AN INSTRUMENTED TOILET SEAT FOR ANALYZING SIT-TO-STAND

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Introduction

The ability to independently maneuvre oneself on and off a toilet is an essential everyday task that becomes increasingly difficult with age. In fact, such sit-to-stand (STS) transitions are very physically demanding and are responsible for 41% of falls within nursing home [1]. Clinicians commonly test physical function of patients by measuring their time to complete a repeated STS transition test. However, movement is a key determinant of STS strategies [2], and in-lab studies have shown that kinematics can give additional health insights above timing alone [1,3]. Unfortunately, high fidelity quantitative methods to measure human movement are widely unavailable due to their dependence on necessary laboratory technology including motion capture equipment, force plates, experienced personnel, and more. In this study, we developed an instrumented toilet seat that measures the biomechanics of sitting and standing in order to monitor the physical health of patients with or at risk of mobility issues.

Methods

We performed an experiment where four healthy, young participants completed a series of sit-to-stand tasks using the instrumented toilet (Fig. 1). These tasks included sit-to-stand at a "comfortable" speed, two times slower than "comfortable" (enforced with a metronome), as fast as possible, with forward trunk lean, and while leaning to the right side. We used video-based motion capture as a reference, synced with the forces recorded by the instrumented toilet seat. An OpenSim biomechanics model was used to evaluate the kinematics and relate them to the forces detected by the instrumented seat.

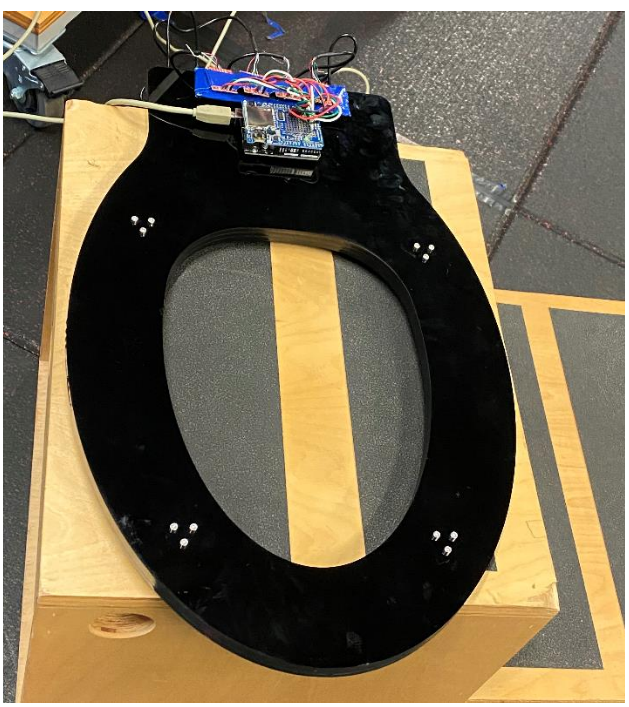

Figure 1: The instrumented toilet seat prototype. Four force sensors (with a max loading of 50kg) are placed between the seat and the ground, bearing the full weight of the participant. The sensors are individually measured, allowing for careful comparison of forces between each of the four locations to determine center of pressure and weight magnitude.

Results and Discussion

We found strong correlations between metrics collected with the instrumented toilet seat and biomechanics metrics extracted from video-based motion capture. This included detecting trunk lean, distal-proximal shifts in weight, time transitioning from sit-to-stand, and location of center of mass. We believe that a larger sample size of participants would find significant results.

We believe further experimentation with clinical populations could find significant relationships between the forces measured by the instrumented toilet and clinically relevant metrics for monitoring disease or injury progression over longitudinal, at-home use. These populations include older adults, people with knee osteoarthritis, people recovering from an injury or surgery, and people with muscle weakness that makes sit-to-stand a challenging task.

We found that a simple set of force sensors in a toilet seat can reliably detect clinical measures related to the challenging task of performing a sit-to-stand transition. This instrumented toilet seat could be a simple and effective way of monitoring biomechanics at-home to improve the information a patient and health team can use to improve a patient's independence.

Significance

This study suggests that embedding common and low-cost sensors in a toilet can provide accurate and frequent analyses of movement. This biomechanics tool could provide clinically accurate monitoring capabilities into patients' homes. The device can distinguish between different movement patterns by measuring force and time and remotely communicates information indicative of patient broader physical health and independence to clinicians or assisted living staff.

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References

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