Understanding Movement: Feasibility of Injury Prevention and Rehabilitation with Spinal Sensors

Daniel Gioia, Claudia B. Rébola
Rhode Island School of Design

ABSTRACT

This experiment was designed using a triangular approach to discover and test the viability of potentially using inertial measurement unit (IMU) sensors to monitor spinal movement and assist those with joint and spine injury in understanding recuperative and detrimental spinal movement throughout an exercise or activity.

Seven subjects (four male, three female) were outfitted with ~~a~~ three panels to replicate and visualize what the sensors would track. They were asked to perform one or more of the following: a series of commonly prescribed physical therapy rehabilitation exercises, a variety of skill-based tasks, and/or a seated activity. The positions of the panels varied depending on the focus area of rehabilitation and the tasks performed.

The results indicated that subtle movements of the body were able to be tracked over time – including flexion, extension, and torsion. Visibility of poor form and posture were amplified. The results also indicated the patterns in movement and fluidity between those proficient in skill based activities, as well as those who were somewhat novice.

INTRODUCTION

Back pain is a serious issue. It is estimated that roughly 80% of people will experience back pain at some point in their lifetime. Lower back pain (LBP) is the leading cause of disability, and costs billions of dollars annually. Back pain can appear in a variety of forms, and originate from a vast number of injuries and sources.

While there are remedies for certain back problems, there are many spinal injuries that have very few treatment options. Problems such as disc injuries are lifelong problems that never truly heal.

The spine itself is a complicated series of vertebrae and discs that work synergistically to serve a series of important tasks. The spine supports your body and gives you structure, allows you move, bend, and lift things, and protects your spinal chord – the most important nerve in the body.

Through the spinal chord, feedback is sent back and forth from the brain to the body. When one of the discs between the vertebrae begins to bulge, herniate, or degenerate, pressure is placed on the spinal chord, which produces pain, limits range of motion (ROM), and often causes crippling numbness. Unfortunately, once a disc is injured in this way, the options are limited. Physical therapy, steroid injections, or invasive surgery are some of the only remedies for injured discs, and even with these options, the disc never truly heals.

<u>Physical Therapy</u>

Physical therapy has been proven effective in keeping pain from disc injury at bay, as it has for many other types of injuries. Unfortunately, physical therapy can be expensive, and the effectiveness of the exercises wears off after patients stop visiting their physical therapist, despite continuing the exercise regimen laid out for them. Relapses are frequent. Approximately 70% of patients suffering from LBP have one or more relapses within the first year of the event of injury.

To those injured, there is an enigmatic aspect to the recurrence of pain. In a previous study, it revealed that those disabled were unaware of what was triggering their relapse. While those suffering are often health literate, something is not translating in the interpretation and application of self-management of back pain.

One logical reason that the majority of self-management pain methods are failing, is that without having a medical expert like a physical therapist to monitor your form and workout routine, exercises are not performed to their effective limit. Misinterpreting the movement and position of one's own spine during an exercise is a common problem in all facets of fitness. There is currently no system for replicating the function of a physical therapist or tool for measuring spinal movement outside of a clinical setting.

PURPOSE

The purpose of this experiment was to test the accuracy of using IMU sensors to monitor spinal movement. This experiment was crafted in hopes of leading to a possible solution or system to reduce the relapse from spinal injury and to put the health of those debilitated back into their own hands – reducing the cost, complexity, and mystery behind spinal injury.

METHOD

<u>Subjects</u>

The subjects tested consisted of four males and three females, ages ranging from 22 to 29. While only one of the subjects suffered from a spinal injury, they were all able to successfully complete all of the tasks they were assigned in order to produce relevant data.

Data Collection Tool

In order to simulate the IMU sensors, three panels were placed in specific locations on the body by fastening them to compression shirts, sleeves, and leggings. The locations of these sensors depended on the targeted area of study.

For spinal movement, the first panel was placed between the scapulae (shoulder blades), the cervical curve, and the thoracic curve of the spine. The second was placed directly below the first, between the thoracic and lumbar curves, and the last panel was placed below the second, between the lumbar and sacral curves (Figure 1).

For leg movement, the first panel was placed on the side of the hip directly on the iliac crest. The second panel was placed in the middle of the thigh facing outward. The last panel was placed on the calf, also facing outward.

And lastly, for arm movement, one panel was placed on the upper arm facing outward, the second was placed on the forearm facing outward, and the third panel was placed on the back of the hand.

To track movement, the position of each panel was measured relative to the position of each other panel and the ground using an angle finder and a tape measure. Data was manually recorded into a notebook and was later plugged into a spreadsheet for comparison and analysis.

Triangulation

In order to properly confirm the validity of the results, design triangulation was implemented. What this means is that three approaches to testing of this concept were applied to the experiment. Having three different tests that produce accurate data and measurements confidently confirms that the measuring technique has validity.

Experiments

Physical therapy replication. Subjects were asked to perform a series of physical therapy rehabilitation exercises while wearing the three panels.

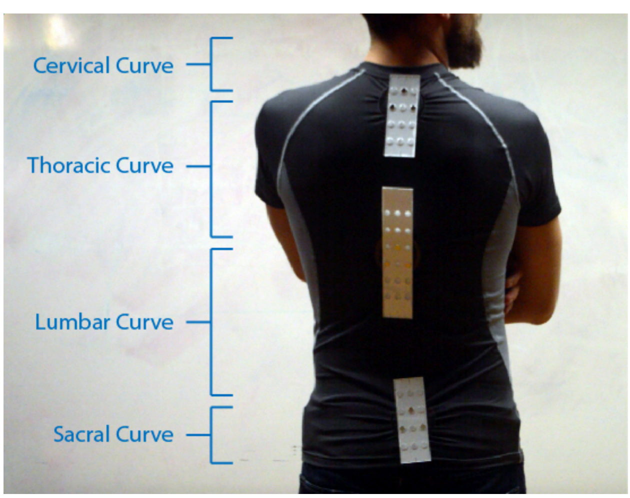

Figure 1: Subject wearing spinal panels.

Subjects first wore the three panels along their spine and performed five commonly performed disc injury physical therapy exercises in front of a camera. The exercises consisted of the following: planks, side-planks, spinal extensions, quadruped arm/leg raise and cat/camels. Angles of the panels were measured and documented at various points during each exercise to determine flexion, extension, and torsion, especially in moments of form and postural degradation.

Subjects then wore three leg panels and performed five commonly performed knee injury physical therapy exercises. The exercises consisted of body-weight squats, quadriceps stretches, wall squats, quadriceps isometrics, and supine hamstring stretches. Again, angles of the panels were measured and documented at various points during each exercise. Special note of the knee angle was taken in moments of bad form.

Subjects were then outfitted with three arm panels and were asked to perform elbow and wrist physical therapy exercises. Those exercises included wrist flexion, wrist extension, forearm pronation/supination, radial/ulnar deviation, and broom handle extensions. The angles of the panels were again measured throughout the exercises. When form started to waiver, additional measurements were taken.

Skill-based tasks. Subjects were asked to perform skill-based tasks wearing panels on their arms. Upper arm, forearm and hand movement were all measured and compared between subjects who considered themselves experts in the performed tasks and those who considered themselves novice. This was measured to see if patterns in the skills were visible and to see if the differences in movement and form were apparent.

First, the subjects were asked to simply hammer a nail into a piece of wood. A video camera was set up on the profile of each subject to assist in the analysis. Angles were then measured afterward by using the footage as to not disturb the natural flow of the movement.

Next, the subjects were asked to throw a Frisbee. Again, a video camera was set up to record the movements. Angles were then measured afterward on a computer.

Lastly, the subjects were asked to draw a perfect circle on a whiteboard. A video camera was again set up at their profile to measure the movement and to assist in the analysis. Again, the angles were measured on a computer afterward.

Extended sitting. Each subject was asked to adorn the spinal panels while sitting and working at their desk. Every 10 minutes over the course of 30 minutes, the angle of each spinal panel was measured for flexion, extension and torsion using an angle finder and tape measure to determine how the posture changed over a period of time.

Data Analysis

Physical therapy replication. All of the data collected from the movement and angles of the spine, leg and arm during the physical therapy rehabilitation exercises was placed into a spreadsheet. The position of the panels was compared between good and bad form to see if the difference would be readable with IMU sensors.

Skill-based tasks. Angles of the arm during skill-based tasks were reviewed and measured after the experiment. Subtle differences in movement between those who claimed to have skill and those who claimed to be novice were analyzed and noted.

Extended sitting. Data collected on the angles of the spine during extended sitting were also added to a spreadsheet. This information was then analyzed to identify if subtle shifts in posture over time were detectable using spinal sensors.

RESULTS

Roughly 85% of the measurements between good and bad form during physical therapy rehabilitation exercises showed a difference in spinal flexion, extension, and/or torsion. Those areas where no change in spinal flexion, extension or torsion occurred were areas in which the risks of having bad form were not relevant (Table 1).

In performing skill-based tasks, those who self-identified as "skilled" had more complex compound movements performing their tasks. Subtle movements, like a flick of the wrist when swinging a hammer, were all able to be measured and documented.

Table 1: Measured Difference Between Good and Bad Form

	Flexion/Extension		Torsion	
	P1-P2	P2-P3	P1-P2	P2-P3
Plank	●	●	○	○
Side-Plank	●	●	●	●
Extension	●	●	○	●
Quadruped	●	●	●	●
Cat/Camel	●	●	○	○

	Flexion/Extension		Torsion	
	P1-P2	P2-P3	P1-P2	P2-P3
Squats	●	●	●	●
Wall Squats	●	●	●	○
Quad Stretch	●	●	●	○
Hamstring	●	●	●	●
Isometrics	○	●	●	●

	Flexion/Extension		Torsion	
	P1-P2	P2-P3	P1-P2	P2-P3
Flexion	●	●	●	●
Extension	●	●	●	●
Pro/Supination	○	●	●	●
Radial/Ulnar	○	●	●	●
Broomsticks	○	●	●	●

● = Change in angle ○ = No change P = Panel

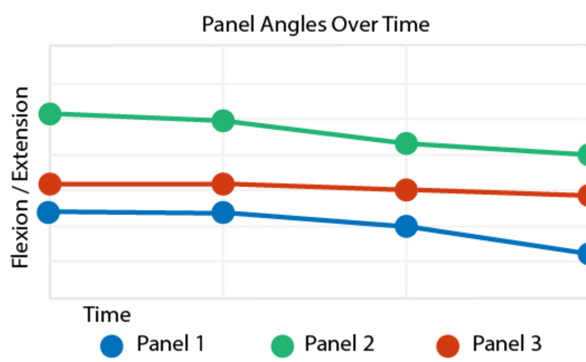

Figure 2: Changes in spinal flexion over 30 minutes.

Those who identified as "novice" in the tasks requested of them tended to rely more on elbow movement rather than shoulder and wrist movement.

Changes in spinal flexion were successfully measured over the course of 30 minutes during the final exercise. The first and second panel seemed to have the most movement, while the third, lowest panel, seemed to move the least (Figure 2).

DISCUSSION

Understanding and controlling the movement of the spine is difficult, especially for those suffering from spinal injuries who are in desperate need of pain relief. The benefit of seeing a physical therapist for a disc injury is proven. Physical therapists provide expertise in providing exercise routines, identifying problem areas, and monitoring form throughout the therapy session. Unfortunately, recurrence of injury is also proven, so developing a system to reliably place patients' spinal health in their own hands is a must.

With the vast majority of the population suffering from back pain at some point in their life, and upwards of 50 billion dollars spent annually on pain management, finding a solution to the spinal injury and its relapses could greatly improve the quality of life of millions of people.

Spinal injury relapse is often shrouded in mystery to those effected. Debilitating flare ups seem to come out of nowhere and last for days, even weeks at a time. With technology that monitors spinal movement, those suffering from injuries can do more than properly perform physical therapy exercises on their own. They can start to analyze their own data and learn what patterns or habits are causing their injuries to recur. Sensors can take the ambiguity out of spinal injury.

Currently, no system exists for monitoring the spine during movement – at least in any consumer or medical setting. All spinal measuring devices, like the Flexicurve and the Spinal Mouse, exclusively deal with the spine in a static state. Devices that currently exist to monitor your back exist exclusively in the consumer market as posture correcting devices and do not capture the complexity of the spine, nor do they aid in physical therapy form correction.

CONCLUSION

While the spine is a complicated combination of bones and tissues, this experiment proves that by using design triangulation, spinal movement can clearly be simplified and captured with the use of just three spinal sensors. Additionally, there is enough evidence here to confirm that the majority of bad form in physical therapy exercises for the spine, can be directly linked to spinal flexion, extension, and torsion. Beyond the spine, there is enough evidence to assume that the application of IMU sensors to other parts of the body could yield fruitful results in terms of physical therapy rehabilitation.

Through the monitoring of skill based activities, the visibility and dissection of movements, which may not have been directly visible to the naked eye, were amplified and analyzed. The most important benefit of this branch of the experiment was understanding if patterns could be found in movement using this system – which they were. Finding patterns in something like wrist movement when swinging a hammer confirms consistent results.

Lastly, validating that this device can accurately collect data on spinal movement and alignment over time is incredibly important information. Understanding spinal alignment before and after an event or physical therapy session is key to eliminating mystery and understanding what is positively and negatively effecting the spine.

While further research is needed to confirm the effectiveness of IMU sensors mounted to the body by using actual sensors over the course of a few weeks, these tests confirm that this system can definitely and consistently monitor spinal movement.

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