# Smart Compression Garments in Kinesiology: Current Capabilities and Future Applications in Muscular Fatigue Management

Skylar Mountford

University of Calgary

KNES 381: Computer Applications in Kinesiology

For: Dr. John Holash

April 4th, 2025

In recent years, health-related fitness devices have surged in popularity by evolving from specialized tools tailored to elite athletes to everyday essentials. Information that once required expensive, restrictive lab equipment coordinated by trained experts can now be monitored through affordable wearable technology that seamlessly integrates into daily life, providing personal agency regarding health metrics[1]. As popular devices such as smart watches that encourage the pursuit greater activity levels, individuals may often find themselves risking personal injury due to overuse or fatigue that these wearables are not capable of measuring. Nearly 50% of all sports-related injuries are preventable, and advancements in compressive "Smart Apparel" that can monitor muscle activity, exertion levels, and fatigue begin to emerge as the next frontier in preventing overtraining injuries[2]. The development of innovative smart activewear represents the next breakthrough in biomechanical analysis, extending performance optimization and personalized injury prevention comparable to that of a laboratory to the average consumer.

The current methods of measuring muscle activity and fatigue parameters are highly limited to a restrictive laboratory setting, with electromyography (EMG) as the gold-standard for this objective[3]. Regarding kinematic analysis and biomechanical monitoring, using motion capture systems with physical markers to detect joint positions is the most reliable technology available while developments in video analysis continue to improve. Therefore, to receive accurate performance metrics regarding physical exertion, joint stress, and muscle fatigue, the options are highly limited for the average individual and have inherent drawbacks even in professional settings. These devices often require a specialized indoor area to house the motion trackers and electronic devices that track this kinematic data, limiting the scope of research that can be performed in an athlete's natural environment[1]. Additionally, the setup of these devices often requires wires and other restrictive equipment that eliminate the possibility of tracking many different types of movement. These drawbacks in standard kinematic analysis have encouraged researchers to modify the application of EMG to new innovative wearable technology that can be used in a more practical manner.

Since intramuscular EMG electrodes embedded in the muscle tissue cannot feasibly be used during complex movements, surface EMG (sEMG) electrodes are placed on the skin along the length of a muscle to detect the electrical activity of motor unit action potentials that distributes along the skin's surface[4]. While this greatly reduces the restrictions inherent to previous methods of biomechanical analysis, there are limitations with this approach's effectiveness. First is that the amplitude of the EMG signal does not correlate to muscle force in a linear manner and depends on the number of motor units recruited next to the electrode. These electrodes must be placed in the midline of the muscle, and as the fabric of these garments moves the electrodes will shift, decreasing the signal amplitude of high frequency readings which may falsely indicate fatigue[4]. Additionally, to increase signal quality and reduce skin resistance a salt-based electrode gel must be placed between the sensor and skin which may dissipate with perspiration while exercising[5]. With these shortcomings of EMG wearables in mind, many research teams have focused their studies on the application of force myography (FMG) as an alternative approach to this objective.

The foundation of FMG technology dates back as early as the 1950s, but due to the limited application of sensors and computer technologies at this time this approach did not gain much momentum until the 1990s where it was initially used in developing prosthetic devices[6]. Towards the late 2010s, interest in the development of FMG technologies increased beyond prosthetics with research showing a high correlation between sEMG and FMG signals in gait cycle analysis[6]. Whereas sEMG records electrical activity, FMG reflects the mechanical counterpart of muscle activity by embedding sensors between compressive clothing and the skin to detect deformations caused by volumetric changes of active muscles[3]. Machine learning algorithms process this data to analyze movement patterns which can effectively be used to estimate muscle fatigue through changes in muscle stiffness patterns over the duration of exhaustive physical activity. These sensors are less affected by skin impedance and do not require direct contact with muscles via electrodes, making their application in compression garments a viable alternative approach for monitoring physiological parameters of exercise[6]. Regarding the effectiveness of FMG for this objective, a 2015 study found that FMG signals detected overall fatigue levels in a cycling activity more reliably than sEMG[2]. Considering the shortcomings of sEMG alongside the promising functionality and low manufacturing cost of the sensors used in FMG technology, the feasibility of using this approach in commercially available smart apparel becomes increasingly more apparent[6].

Because research regarding FMG to monitor muscle fatigue has predominantly emerged in the past 7 years, there are currently no commercially available products that utilize this technology. Additionally, sEMG has an extensive research background making it easier for engineers and designers to implement these sensors into the newest advancements in smart apparel including compression shirts, shorts, and leggings from companies such as Athos and Myontec. These products utilize textile-based wireless transmission of movement data to computer and smartphone applications, allowing for real-time feedback on muscle performance to optimize workouts and reduce the risk of injury[7].While these products have vastly improved beyond wired EMG electrodes and motion capture software, design improvements such as anti-slip fabrics are being pursued to minimize the previously mentioned issues regarding data reliability. Furthermore, researchers at ETH Zurich are exploring the integration of conductive, elastic yarn wrapped with a rigid wire that forms a capacitor that can hold an electric charge[8]. This patent-pending technology would eliminate many of the downsides associated with currently available sEMG wearables and removes the need for batteries and sensors which drive the high production costs and difficulties with maintaining these garments[8]. It is safe to assume that with so much groundbreaking research emerging in the field of smart apparel, expert-level biomechanical analysis through comfortable and affordable garments will soon be available to the average fitness enthusiast to optimize their exercise regimen and provide an upstream approach to fatigue-related injury prevention.

## References

1. Belbasis A, Fuss FK. Development of Next-generation Compression Apparel. Procedia Technology. 2015;20:85–90.

2. Belbasis A, Fuss FK, Sidhu J. Muscle Activity Analysis with a Smart Compression Garment. Procedia Engineering. 2015;112:163–8.

3. Belbasis A, Fuss FK. Muscle Performance Investigated With a Novel Smart Compression Garment Based on Pressure Sensor Force Myography and Its Validation Against EMG. Frontiers in Physiology. 2018 Apr 19;9.

4. De Luca CJ. The Use of Surface Electromyography in Biomechanics. Journal of Applied Biomechanics [Internet]. 1997 May;13(2):135–63. Available from: https://journals.humankinetics.com/view/journals/jab/13/2/article-p135.xml

5. Joachim Taelman, Tine Adriaensen, Caroline, Linz T, Spaepen A. Textile Integrated Contactless EMG Sensing for Stress Analysis. Conference proceedings. 2007 Aug 1;

6. Xiao ZG, Menon C. A Review of Force Myography Research and Development. Sensors [Internet]. 2019 Jan 1 [cited 2020 Feb 23];19(20):4557. Available from: https://www.mdpi.com/1424-8220/19/20/4557/htm

7. Khokhlova L, Belcastro M, Torchia P, O'Flynn B, Tedesco S. Wearable Textile-Based Device for Human Lower-Limbs Kinematics and Muscle Activity Sensing. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering. 2021;70–81.

8. Elhardt C. Detecting exhaustion with smart sportswear [Internet]. ETH Zurich. 2023 [cited 2025 Apr 4]. Available from: https://ethz.ch/en/news-and-events/eth-news/news/2023/03/detecting-exhaustion-with-smart-sportswear.html