

Literature Review

Inertial Measurement Units (IMUs) have become a fundamental component in biomechanics research because of their capacity to capture and record motion/orientation in three-dimensional space. One of the primary areas of focus has been gait analysis, which focuses on the dynamics of walking and running. Gait analysis requires gathering metrics such as step length, cadence, and symmetry. Its applications are broad, ranging from post-injury or surgical rehabilitation to optimizing sports performance and diagnosing various movement disorders. Another significant area is posture monitoring. Researchers are focused on understanding spinal and joint alignment during activities or rest. This has practical implications in ergonomic evaluations, physiotherapy, and tracking treatments for conditions like scoliosis. Furthermore, the realm of sports biomechanics uses IMUs to breakdown the detailed mechanics of specific sports-related movements, be it a golf swing, a baseball pitch, or a tennis serve. Overall, such insights not only enhance athletic performance but also aid in injury prevention and provide invaluable feedback for the user to better understand optimal movement and joint health.

Furthermore, some research and/or commercial products also incorporate video analyses for motion tracking and biomechanical analyses. Specifically, the paper "Fusion of Multi-Sensor-Based Biomechanical Gait Analysis Using Vision and Wearable Sensor," by V. Bijalwan, V. B. Semwal and T. K. Mandal focuses on the integration of vision systems and wearable sensors for biomechanical gait analysis. The authors of the paper looked to compare these two complementary systems and set the foundations for similar future tracking technologies.

For video acquisition, the researchers used the Microsoft Kinect V2 human motion capture system. The Kinect system uses an RGB-D camera to capture joint position/orientation in space (software package w/ the system). Joints are represented by numbers (0-24). Every joint has 11 different properties: color (x, y); depth (x, y); Camera (x, y, z); and orientation (x, y, z, w). The raw data is stored in .json files. The researchers then processed the data to remove any noise and statistical outliers. Inverse kinematic equations are then solved with the processed (x,y,z) data to calculate joint angles.

For the IMU method, the researchers placed a sensor at 3 different locations for each subject — the shank just above the ankle, at the end of the thigh near the hip, and the side of the knee. IMU sensors were attached via velcro on tight trousers. Data was transmitted via Bluetooth. The IMU sensor used by the researchers (BWT 61CL-E) has a built in Kalman filter to process the incoming data. The x,y,z data is then once again used to solve the inverse kinematic equations and estimate joint angles.

Some of the challenges with the Kinect system are that the computer vision system has a limited multi angle views, i.e. analyze the gait from the frontal plane, or sagittal plane, etc. The IMU method poses challenges in signal noise and the need for frequent recalibration.

I believe future directions for this project include packaging an all in one IMU based wearable for the everyday user. The target user is the individual, not a research/medical device. The first supported movement could be a gait analysis, as that is the

most widely researched. However, the goal should be to support the basic movement patterns of the human body — bend, push, push, lunge, and anti-twist. That is quite an ambitious step, so more specifically, supporting the squat movement would be optimal. Due to its compound nature, it would provide a full body biomechanical analysis. The product must be intuitive and informative.

Competitive Analysis (current market)

Delsys Incorporated:

Primary Focus:

Delsys specializes in developing high-quality Electromyography (EMG) systems, sensors, and related software solutions. Their products are used to capture and analyze muscle activity and movement.

Product Range:

They offer a range of products including wired and wireless EMG sensors, accelerometers, and complementary software for data collection and analysis. Their Trigno™ wireless systems, for instance, are well-regarded in the research community for their flexibility and reliability.

Applications: Their systems are used in a wide range of applications from clinical research, sports science, and rehabilitation to ergonomics, human-machine interaction, and more.

Myontec:

Primary Focus:

Myontec designs wearables that record and analyze electromyography (EMG) data, essentially capturing and interpreting electrical activity from muscles. Their technology aims to provide insights into muscle load, imbalances, and other metrics during physical activity.

Flagship Product:

One of their well-known products is the Mbody – a pair of smart shorts that monitor the activity of the wearer's major upper leg muscles. The data collected from the shorts is then sent to an accompanying app, providing real-time feedback and post-exercise analysis.

Applications:

The wearables are used across a spectrum of users, from elite athletes looking to optimize performance and reduce injury risk, to everyday fitness enthusiasts aiming to monitor and improve their exercise routines. The insights can help in tailoring training programs, rehabilitation efforts, and more.

Unique Selling Proposition:

Myontec's wearables stand out because they offer real-time muscle monitoring that's portable and user-friendly. This allows users to understand their muscle behavior in different scenarios, be it during a sports game, gym session, or rehabilitation exercise.

ChatGPT Analysis

Prompt: Can you provide me with a literature review and competitive analysis of the current space of biomechanics wearables/trackers?

A. History and Evolution:

- Starting with basic pedometers, the integration of sensors in wearables has exponentially increased over the past two decades.
- Studies from the early 2000s have shown the advantages of wireless sensors for monitoring gait and posture in rehabilitation settings.

B. Technology:

- The incorporation of IMUs (Inertial Measurement Units), which typically contain accelerometers, gyroscopes, and sometimes magnetometers, has revolutionized motion tracking.
- Recent advancements include the miniaturization of sensors, improved battery life, and increased sensor accuracy.
- EMG sensors in wearables are typically used for tracking muscle activation patterns.

C. Applications:

- Rehabilitation: Many studies have focused on the benefits of real-time feedback for patients recovering from injuries.
- Sports Performance: Athletes use wearables to optimize their techniques and prevent potential injuries.
- Daily Activity Monitoring: The general public uses wearables for posture correction, especially in occupations that involve prolonged sitting.

D. Challenges and Limitations:

- Issues with sensor drift, the need for frequent calibrations, and the challenge of accurately interpreting complex biomechanical data are recurrent themes in the literature.

Competitive Analysis of Biomechanics Wearables/Trackers:

A. Major Players:

- Fitbit: One of the pioneers in fitness tracking wearables. While mainly focused on fitness tracking, some devices offer advanced metrics that can touch on biomechanics.
- Garmin: Offers a range of sport-specific wearables that often include biomechanical metrics such as cadence, stride length, and ground contact time for runners.
- WHOOP: Measures recovery and strain, focusing on the relationship between workout strain, recovery, and sleep.
- Myontec Mbody: Professional shorts that come with built-in EMG sensors. Used to analyze muscle load, balance, and other metrics.
- Lumo Bodytech (Lumo Run): A wearable sensor offering real-time feedback on running form.
- NURVV: Uses smart insoles to analyze runners' biomechanics from the ground up.

B. Unique Selling Propositions (USPs):

- Some devices focus on battery life, making them ideal for long-duration activities.
- Others emphasize real-time feedback, which can be invaluable for immediate corrections during activity.
- Integration with third-party platforms and community features are also common selling points.

C. Challenges Faced:

- Accuracy: One of the most common criticisms faced by wearables is the accuracy of their data, especially when compared to laboratory-grade equipment.
- Price Point: High-tech wearables can be expensive, potentially limiting their market.
- User Interface: Providing complex biomechanical data in a way that's easily digestible for the average user is a constant challenge.

To Further Explore

- "Estimation of Foot Orientation and Ground Reaction Forces With Inertial Sensors" Favre, J., Jolles, B.M., Siegrist, O., and Aminian, K.; *Gait & Posture*, 2008
- <https://ieeexplore.ieee.org/document/7549114> V. B. Semwal and G. C. Nandi, "Generation of Joint Trajectories Using Hybrid Automate-Based Model: A Rocking Block-Based Approach," in *IEEE Sensors Journal*, vol. 16, no. 14, pp. 5805-5816, July15, 2016, doi: 10.1109/JSEN.2016.2570281.

- <https://ieeexplore.ieee.org/document/7471408> V. B. Semwal, C. Kumar, P. K. Mishra and G. C. Nandi, "Design of Vector Field for Different Subphases of Gait and Regeneration of Gait Pattern," in *IEEE Transactions on Automation Science and Engineering*, vol. 15, no. 1, pp. 104-110, Jan. 2018, doi: 10.1109/TASE.2016.2594191.
- Myontec Mbody: <https://www.myontec.com/>

Citations

V. Bijalwan, V. B. Semwal and T. K. Mandal, "Fusion of Multi-Sensor-Based Biomechanical Gait Analysis Using Vision and Wearable Sensor," in *IEEE Sensors Journal*, vol. 21, no. 13, pp. 14213-14220, 1 July1, 2021, doi: 10.1109/JSEN.2021.3066473.