Datalogging Shirt for Baseball Pitchers

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Abstract

Baseball pitcher elbow injuries have been increasing in frequency and severity. The ulnar collateral ligament (UCL) prevents valgus (lateral) stress on the elbow, but the forces generated by throwing are great enough to tear the UCL on each pitch. While research has shown that high quality pitching mechanics incorporate stabilizing muscles and help reduce elbow injuries, particularly severe UCL tears, modern mechanics analysis methods are clumsy and expensive, requiring pitchers to enter laboratories for analysis.

As no single device for measuring the quality of pitching mechanics currently exists, a device which combines a compression shirt with fabric mounted accelerometers has been proposed. This product is lightweight, unobtrusive to pitching motion, and capable of measuring critical components of mechanics quality, including arm accelerations and velocities at the forearm and upper arm. Previously, no material existed which would leave pitching motion uninhibited. However, increased focus on heat retention and proprioception, or perception of body in space, has led to an increased acceptance of compression clothing in all sports, including baseball. Worn during bullpen sessions or exhibition games, this device can be used to show when a pitcher becomes fatigued and his mechanics worsen, as well as display real-time information on a monitor in the dugout. Data can also be downloaded and analyzed immediately following a game by a pitching coach or team athletic trainer, and tests have shown that this device can show a definitive delta between good and bad mechanics. It may be able to provide medical information as well.

A substantial market exists for this product, with upwards of $54 million in lost salary due to elbow injury accrued by Major League Baseball each season. While this device is strictly nonmedical, it moves clumsy in-lab analysis onto the field. It has the potential to be utilized as an injury-prevention device, although its primary purpose is to provide pitching mechanics analysis. Additionally, the device is extremely inexpensive, with a per-unit cost of under $200.
The Need for Project

With the high frequency and cost of pitching elbow injuries, the ability to measure the quality of mechanics is vital. Ulnar Collateral Ligament.

The suffering and expense associated with increasingly prevalent pitcher elbow injuries in baseball has generated an intense need for preventative treatment. While some elbow injuries are simply bad luck, some are derivative of poor mechanics. (Rep. 5.1) Meanwhile, proper mechanics can be extremely useful in the prevention of pitcher elbow injury, and a device which can analyze those mechanics in a realistic, on-field game situation can help reduce the $54 million in lost salary accrued by Major League Baseball each year. (Rep. 4.2) Additionally, an inexpensive device which provides relevant, on-field analysis can limit injury at all levels of competition, and its use may stretch beyond the sport of baseball.

The Design Project Objectives and Requirements

**Design Objectives (Rep. 3.1)**

This device must be able to gather pitching mechanics data in a way which does not impede pitching motion and does not require that the pitcher move his practice off the field and into a laboratory. It must be able to output the data in a meaningful format and show a difference between good and bad mechanics.

**Design Requirements**

The device needs to be constructed of a lightweight, unobtrusive material already used by pitchers during game days. It must also capture data at a rate already used for pitching mechanics analysis, around 200 Hz. There cannot be any massive objects on or around the pitching arm, and the device should be able to be easily washed without damaging the electronic or physical components.

**Design Concepts considered**

Three design concepts were considered for prototyping. All three concepts relied on the same basic concepts and existing technology, but had fundamentally different constructions. These designs shared the common goal of using an available data acquisition system, namely LabVIEW and the Northeastern-supplied National Instruments DAQ card.

**Frame on Sleeve Design**

The first design concept included a hinged, carbon fiber frame on
which sensors, including accelerometers, goniometers, and strain gauges were to be placed. This frame would surround the elbow and was to be mounted to a compression sleeve made of an elastic material. However, this device was determined to be too bulky and difficult to assemble, and the most valuable data is generated closer to the wrist, so accurate numbers would be more difficult to obtain.

**Sensors on Sleeve Design**

The second design was based on a compression sleeve mounting platform with no external hard frame. Sensors, particularly accelerometers/gyroscope combinations, or inertial motion units (IMU’s), were to be mounted along the sleeve at points close to each of the joints and at the midpoints of each arm section. Unfortunately, the software needed to correctly operate the IMU’s was far too complex to be used with the required DAQ system, and questions surrounding the bulk of larger sensors left uncertainty around the device’s comfort for the user.

**Sensors on Shirt Design**

Based on a compression shirt, not a sleeve, and using only small, fabric-mountable accelerometers, the shirt was designed to use only three sensors at physiologically critical locations, with the sensors connected with lightweight and flexible conductive thread. The shirt allows for the placement of a data transmission port on the back of the user for maximum comfort and utility during testing. The smaller number of sensors allows for reduced bulk and a substantially increased sampling rate, generating higher quality data than the alternatives above.

**Recommended Design Concept**

A compression shirt with three accelerometers mounted directly to the fabric provides excellent data while providing negligible resistance to pitching motion.

**Design Description**

The prototype design (Rep. 10) is an Under Armour long sleeve compression shirt with three triple-axis Analog Devices ADXL335 accelerometers, each mounted on a flexible LilyPad breakout board. These accelerometers are sewn directly to the shirt with conductive thread, which itself conducts signals from the sensors to a serial port at the bottom of the shirt. This serial port is mated to a ribbon cable which connects to the breakout board for a National Instruments PCI-6221 data acquisition card, and this card interacts with LabVIEW to
provide real time data monitoring as well as datalogging.

**Analytical Investigations**

Maximum angular velocities computed from previous studies (Rep. 10.2) were used to determine sensor specifications. These studies showed acceleration spikes of up to 750 G’s during a pitch, below the 10,000 G survivability point of the ADXL335 sensors. These studies also showed that the most critical measurement points were at the midpoints of both the forearm and upper arm.

**Experimental Investigations**

The first experiment (Rep. 11.1) attempted was the construction of a trebuchet/pendulum device used to determine whether accelerometer values were within expected ranges. Values were calculated within a single axis, after which the accelerometer was attached to the beam and proved to output expected values. This allowed for each axis of each accelerometer to be calibrated to nominal values through software integration in LabVIEW.

The second experiment (Rep. 11.2) tested the conduction and strength associated with the conductive thread. Each sensor was placed through a series of motions while connected to the DAQ system with standard wire. Then, the same sequence of motions was repeated with the conductive thread to ensure the data remained high quality. The tests showed no degradation in signal when moving from wire to conductive thread, and the thread maintained its integrity even after being substantially stressed.

Finally, two pitchers from the Northeastern club baseball team wore the shirt and pitched while the shirt logged data. The pitchers found the shirt provided zero discomfort and in no way inhibited their pitching motion. The values recorded show a significant delta between fatigued and normal pitches, as well as distinguishing between different pitch types and illustrating several known mechanical flaws. This data, when combined with video taken during the testing session, proves correct operation of the device.

**Key Advantages of Recommended Concept**

The main advantages of this design concept are its simplicity, its ability to provide high quality data in a real game situation which distinguishes between good and poor pitching mechanics, and its low cost combined with high reliability and ease of use.
The proposed apparatus is very simple, comprised of easily obtained parts and other off-the-shelf items. There is no need for complicated analysis tools, as LabVIEW can be used to capture data. This data can then be analyzed with Microsoft Excel in a matter of seconds, providing immediate results. Macros were also written to immediately turn the raw data into easily analyzed plots.

The data provided by the shirt is comparable to the data generated by extremely expensive video-based mechanics analysis, but without requiring a pitcher to sacrifice his game intensity to move into a laboratory. With a sampling rate of over 200 Hz on three accelerometers in three different axes, substantial data is captured on each pitch. This data can be viewed in real time or analyzed later, and shows an obvious delta between good and poor mechanics.

Cost was a major consideration, as current methods for pitching mechanics analysis cost thousands of dollars and require a pitcher to move into a laboratory setting. As such, the shirt was built with inexpensive components and uses a common data acquisition hardware and software suite.

**Financial Issues**

The proposed datalogging shirt will be inexpensive to manufacture and its cost will be low for consumers. The overall cost of the components used in the prototype is just under $175. Factoring in the benefits of mass production and volume pricing, the completed product could be sold for $175, substantially less expensive than modern video-based analysis techniques while providing high quality, real-time data. With support equipment, the cost rises to $500, but support equipment can utilize any number of shirts.

**Recommended Improvements**

With the addition of gyroscopes, bend sensors, and a wireless transmission standard, this device gains additional utility. Additional position data could be captured through the implementation of gyroscopes and bend sensors. These sensors would allow for the dead reckoning of the position of relevant arm loci and improve the quality of the analysis. (Rep 13.1) Adding a wireless data transmission interface would allow for real-time monitoring of a pitcher during a game while reducing the overall complexity and bulkiness of the current apparatus.