GymSoles++: Using Smart Wearbales to Improve Body Posture when Performing Squats and Dead-Lifts

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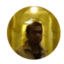

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ABSTRACT

Squats and dead-lifts are considered two important full-body exercises for beginners, which can be performed at home or the gymnasium. During the execution of these exercises, it is essential to maintain the correct body posture to avoid injuries. In this paper, we demonstrate an unobtrusive sensing approach, an insole-based wearable system that also provides feedback on the user's centre of pressure (CoP) via vibrotactile and visual aids. Solely visualizing the CoP can significantly improve body posture and thus effectively assist users when performing squats and dead-lifts. We explored different feedback modalities and conclude that a vibrotactile insole is a practical and effective solution.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; *Haptic devices*; User studies.

KEYWORDS

Smart Insoles, Improving Body Posture, Center of Pressure, Google Glass, Squats, Dead-lifts, Vibrotactile Feedback, Visual Feedback, Vibrotactile Insole, Sensory Extrimities

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1 INTRODUCTION

The proper execution of exercises is important to achieve desired training goals and to prevent the occurrence of various injuries. Exercises, such as squats and dead-lifts, are elemental full body exercises [3, 9] and contribute to a healthy body when executed properly. Existing assistive systems to evaluate exercises, such as squats and dead-lifts, usually rely on expensive motion tracking systems [2], or on multiple Inertial Measurement Unit (IMU) systems [6]. Both solutions have clear limitations in a gym setting, as they are highly obtrusive, require inconvenient setup, and extensive calibration. Alternative solutions, such as force plates, are bulky and generally developed for laboratory use. We view smart insoles to be a possible solution, as they provide rich information and overcome many issues previously mentioned [8]. Currently, commercial smart insoles, such as Nike+ [1] and Adidas MiCoach [5], track user activity including step counting and stride information. While these metrics may be useful, the lack of immediate feedback severely limits their effectiveness.

Figure 1: User performing squats with the GymSoles++ prototype. The pressure sensitive insole calculates the body's Center of Pressure (CoP). A rubber layer on top of the insole incorporates 8 vibration motors that map the CoP to vibrotactile feedback. The CoP is also visually displayed on a Google Glass.

Previous research [4] introduced an insole-based approach utilizing foot pressure data, with the focus to improve body posture during squats and dead-lift exercises. The user's needs had been identified and possible system requirements were derived by conducting expert interviews with four professional trainers. Consequently, a proof-of-concept system was developed and user studies were carried out to evaluate two feedback types interpreting the Centre of Pressure (CoP); 1. Vibrotactile feedback at the side walls of a shoe and 2. Visual feedback on a screen. Independent from the feedback type, it has been found that solely visualizing the CoP resulted in an improved body posture. Considering the insights provided, we further developed the system satisfying the users' and reviewers' suggestions.

In GymSoles++, we introduce a flexible force-sensitive vibrotactile insole connected to a Peripheral Head-Mounted Display (a pair of Google Glass) providing visual feedback wherever the user is performing exercises (*see Figure 1*). Unlike the previous system [4], GymSoles++ is fully mobile and provides a further tweaked feedback aiming to be less obtrusive.

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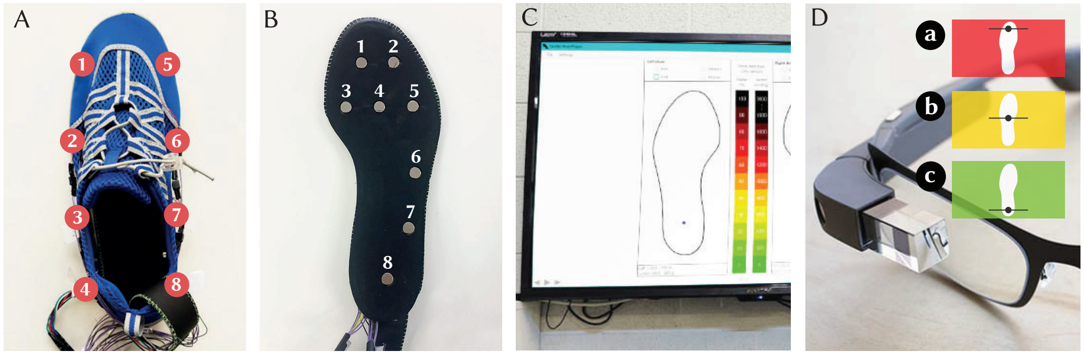

Figure 2: A: Shoe prototype (UK size: 10-11). The sensing.tex FSR-based plantar pressure insole is inserted and 8 vibration motors (ROB-08449) are attached at the inside of the shoe's wall. B: 3D-printed insole Prototype (UK size: 10-11). Then pressure insole is covered by a 6mm thick rubber layer (ninjaflex 85A filament) that incorporates 8 vibration motors. D: Visualization at the static Monitor. The black dot visualizes the user's CoP. C: Visualization at the PHMD of our choice: Google Glass. The changing background color enables the user to perceive this information with his peripheral vision, without visually focusing the display.

2 GYMSOLES++

2.1 Motivation

The motivation of this work is based on a variety of suggestions and other qualitative insights gathered from the earlier GymSoles evaluation. Since users asked for a less obtrusive feedback. Designing subtle feedback seems to be particularly challenging as feedback should just noticeable, but not obtrusive. As a first step, we developed a fully mobile prototype that allows the user to move freely. We 3d-printed a flexible insole and attached vibration motors to it. As the foot's cornea reduces the perception of sensitivity, the vibrotactile feedback under the feet may be perceived as less obtrusive. Moreover, in addition to the previous evaluation, where we used a stationary LCD screen, we also developed a visualisation on a peripheral head-mounted display (PHMD) [7] – a pair of Google Glass.

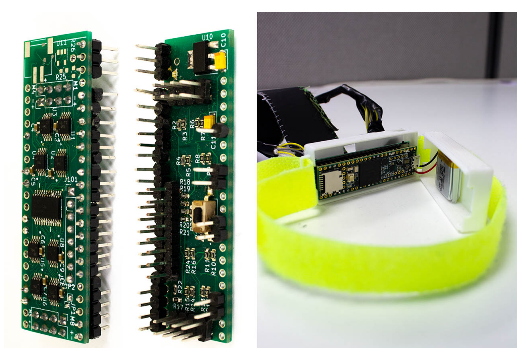

Figure 3: Customized PCB consisting of 8 Motor Drivers and Multiplexers. It is designed to plug a Teensy 3.6

2.2 Miniaturized Hardware

To make the system truly mobile, we developed a custom PCB (*see Figure 3*). The board is capable of computing the pressure data from the sensing.tex insole and controlling 8 vibration motors. Hence, the PCB incorporates 8 DRV 2605L Motor Drivers. An I2C multiplexer, TCA9448A, interfaces with a Teensy 3.6, as all the drivers have the same fixed I2C address. A voltage divider circuit is integrated to interface with the pressure sensitive insole. A Bluetooth Low Energy modem by Nordic is also included enabling wireless communication with our visual feedback systems, such as the Google Glass. The entire hardware is enclosed into a small white box that can be strapped around the ankle.

2.3 Vibrotactile Feedback

The previous GymSoles incorporated vibration motors attached to the side wall of a shoe (*see Figure 2 - A*). As the sock increases the attenuation, the motors were driven with max power, creating an extra noise. In GymSoles++, we designed a flexible vibrotactile insole, which has 8 motors embedded into the insole itself (*see Figure 2 - B*). The placement of the motors were primarily decided according to the density of the cutaneous sensory extremities of the sole. Although thick cornea of the foot sole dampens perception, when embedding the motors this way, the prototype provides feedback by directly stimulating cutaneous sensory receptors of the soles. Hence, we set the vibration intensity to a lower level than before to minimise the noise generated. The rubber insole was 3d-printed from a ninjaflex 85A filament.

2.4 Visual Feedback

Previously, a Java application developed for a large monitor provided visual feedback (*see Figure 2 - C*). If the display is situated unfavourably, this forces the user to angle the head in a manner that loses focus. As a solution, we modified the visualisation and fit it as an Android app running on Google Glass. To make the visualisation clearer, the background color was also changed, such as from green to red, according to the deviation of CoP from the correct location. This way, the user can perceive visual feedback without focusing on the display (*see Figure 2 - D*). Once visually focused on the screen, the user can see a more precise visualization of his CoP. Our PHMD, Google Glass, receives CoP data from our prototype via Bluetooth LE.

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