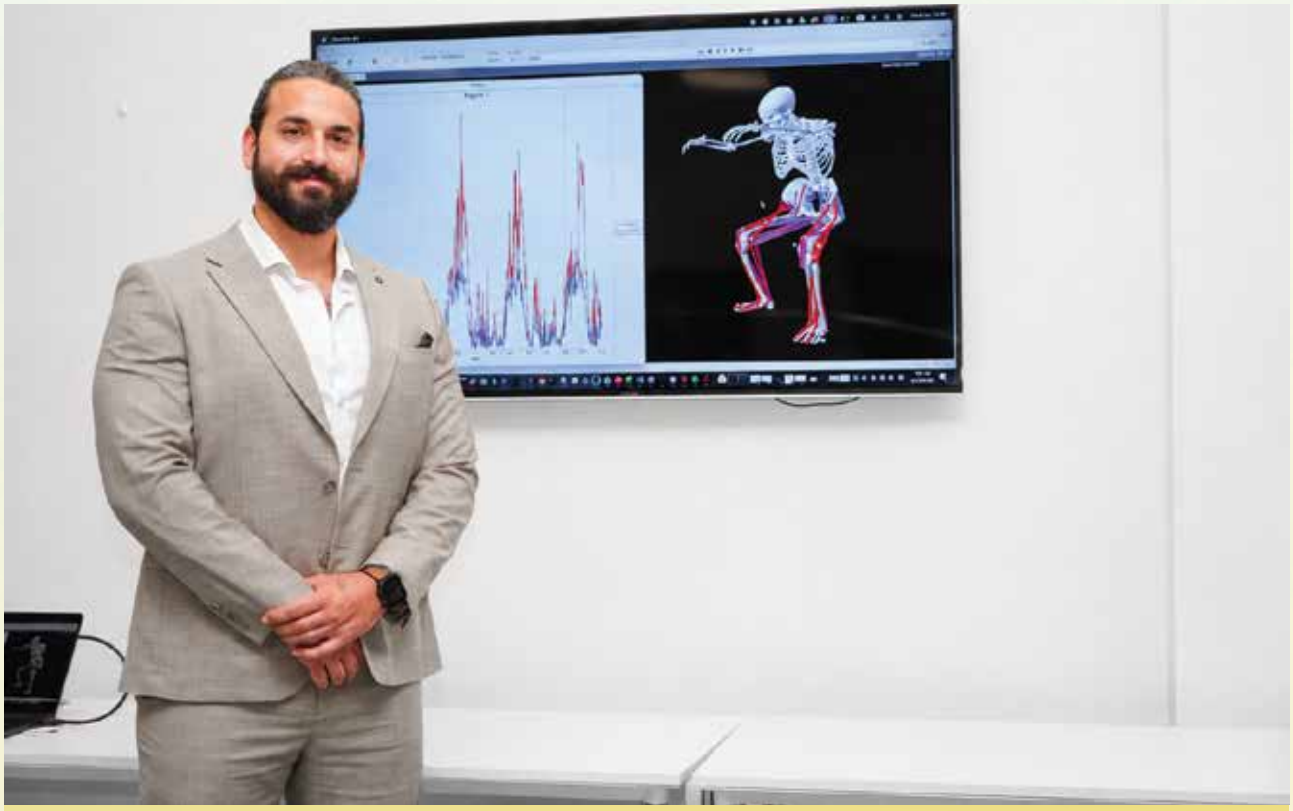
# Beyond Steps and Heart Rate

## A Wearable that Reveals What Muscles and Joints Endure



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Modern fitness trackers and smartwatches have made it routine to count steps, measure heart rate, estimate calories burned, and assess recovery readiness based on cardiovascular metrics. None of these devices, however, answers a more fundamental question for anyone who moves, trains, or recovers from injury: how much mechanical load is actually passing through the muscles, tendons, and joints during each movement? Nor can they determine whether the muscles have recovered and are ready for the next workout. That information has so far been confined to specialised biomechanics laboratories equipped with camera-based motion capture, force platforms, and trained analysts. A new wearable system developed at Qatar University

aims to bring that laboratory-grade insight onto the body, in real time.

The invention, recently published as a United States patent application (US20250352122A1), is the first of its kind to emerge from the College of Sport Sciences, developed in collaboration with the College of Engineering. It was invented by Dr. Rony Ibrahim of the College of Sport Sciences and Prof. Uvais Qidwai of the College of Engineering.

## The problem of looking inside movement

The forces inside the body cannot be measured directly without invasive procedures. Biomechanists therefore estimate them indirectly, by combining how the body moves with the external forces acting on the body, and with how its muscles activate. Two complementary signals capture this. Inertial measurement units (IMUs), the same miniature accelerometers, gyroscopes, and magnetometers found in smartphones, track how each body segment accelerates and rotates. Surface electromyography (EMG) records the electrical signals that muscles emit when they contract. Together, motion and muscle activity provide the raw material from which external forces can be reconstructed and internal loading can be estimated.

The difficulty lies in placement. For an IMU to report clean orientation data, it should sit where the skin minimally deforms during contraction. For EMG electrodes to capture a strong, uncontaminated signal, they must sit directly over the belly of the muscle. Conventional integrated sensors force both components into a single housing at one location, which compromises one measurement in order to serve the other.

## A design that separates to improve

The central innovation decouples the two




**During user testing of the innovation.**

sensors so that each can be positioned where it performs best, while keeping them part of one connected system. The EMG electrodes attach over the muscle belly, through detachable wires of adjustable length or wirelessly, while the IMU is placed on the same body segment at a site with minimal skin movement. For the thigh, for instance, the electrodes can read the vastus medialis at its belly while the IMU sits on the lateral mid-thigh, where the underlying tissue stays comparatively still. The result is cleaner data from both channels and a more accurate picture of what the limb is doing.

Turning signals into forces

Raw motion (IMU) and muscle (EMG) signals

are not, in themselves, measures of joint or tissue load. The innovation bridges that gap with machine learning. The model is first trained in the laboratory against gold-standard references: three-dimensional motion measured by optoelectronic camera systems, ground reaction forces measured by force platforms, and muscle activity recorded by EMG. These laboratory data are processed through a detailed musculoskeletal model in OpenSim, a widely used open-source simulation platform, to compute the internal loads that cannot be measured directly. Once trained, the model reproduces those same estimates from the wearable's field data alone ($r = 0.9$, RMSE = 0.08 N-m; Figure 1), scaling its predictions to the individual through inputs such as body mass, height, age, the movement being performed, and any external weight being lifted.

From these inputs, the system can report, in real time, a broad set of variables that matter clinically and athletically: muscle activation patterns, net joint torque and power, ground reaction forces, joint contact forces, individual muscle and tendon forces, ligament tension, cartilage stress, intervertebral disc pressure, and bone strain. A live dashboard presents these values graphically, with colours that shift as readings approach preset thresholds, allowing a coach, clinician, or user to adjust technique or intensity during the activity rather than after it.

## Where it can be used

The applications span several of Qatar University's research priorities in health and digital technology. In rehabilitation and physiotherapy, the system provides objective, continuous feedback on whether recovering joints are being loaded appropriately. In sport, it helps athletes refine movement and manage the loads associated with injury risk. For telehealth and remote care, it enables home-based monitoring of patients who cannot easily attend a clinic. Across all of these settings, the device shifts musculoskeletal assessment from occasional laboratory snapshots to continuous measurement in everyday life.

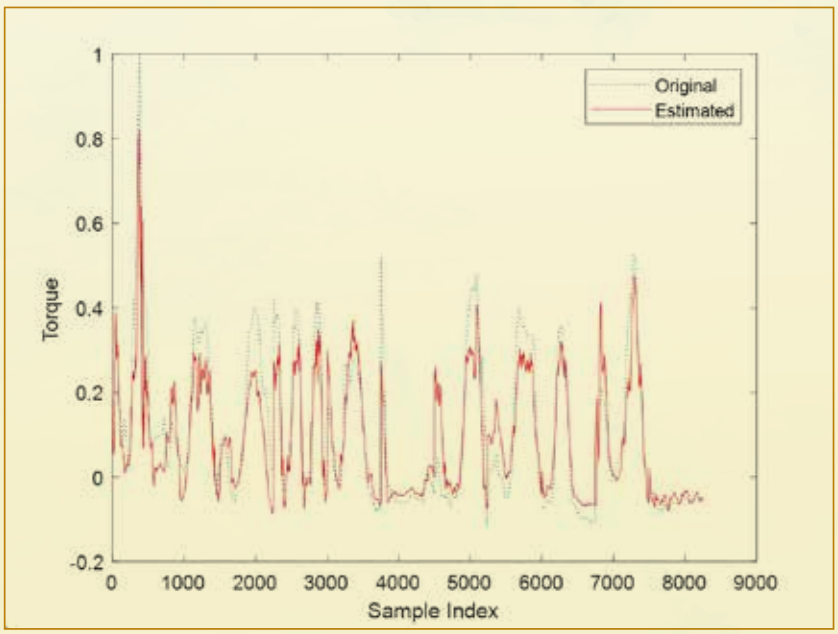



**Figure 1:** Original (Gold standard) and estimated knee joint torque (N×m) in a bilateral squatting movement.