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Critical observations on the conceptual framing and categorization of wearbles in the manuscript by W. Iwasyk et al.: "Wearable Technology in Orthopaedic Surgery: Applications and Future Directions"

Steven Lankheet
Phd Student
1. Department of Orthopedic Surgery, Medical Spectrum Twente, Enschede, The Netherlands 2. Biomedical Signals and Systems, University of Twente, The Netherlands

Other Contributors:

Wiebe Verra
Orthopedic surgeon
Department of Orthopedic Surgery, Medical Spectrum Twente, Enschede, The Netherlands

Femke Schröder
Technical Physician
1. Department of Orthopedic Surgery, Medical Spectrum Twente, Enschede, The Netherlands, 3. Biomedical Device Design and Production, University of Twente, The Netherlands

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Steven Lankheet

Dear Editor,

This letter was prepared in response to the manuscript by Iwasyk et al., titled "Wearable Technology in Orthopaedic Surgery: Applications and Future Directions." We commend the authors for addressing an increasingly relevant topic in orthopedic care and for their effort to synthesize a broad and rapidly evolving body of literature. Wearable technologies hold great promise for improving perioperative monitoring, rehabilitation, and patient engagement. The authors' enthusiasm for innovation is evident and appreciated.

However, we would like to offer several critical observations that we believe may help refine the conceptual framing and categorization of wearables in the manuscript. With the intention of clarifying definitions, improving the uptake, and supporting the continued advancement of wearable technologies in orthopaedic surgery.

1. Overextension of the Term "Wearables"
The manuscript adopts an expansive definition of "wearables," grouping together body-worn sensing devices with fundamentally different technologies such as software platforms, including communication tools and education platforms. While these tools may play supportive roles in patient education or rehabilitation, they should not be classified as wearables as they are not worn on the body [1].

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Importantly, AR/VR systems are used intermittently and do not deliver the continuous, real-time, or objective data collection on physical function, behaviors, or perceptions that the manuscript attributes broadly to wearables. A clearer delineation between wearable technology for daily use and adjunctive digital platforms would strengthen the claims on the importance of incorporating wearables into the fields of orthopedics.

2. Conflation of Sensors and Wearables
Throughout the manuscript, sensing technologies such as IMUs and accelerometers are discussed interchangeably with wearables, without a clear distinction between the sensor components and the devices that incorporate them. If IMUs are categorized as standalone wearables, then consistency would require equal treatment of other sensor types, such as temperature, pH, or pressure sensors. As the manuscript aims to inform a clinical audience about the technical possibilities of wearable technology, the lack of explanation regarding how sensors are embedded into wearables may hinder interpretation and limit practical understanding. For a clinical audience, it may be helpful to briefly explain how sensors are embedded into wearable systems. This clarification would enhance practical understanding and support informed clinical interpretation.

3. Poorly Defined and Overlapping Wearable Categories
The categorization presented in Figures 1 and 2 lacks internal consistency and conceptual clarity. The figures mix form factors, functions, and platforms without a coherent framework. For example, smartwatches, apple watches and Actigraphs are all wrist-worn activity trackers but are presented as separate categories. Moreover, categories such as smartphones and communication tools reflect similar underlying platforms. This inconsistency hinders meaningful comparisons across technologies and makes it difficult to assess their specific clinical roles or utility. A more structured classification system would improve the interpretability and applicability of the manuscript.

4. Misrepresentation of Smart Implants
Smart implants are presented as part of the wearable technology ecosystem, yet they differ fundamentally from the ideology of the other wearables. While we acknowledge the rationale for their inclusion, their primary function is typically to inform implant design or surgical technique, rather than to support real-time patient monitoring or feedback. This is sometimes explicitly stated in these papers such as “Understanding these intraoperative hip forces could aid surgeons in making the optimal decisions regarding implant placement and component selection” [111]. Another paper is cited that describes the use of a sensor which could help the individual patient. However, it does require an external data sensor which hampers outpatient measurements and is only tested in the lab on plastic bones which are both not clearly stated in the manuscript [115]. This manuscript does not provide any exclusion criteria or critical appraisal of the included papers. The use of clinical studies combined with experimental setups and animal studies is in our opinion misleading. For example, the statement “The sensor showed a 32.6% increase in signal in partially loosened implants” [115] when it is only tested in a single plastic bone model overstates the clinical readiness. A clearer separation is warranted to avoid overestimating their intended use for routine clinical care.

Figure 1: Overview of the proposed framework to categorize both the wearable categories in Orthopedic surgery and the underlying sensors. Each wearable is mentioned with the primary wear location, intended duration of use, and usage context (continuous, intermitted, or intraoperative). In addition, an example of the possible integrated sensors are shown as icons for each category. The sensors from top to bottom and left to right are: accelerometers, global positioning systems, pH, force, inertial measurement systems, temperature, ultrasound, and electrocardiogram sensors.
To address these issues, we propose a revised framework with a focus on wearable sensors that separates: sensors (e.g., IMUs, temperature sensors, pH sensors) as the data collection technologies and form factors (e.g., smartwatches,

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smart implants, and smartphones) as the mechanisms the patient interacts with these wearables. The framework is extended with the characteristics (e.g., intended duration of use, and usage context) to clarify how each platform fits into orthopedic workflows. This structure allows for clearer comparisons, avoids conceptual overlap, and better reflects the diversity of technologies in orthopedic care. A proposed overview of such a framework is given in figure 1. We believe such a framework would strengthen future reviews and would help to better inform the clinical audience.

Sincerely,

Steven Lankheet1&2, Wiebe Verra1 & Femke Schröder1&3

3. Department of Orthopedic Surgery, Medical Spectrum Twente, Enschede, The Netherlands
4. Biomedical Signals and Systems, University of Twente, The Netherlands
5. Biomedical Device Design and Production, University of Twente, The Netherlands

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