

BuddyBack: A Multimodal Smart Posture Correction System

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ABSTRACT

Poor posture affects over 65% of children and 41% of office workers, contributing to musculoskeletal pain and significant productivity losses. This paper introduces *BuddyBack*, a multimodal smart posture correction system comprising a desk-mounted edge device, an RGB camera, a haptic vibration motor, and a web-based dashboard. The system performs real-time pose estimation using MoveNet, delivering corrective feedback through simultaneous visual and tactile channels. Fully on-device inference ensures low-latency feedback and preserves user privacy by keeping all video data local. Usability tests demonstrate that all participants reported increased postural awareness, with 70% rating feedback clarity at the highest level and zero reported intrusiveness. These results validate the effectiveness of ambient, multimodal feedback loops for ergonomic intervention.

CCS CONCEPTS

• Human-centered computing → Haptic devices; User studies.

KEYWORDS

posture monitoring, multimodal interaction, haptic feedback, edge computing

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1 INTRODUCTION

Postural disorders are highly prevalent, affecting 65.3% of Chinese children and adolescents [16], 79.3% of Portuguese students [10], and 41.6% of Iranian office workers [4]. The economic impact is substantial, with poor posture causing work-related musculoskeletal disorders that significantly decrease worker productivity [8]. To

mitigate these risks, recent research has focused on digital health interventions that leverage continuous, automated posture tracking. However, delivering real-time corrective feedback within these systems without disrupting the user's natural workflow remains a significant challenge [1]. Existing solutions each address part of this problem, but introduce distinct trade-offs: wearables require constant body contact [6], furniture-embedded sensors tie monitoring to specific equipment, and screen-only visual alerts are easily ignored during focused work. To address these limitations, we introduce BuddyBack, a desk-mounted edge system designed to decouple posture monitoring from specialized furniture or wearables, employing an ambient multimodal interaction approach to deliver corrective feedback without inducing alert fatigue. Utilizing subtle haptic interventions, the system provides immediate, non-visual correction that operates below the threshold of conscious annoyance [14], allowing users to adjust their posture without interrupting their primary on-screen visual workflow.

2 RELATED WORK

Recent work demonstrates that posture monitoring is no longer confined to a single sensing modality. Wearable solutions such as the Smart Lumbar Vest combine inertial-measurement units with on-body vibration motors and a companion Android app to warn users the instant they slouch [9]. Furniture-embedded approaches push sensing into the environment: the IoT “Smart Chair” integrates pressure and distance sensors in seat and backrest cushions to flag incorrect sitting positions in real-time [7]. Other researchers have fused electromyography with flex sensors in the Posture Guardian wearable, showing that TinyML models can run entirely on-device and still provide timely haptic cues [5]. Hybrid sensor stacks can be low-cost as well, an ultrasonic load-cell desk add-on reaches 99% detection accuracy while keeping the bill of materials under \$30 [12]. Camera-only systems like SmartPosture pair CNN-based pose estimation with flexible sensors and deliver corrective feedback through both web and haptic channels [13]. Collectively, these studies validate the feasibility and user acceptance of multimodal, real-time feedback loops, an insight that directly informs BuddyBack's design philosophy. BuddyBack extends existing posture monitoring approaches by avoiding wearable devices [5, 9] and specific furniture dependence [7], while combining camera-based on-device inference with haptic feedback and a gamified dashboard

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for privacy-preserving, long-term posture tracking [13].

3 SYSTEM DESIGN

Our system introduces a compact, edge device housed in a custom 3D-printed enclosure, designed to be placed laterally on the desk surface at approximately 1 meter from the user. From this profile perspective, the system captures the user’s upper body and provides real-time multimodal feedback: tactile alerts are propagated indirectly through desk-surface vibrations, while postural scores are shown on an integrated visual display. Figure 1 shows the operational setup (left) and the assembled prototype (right). Hardware components include a Raspberry Pi 4 for power-efficient computation, a USB RGB camera with a 90° field of view (ideal for typical desk setups), a 4.3-inch LCD touchscreen, and a vibration motor. Critically, all pose estimation runs locally, and camera images are never transmitted over the network, fully preserving user privacy [11].



Figure 1: Setup (left), assembled prototype (right).

3.1 Posture Analysis Algorithm

The system employs MoveNet Lightning [15] to extract body joints, selected for its balance between performance and efficiency. On the Raspberry Pi 4, the model achieves an inference speed of 17 FPS while maintaining robust tracking under varying lighting conditions. Based on the extracted joints, the system computes three posture scores ranging from 0 to 100: **Neck score** measures the flexion and extension of the neck by tracking the angle and vertical deviation between the ear and shoulder joints, capturing forward head tilt. **Torso alignment score** evaluates the angle between hip and shoulder joints relative to the vertical axis, detecting forward leaning or slouching behaviors. **Shoulder symmetry score** computes the Euclidean distance between the left and right shoulder joints, identifying asymmetrical positioning or leaning to one side.

The system implements temporal smoothing through sliding window analysis at two time scales: a 30-second window for real-time User Interface (UI) updates and a 120-second window for alert generation, in order to filter transient movements while remaining sensitive to sustained postural deviations.

3.2 On-device User Interface

The device runs an on-device user interface displayed on the built-in display. As shown in Figure 1, the interface adopts a split-screen layout: the left panel presents real-time posture metrics through progress bars for the neck, torso, and shoulders, with colors transitioning from green through yellow to red according to configurable sensitivity thresholds. Numerical scores provide quantitative precision, while color coding enables an at-a-glance assessment. The right panel shows the live camera feed augmented with MoveNet

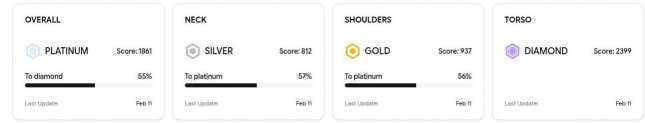


Figure 2: Gamification badges displayed in the web interface. skeleton joints and postural reference lines, allowing users to verify that the camera correctly detects their position [3] and to self-correct minor deviations by observing their own posture in real-time.

3.3 Haptic Feedback

The vibration motor provides tactile alerts when prolonged postural misalignment is detected. To calibrate the alert threshold, a preliminary qualitative user test was conducted involving 10 participants who used the device for 45 minutes. Feedback was collected through short interviews to evaluate user comfort and responsiveness, as triggering alerts too frequently causes annoyance, while triggering them too rarely renders the device ineffective. Based on these tests, the system sends an alert when the user has maintained poor posture for at least 50% of the time in the past two minutes, provided that no alert was issued in the previous five minutes. This cooling period prevents alert fatigue while ensuring timely corrections. The haptic alert consists of a discrete sequence of three 500ms pulses that terminate automatically without requiring user intervention. The vibration is transmitted indirectly through the desk surface on which the device rests, rather than requiring direct contact with the user’s body. This design choice proves particularly effective: desk-conducted vibrations are immediately perceptible without being intrusive, and the physical coupling between device and surface ensures reliable signal propagation regardless of user position. Once an alert has been triggered, the system starts a countdown before any subsequent vibrations can be activated, further reducing the risk of disturbance. Grounded in multimodal interaction principles, vibrations provide alerts without interrupting the user’s primary visual task or forcing gaze shifts. In preliminary tests, users explicitly preferred this over audio alerts, noting that haptics are less embarrassing in shared workspaces and less disruptive to concentration. Furthermore, users can customize vibration intensity to their personal sensitivity directly from the web interface settings, ensuring the alert remains perceptible without becoming a source of distraction.

3.4 Web Interface

BuddyBack features a responsive web dashboard that allows users to customize settings, monitor long-term statistics and engage with a gamification framework. The gamification system is built around a multi-category ranked tier structure that progresses from BRONZE to SILVER, GOLD, PLATINUM, and DIAMOND, with each tier represented by a custom badge. Rank cards distributed across the dashboard highlight the user’s progress: each card shows the current score together with a progress bar toward the next tier, turning abstract self-improvement into a tangible progression indicator (Figure 2). Alongside the ranks, the application tracks usage streaks through a prominent “X days streak” label, a consistency score that rewards regular posture sessions, and a session-tracking system that summarizes activity across daily, weekly, and monthly views.

4 USER SURVEY

To evaluate the system’s usability and perceived effectiveness, we conducted user tests with 30 participants, mainly university students. Each participant was asked to use their computer as they normally would during a typical work or study session. Participants received only minimal instructions: they were briefly informed about the device’s purpose, but no guidance was provided on how to interact with the interface, thereby allowing an assessment of the system’s intuitiveness. During the sessions, we observed how participants reacted to feedback. After each session, participants completed a questionnaire with items rated on a 4-point scale covering: feedback clarity, daily use comfort, perceived postural awareness improvement, and adoption willingness. Additionally, the questionnaire concluded with an open-ended item to capture qualitative feedback and broader reflections on the user experience.

4.1 Quantitative Results

The age distribution of the 30 participants was: 60% aged 18–24, 30% aged 25–34, and 10% over 35. **Clarity.** 70% of testers rated feedback clarity at the highest level (4/4), with the remaining 30% giving 3/4. Display information clarity was rated 4/4 by all but one participant, who gave 3/4 citing initial difficulty in interpreting the numerical score values. **Acceptability.** Initial tests revealed that the vibration frequency was too high, prompting complaints about excessive alerts. Adjusting sensitivity thresholds and increasing the alert cool-down, user satisfaction improved significantly. In the final configuration, 70% of testers stated the product was not annoying at all, and no user rated the system 3 or 4 out of 4 on the intrusiveness scale. Some participants noted that the slight nuisance of the product was actually beneficial, as it encouraged good posture to avoid being “disturbed” by vibration. **Postural awareness.** All testers reported improved postural awareness: 70% gave the maximum 4/4 rating, with the remaining 30% rating it 3/4. **Adoption potential.** When asked whether the product was helpful, 50% rated it 4/4, 40% gave 3/4, and 10% gave 2/4. Regarding daily-use comfort, 60% rated it 4/4 and 40% rated 3/4.

4.2 User Insights

Participants identified several strengths of the system. The complementary visual and haptic feedback was widely appreciated: users valued being able to check their posture status on the display in addition to receiving vibration alerts. Several testers noted practical benefits for preventing neck pain during prolonged computer use. The non-intrusive nature of vibration compared to audio alerts was frequently cited as a key advantage. Areas for improvement included: reducing webcam preview latency, likely due to Raspberry Pi 4 hardware limits and addressable with a more powerful single-board computer; reducing vibration motor noise by selecting a higher-quality component; and adding chair height detection to alert users when their seat is too high or too low.

5 CONCLUSION AND FUTURE WORK

BuddyBack suggests that a low-cost posture correction system combining camera-based pose estimation with visual and haptic feedback can effectively promote postural awareness without being intrusive. The dual-channel feedback strategy was effective

and well-tolerated by all participants, and user evaluations confirm the practical value of this approach in promoting healthier ergonomic habits. Future work will investigate long-term user adherence and habituation, while improving hardware issues such as webcam latency and motor noise. Software improvements will include replacing the fixed geometric scoring system with a personalized adaptive model. Using privacy-preserving, on-device machine learning [2], the system will learn individual body proportions and postures locally, enabling tailored feedback across diverse users and workspaces without transmitting sensitive data.

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