partly recovered by the next morning, consistent with temporary spinal compression during a day of sitting and standing, followed by overnight unloading. Calf circumference increased slightly by the end of the workday, suggesting some fluid build-up in the lower leg, and then moved back toward baseline by the next morning; ankle changes were small. Flexibility on the sit-and-reach test improved after the workday and remained better the next morning. Back muscle endurance (Biering–Sørensen test) also improved, most clearly by the following morning. In contrast, the reflex response times of the low back muscles were highly variable and did not show clear changes across sessions. Low back motion was mostly stable over time. Bending forward, side bending, and twisting did not change meaningfully between sessions. There was a small reduction in backward bending (extension) from baseline to the next morning, but given the small sample and variability, this finding should be interpreted cautiously.

Table 9: Descriptive statistics (mean ± SD) across three sessions and pairwise comparison p-values for Session 1 vs. Session 2, Session 1 vs. Session 3, and Session 2 vs. Session 3.

Variable	Session Mean ± SD	Session 2 Mean ± SD	Session 3 Mean ± SD	Overall p value	Adjusted p value		
					S1–S2	S1–S3	S2-S3
Spine Height (cm)	83.74 ± 4.68	82.93 ± 4.61	83.59 ± 4.91	<.001	<.001	.564	<.001
Calf Circumference (cm)	38.65 ± 4.68	38.93 ± 4.62	38.46 ± 4.49	<.001	.019	.222	<.001
Ankle Circumference (cm)	21.82 ± 2.05	21.94 ± 2.06	21.77 ± 2.01	.012	.100	1.000	.013
Sit-and-reach Test (cm)	18.16 ± 8.61	19.98 ± 8.26	19.29 ± 8.44	<.001	<.001	.008	.030
BS Endurance test (sec)	76.38 ± 43.13	86.06 ± 39.06	99.13 ± 41.31	<.001	.179	<.001	<.001
Right Back Muscle Reflex Activation time (ms)	56.63 ± 38.67	63.86 ± 40.68	44.45 ± 29.29	0.369	1.000	1.000	.347
Left Back Muscle Reflex Activation time (ms)	67.92 ± 53.20	78.15 ± 40.52	53.03 ± 31.74	0.282	1.000	1.000	.142

(Note: Overall p-values represent results from the within-subjects repeated-measures ANOVA. Pairwise comparison p-values were adjusted using the Bonferroni correction for multiple comparisons.)

Table 10: Mean (± SD) low back range of motion across three sessions, with pairwise comparison p-values for Session 1 vs. Session 2, Session 1 vs. Session 3, and Session 2 vs. Session 3.

Variable	Session 1 Mean ± SD	Session 2 Mean ± SD	Session 3 Mean ± SD	Overall p value	Adjusted p value		
					S1–S2	S1–S3	S2-S3
Forward Bending (°)	53.41 ± 13.05	53.29 ± 14.77	53.42 ± 12.67	.996	1.000	1.000	1.000
Extension (°)	21.75 ± 10.86	19.61 ± 9.34	17.93 ± 9.83	.015	0.394	0.022	.404
Right side bending (°)	29.76 ± 5.42	30.56 ± 6.17	29.50 ± 5.99	.392	0.948	1.000	.495
Left side bending (°)	31.14 ± 5.31	32.46 ± 5.26	28.32 ± 10.06	.066	0.351	0.628	.135
Right twisting (°)	26.93 ± 7.47	26.03 ± 8.05	28.38 ± 8.21	.114	1.000	0.703	.093
Left twisting (°)	28.71 ± 9.71	27.52 ± 9.68	28.25 ± 9.84	.548	0.866	1.000	1.000

(Note: Overall p-values represent results from the within-subjects repeated-measures ANOVA. Pairwise comparison p-values were adjusted using the Bonferroni correction for multiple comparisons.)

6. Discussion

6.1 Feasibility and Acceptability of Study Design

A key aim of this study was to see whether it is practical and acceptable to use wearable sensors to monitor posture and activity in office workers in real life. Using ActiGraph sensors allowed us to objectively track sitting, standing, and walking, and to estimate changes in spine posture across the workday and leisure time. This approach overcomes the limitations of self-report measures, which cannot capture brief postural changes or exact sitting durations. Our findings, together with those of Davidson and Callaghan [50], show that long-term posture monitoring with sensors in real-world office settings is feasible. Our study also added pain ratings and physiological measures, making it possible to link sensor data with back pain outcomes.

All participants completed the initial 24-hour monitoring and all three lab sessions, showing that a one-day protocol was well tolerated and manageable. However, only 20% chose to continue wearing the sensors for the full 7-day period. This drop-off suggests that extended monitoring can feel burdensome and may require extra support (e.g., better incentives, reminders, or easier-to-wear devices) to maintain engagement. The most common problem was mild skin irritation from the adhesives, reported by 80% of participants. While usually minor and short-lived, this discomfort—especially around the lower back—was often mentioned as a reason for not continuing longer. Future work might use gentler adhesives, different sensor placement, or "rest days" without sensors to reduce irritation.

Importantly, we found meaningful differences in posture, pain, and back function after just one monitored workday and evening, suggesting that single-day monitoring can provide useful insights. However, people's posture and pain likely vary from day to day depending on workload, fatigue, and recovery. Evidence from Davidson and Callaghan [50] shows that while one day may broadly represent a person's typical posture, longer monitoring captures natural fluctuations that could be missed in a single day and may be relevant for long-term risk. A practical compromise for future studies may be to monitor at least two non-consecutive days (for example, early and late in the week) or to compare different weekday groups (e.g., Monday vs. Friday) to better capture this variability while still keeping the burden manageable.

6.2 Sitting Duration and Postural Dynamics at Work and LBP

A key question in this study was whether how much people sit, and how they sit during the workday and into leisure time, can help explain who develops LBP. Earlier research showed that simply counting "hours of sitting" has produced mixed results, with some large studies finding only weak or no links with LBP [51]. In our study, PDs did sit longer at work than NPDs, both in total minutes and as a percentage of their workday.

We also looked at postural dynamics—how the lower back moved while sitting—using distributions. This method shows how much time the low back is positioned at particular angles, giving a picture of how static or varied a person's posture is. Across the full range of angles (10th–99th percentiles), PDs and NPDs showed broadly similar patterns, and none of the differences were statistically significant. There was a hint that PDs sat in a slightly narrower "mid-range" of angles and NPDs showed more variation but these trends may simply reflect normal variation in a small sample. Overall, these results are exploratory and highlight the need for larger studies.

Previous lab studies have suggested that movement patterns matter for pain during sitting. Dunk and Callaghan [52], for example, found that people with existing LBP moved and "fidgeted" more during a 90-minute sitting task than those without pain, yet their pain still increased. In our study, PDs tended to be less dynamic during the workday, which seems different from those lab findings. Because our sample was small and our participants mostly had transient, workday-related pain rather than chronic LBP, these differences should be interpreted cautiously. It is possible that, in some cases, reduced posture changes might come before pain develops, suggesting that varying posture proactively could be helpful.

Overall, our exploratory results suggest that both total sitting time and how variable posture is while sitting may be relevant to discomfort, not just one or the other. Only a few previous studies have measured postural variability in real work settings, so this remains an important gap. Using wearable sensors, as in this study and in the week-long field work by Davidson and Callaghan [50], makes it possible to detect subtle but potentially meaningful differences in movement patterns. Together, these early findings support further, larger trials to test whether specific sitting patterns—like frequent posture changes versus long, fixed postures—are linked to higher or lower risk of LBP.

6.3 Uninterrupted Sitting Bouts and Break Frequency

A common concern is that long, uninterrupted sitting increases spinal discomfort because tissues are loaded for too long without relief. In this study, we did not find clear differences between PDs and NPDs in how often they broke up their sitting or how long a typical sitting bout lasted. Both groups changed posture a similar number of times per hour, and their average uninterrupted sitting bouts were very close (about 20 minutes in PDs vs. 18 minutes in NPDs, not statistically different). The longest single sitting bout was, on average, longer in PDs (about 75 minutes) than in NPDs (about 58 minutes), but there was a lot of variation between individuals, so this difference should be interpreted cautiously. Overall, these results suggest that prolonged sitting occurred in both groups, and larger studies are needed to know whether the patterns we saw are real group differences or just normal variation.

These findings fit with earlier research showing that long, static sitting increases discomfort and that changing posture helps [53,54]. However, in our data, simply having more sitting bouts (more sit-to-stand transitions) was not clearly protective. This may be because not all breaks are equal. Very short or low-effort breaks—like briefly standing up or fidgeting for a few seconds—may not be long enough or active enough to relieve back pressure or allow the discs and muscles to recover. Ergonomic advice often suggests standing up and moving every 20–30 minutes [55], and many participants in both groups seemed to do this to some extent. But if most of the day is still spent in long, relatively static sitting bouts, these small breaks may not be sufficient.

In summary, the broader literature supports the idea that frequent, active breaks (for example, standing and walking for a couple of minutes) are helpful for reducing sitting-related back discomfort, but our preliminary results suggest that routine short breaks—especially if brief or passive—may not be enough on their own. How long people sit without meaningful posture change, and what they actually do during breaks, may be just as important as how often they stand up. These are important questions for future research studies to answer.

6.4 Work vs. Leisure Postures and Activity – Context Matters

An important feature of this study was that we tracked posture not only at work but also during evening leisure time, allowing us to separate occupational and non-occupational sitting in relation to LBP. Most past research has focused mainly on workplace sitting, but newer evidence suggests that total sitting across the whole day also matters [12]. At work, sitting is often more constrained (e.g., at a computer), whereas at home people can usually move, stretch, or change posture more freely. In our study, PDs and NPDs spent similar amounts of time sitting during leisure, but differed in what they did when they were not sitting. NPDs spent a larger share of their leisure time standing or walking (about 16%) than PDs (about 9%). PDs spent more of their off-work time sedentary (sitting or lying), which may reflect tiredness or pain by the end of the day and a tendency to rest more. In contrast, NPDs may have felt better and stayed more active (e.g., chores, errands, light exercise). This extra light activity could help recovery by improving blood flow and disc nutrition, while long periods of sitting at both work and home may slow recovery and contribute to ongoing discomfort.

These findings suggest it is important to look at how total daily sitting is accumulated, not only what happens during work hours. An office worker who sits a lot at work and then remains sedentary at home may have a much higher overall exposure than someone who is more active after work. Our results fit with public health advice to reduce sedentary time and break up sitting across the entire day [15]. Although our findings are preliminary and not statistically significant, they point to useful future questions—such as whether encouraging more active leisure time or avoiding long periods of evening sitting can help reduce the impact of occupational sitting on back pain.

6.5 Cumulative Exposure and Temporal Dynamics of Pain Development

Our findings support the idea of cumulative exposure—back pain may not come only from what happens at work, or from a single sitting period, but from the combination of accumulated work and non-work postures across the whole day. An exploratory goal of this study was to track how pain changed over time, not just at the end of the workday. We identified people whose pain increased after work and then eased before bed, as well as people who felt fine after work but developed pain later in the evening. These patterns suggest that both daytime sitting and evening activities (for example, childcare, housework, or sports) can contribute to how pain is experienced over 24 hours.

6.6 Changes in Back Function and Recovery

This study examined how a full workday of mostly sitting affects the spine and back muscles over the day and into the next morning. Overall, changes within individuals were modest, but some clear patterns emerged. We found significant changes in spinal height, lower limb circumference, flexibility, and back extensor endurance, while lumbar range of motion and muscle reflex times changed only slightly. This suggests that one day of sitting does not dramatically damage back function, but it does produce small, measurable effects that may matter over time.

Spinal height decreased from morning to the end of the workday and then partially recovered overnight [27]. Not everyone returned fully to baseline by the next morning, which may indicate that some people recover less efficiently from daily spinal loading.

Reflex response times in the low back muscles did not show large or statistically significant changes, but there was a small delay after work and an apparent recovery or slight improvement by the next morning. This pattern is consistent with research showing that prolonged low-level loading and fatigue can temporarily slow back muscle responses [58]. While our sample was small and we did not compare PDs and NPDs directly, these early findings suggest that neuromuscular "readiness" may not fully bounce back in everyone, which could matter for long-term spinal stability.

Changes in calf and ankle circumference were small, suggesting only mild lower-limb fluid shifts with real-world occupational sitting. The average increase in calf size (~0.3 cm) was smaller than that reported in tightly controlled lab studies with strict, uninterrupted sitting [32,59]. Natural posture changes and incidental movements at work likely reduced swelling, supporting the idea that even brief, real-life micro-breaks help limit vascular pooling [60].

Back muscle endurance (Biering–Sørensen test) and flexibility (sit-and-reach) both improved across sessions, with the biggest gains seen by the next morning. These improvements may reflect a learning effect or short-term physiological changes (e.g., tissue warmth, repeated practice) rather than true training adaptations. Flexibility changes were generally modest and reversible, and we could not determine whether they clearly predicted LBP, although previous work suggests that lower flexibility may be linked to a history of back pain [61]. Low back range of motion remained largely stable, except for a small reduction in extension the next morning, which may reflect temporary stiffness or protective limitation after a day of sitting.

In summary, this study suggests that a single day of occupational sitting produces small but measurable physiological changes—such as reduced spinal height and subtle shifts in flexibility and endurance—without major short-term loss of back function. Because this was a feasibility study with a small sample, these results should be viewed as exploratory and hypothesis-generating, especially regarding differences between PDs and NPDs. Importantly, by measuring at three time points (morning, after work, and next morning), we were able to capture recovery patterns that a simple pre–post design would miss. This multi-time-point approach offers useful guidance for larger future studies aiming to understand how daily sitting loads influence musculoskeletal function, recovery, and LBP risk.

7. Strengths and Limitations of the Study

A major strength of this study is its methodological design. It is one of the few studies to combine objective, continuous data from wearable sensors to measure sitting, standing, walking, and spine posture in real life, and laboratory tests of back function to see how those daily exposures relate to short-term changes in the back. This pairing of field-based monitoring with lab-based testing allowed us to track both exposure (how people sit and move) and response (how their back behaves) in a natural work setting, rather than relying only on self-reported sitting time. Another strength is that we monitored participants across a full 24-hour period, including both work and leisure time, rather than focusing only on workplace sitting. This gave a more realistic picture of total daily posture exposure and short-term recovery. We also went beyond total sitting time and used sensor data to describe how people sit (posture variability and back angles over time), addressing a gap in the literature that usually treats all sitting as the same. A further strength is the active involvement of a participant (patient) partner throughout the project. They reviewed the study plan, observed lab testing, and suggested practical changes to improve comfort and accessibility (for example, performing the sit-and-reach test on a therapy plinth instead of the floor). Their input helped make the protocol more participant-friendly without losing scientific quality. This patient partnership also supports better knowledge translation, as they will help share the findings in clear, accessible ways with people who live and work with LBP.

This study also has several important limitations. First, the sample size was small and based on convenience sampling, which is typical for a feasibility study. The goal was to test procedures, not to detect small effects or make strong conclusions. As a result, many findings are exploratory and may not generalize to all office workers. Second, most monitoring was limited to one workday plus evening and overnight follow-up. This provides only a snapshot and may not reflect someone's usual week, especially as workload, fatigue, and symptoms can change from day to day. Without multi-day or week-long monitoring, we may have missed gradual or cumulative effects of sitting. Third, there were practical issues with the wearable sensors, especially mild skin irritation from adhesives. Although generally minor, this discomfort likely reduced willingness to wear the devices for longer periods and highlights the need for improved attachment methods or sensor designs in future work. Fourth, the observational design means we cannot say that sitting caused pain. Participants were not randomly assigned to different sitting patterns, and other factors (pre-existing pain, individual tolerance, job demands, mood, sleep, etc.) may have influenced both posture and symptoms. Fifth, although we examined overnight recovery, we did not measure sleep duration, sleep quality, or sleep posture. These factors can strongly affect musculoskeletal recovery and may have contributed to differences in next-morning outcomes. Finally, participants knew their posture was being monitored, which may have changed their behavior (Hawthorne effect). Some might have taken more breaks or tried to sit "better" because they were in a study. While our data and feedback suggest most people quickly got used to the sensors, we cannot fully rule out subtle behavior changes that could underestimate typical "worst-case" sitting exposure.

8. Direction for Future Research and Conclusion

This study showed that it is both possible and acceptable to use wearable sensors to monitor sitting behavior, posture, and back function in real-world settings. By combining continuous sensor data with tests of back function in the lab, the study provided an early look at how a typical workday of mostly sitting might affect the spine and LBP. Because this was a feasibility study with a small group of office workers, the results are exploratory rather than final – they are meant to guide and improve future research, not to offer definitive answers.

From a feasibility point of view, the study was largely successful. Most participants tolerated the sensors well over a 24-hour period and completed all three lab sessions. This short-term monitoring captured detailed information on how long people sat, how often they changed posture, how their spine moved, and how their backs felt across the day and overnight. The pairing of this "real-life" exposure data with pain ratings and back function tests is a key strength and shows that this kind of work can be done in everyday office environments, not just in the lab. At the same time, the study clearly identified limits. When participants were invited to keep wearing the sensors for another six days, only a small number agreed. The main reasons were mild skin irritation from adhesive pads and discomfort during sleep or physical activity. This suggests that while one-day monitoring with adhesive-mounted sensors is very workable, long-term continuous monitoring in its current form is more challenging. Future studies will need to explore better sensor designs (e.g., softer straps, textile-based devices, or smaller units) and smarter monitoring schedules (for example, non-consecutive monitoring days) to reduce burden and improve long-term participation.

The early patterns observed in this study are consistent with biomechanical ideas about how sitting might contribute to back discomfort. Participants who reported increased pain after a workday tended to spend more of their workday sitting, had longer uninterrupted sitting bouts, and showed less variation in posture. Those who stayed pain-free were more "dynamic": they changed posture more and were more likely to spend their leisure time standing or walking, rather than remaining sedentary. Small but measurable changes in spinal height, back endurance, and flexibility over the day suggest that prolonged sitting does load the spine and back muscles, even if these changes are mostly reversible by the next morning. These findings support the idea that how long people sit, how often they move, and what they do after work all matter, not just total "hours of sitting" at the office. However, this study was not designed to prove cause and effect. The sample was small, the monitoring period was short (essentially one main workday), and participants were observed, not assigned to different sitting patterns. Important factors such as sleep quality, stress, mood, and workload were not fully measured. As a result, we cannot say that certain sitting behaviors caused pain; we can only say that certain patterns appeared more often in people who reported more discomfort. These limitations are typical of feasibility work and underline the need for larger, longer, and more controlled studies.

Looking ahead, future research should build on this foundation in several ways. Larger longitudinal studies are needed to follow people over multiple days and weeks, across different types of jobs and age groups. These studies should monitor work and non-work hours, and include validated measures of sleep, mood, and workload. With bigger samples and longer follow-up, researchers could test whether specific patterns – such as long uninterrupted sitting, low posture variability, or very sedentary evenings – reliably predict who develops or maintains LBP. This would help establish the timing and direction of effects (for example, whether changes in sitting behavior come before pain, or whether pain leads to more sitting). Experimental studies, such as randomized controlled trials, will also be important. These could test practical strategies to reduce or break up sitting (for example, scheduled walking breaks, sit–stand desks, or movement prompts) and then use wearable sensors to verify whether these strategies truly change behavior and reduce symptoms. The technology used in this feasibility study is well suited to monitor such interventions. In the future, real-time feedback systems could be tested – for example, apps or devices that gently vibrate or send a message when someone has been sitting too long or is holding a very static posture. Finally, sleep should be a stronger focus in future work. Because overnight rest is when tissues rehydrate and recover, differences in sleep duration, quality, and posture could explain why some people bounce back quickly while others still feel stiff or sore the next morning. Incorporating sleep questionnaires or devices that can track sleep and movement would give a more complete picture of how sitting, recovery, and pain interact across the full 24-hour cycle.

In summary, this feasibility study does not provide final answers about how sitting causes LBP, but it offers a solid, methodologically sound starting point. It shows that we can measure sitting behavior and back function in real life, identifies promising patterns and challenges, and lays the groundwork for future research and practical strategies to reduce LBP risk in office workers.

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Appendix 1: Activity Diary

24 hours Activity Diary			
woke up			
			*instrumentation felt weird, jiggling, uncomfortable, shower?
Time	**Posture**	**Activity**	**Notes**
8:30 AM - 8:45 AM			
8:45 AM - 9:00 AM			
9:00 AM - 9:15 AM			
9:15 AM - 9:30 AM			
9:30 AM - 9:45 AM			
9:45 AM - 10:00 AM			
10:00 AM - 10:15 AM			
10:15 AM - 10:30 AM			
10:30 AM - 10:45 AM			
10:45 AM - 11:00 AM			
11:00 AM - 11:15 AM			
11:15 AM - 11:30 AM			
11:45 AM - 12:00 PM			
12:00 PM - 12:15 PM			
12:15 PM - 12:30 PM			
12:30 PM - 12:45 PM			
12:45 PM - 1:00 PM			
1:00 PM - 1:15 PM			
1:15 PM - 1:30 PM			
1:30 PM - 1:45 PM			
1:45 PM - 2:00 PM			
2:00 PM - 2:15 PM			

Appendix 2: Participants' Contact Information Collection Form

Participant ID: ___________________________

Preferred Method of Diary Completion:

- Online (Google Document) ☐
- Offline (Printed Copy) ☐

Contact Details:

- **Email Address:** ____
- **Phone Number:** ____
- **Preferred Contact Method:**
  - Email ☐
  - Phone Call ☐
  - SMS/Text Message ☐

Consent for Participation and Contact:

By signing below, I consent to being contacted by the research team for the purpose of reminders to complete the activity diary and to rate my perceived back pain at specified intervals. I understand that my contact information will be used solely for this purpose and will be kept confidential.

Participant Signature: ____________________________

Date: _________________________________

Appendix 3: Questionnaire 1 – Likert Scale to Assess Feasibility of the Study Design

Please choose to what extent you agree/disagree with the following statements according to your experience in this study. Please choose your option by giving a (√) mark

	Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
I did not mind attending the lab sessions					
Wearable devices did not interfere in my usual tasks at home					
Wearable devices did not interfere in my usual tasks at work					
Wearable devices were not bothersome to me					
All study information and instructions were easy to understand					
I would recommend using the same study procedure to assess sitting behaviors of workers					

Appendix 4: Questionnaire 2 – Open-ended Questions to Assess Feasibility of the Study Design

Open-ended questions regarding involvement of the participants with the study design and protocol. Please answer the following questions.

1. What are your reasons for deciding to participate in the study?
2. Were there any difficulties for you in participating in this study?
3. Did you experience any barriers to attending the lab sessions? If so, what were they?
4. What things made it easier for you to attend the lab sessions?
5. Thinking about the lab sessions, what did you like and not like?
6. Were there any difficulties for you in wearing the wearable devices for continuous 24 hours?
7. Do you think wearing wearable devices interfered your normal activities at home? If so, why?
8. Do you think wearing wearable devices interfered your normal activities during working hours at the workplace? If so, why?
9. Do you have any ideas about how we might increase recruitment, retention, and adherence rates for this study?
    - The recruitment rate means the percentage of participants who enrolled in the study compared to the number of participants who will express interest in participating in the study.
    - The retention rate means the percentage of study participants who will continuously wear the wearable devices for 24 hours and attend all three laboratory sessions.
    - The adherence rate to wearing the sensors means the percentage of participants that successfully wear the sensors for the entire study period (except in case of any adverse reaction to the skin).

The adherence rate to lab sessions means the percentage of participants who attended all three lab sessions compared to the recruited participants.