

# BMJ Open Effects of smart garments on the well-being of athletes: a scoping review protocol

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## ABSTRACT

**Introduction** With the advancements in wearable electronics, electronically integrated smart garments started to transpire in our daily lives. Smart garment technologies are incorporated into sportswear applications to enhance the well-being and performance of athletes. Smart garments applications in the sports sector are increasing, and the variety of smart garment applications available in the literature is overwhelming. Therefore, it is essential to compare the vast array of technologies incorporated in smart garments for athletes to understand the knowledge gaps for future studies. The protocol paper aims to examine the smart garments used in the sports domain to enhance the health and well-being of athletes.

**Methods and analysis** Relevant studies will be retrieved using predefined search terms from Scopus, Web of Science, Science Direct, PubMed and IEEE Xplore. The retrieved articles will be eliminated in two phases: title and abstract screening and full-text screening. The included articles will be primary studies published in the English language within the last 10 years. Subsequently, the included articles will be further studied to extract data using a data extraction form. The extracted data will undergo a thematic analysis. Also, quantitative analysis will be carried out using descriptive statistics.

**Ethics and dissemination** The results of this review will provide a comprehensive understanding of smart garment concepts used in the sports domain. The findings of this scoping review will be shared through a journal publication and a conference presentation. Ethical approval is not needed for this scoping review.

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## INTRODUCTION

Smart garments are clothing items that are made with intelligent materials or electronic technologies, which can sense, react or adapt behaviour to the circumstances.<sup>1</sup> These smart garments are also known as a branch of wearable computers that evolved from the essential monitoring devices such as heart rate monitors, fitness monitors and smart wristwatches like Fitbit. Smart garments can be worn like regular clothing, and they can measure a broad spectrum of biomechanical and physiological metrics and provide advanced functions like posture controlling

## Strengths and limitations of this study

- The proposed study uses existing scoping review methodology to identify the effects of smart garments on the well-being of athletes.
- The study will give an in-depth understanding of the current state of smart sportswear for athletes.
- The review will investigate literature from the last 10 years.
- The scoping review will consider studies published in the English language.
- To capture a broad spectrum of smart garment applications incorporated in professional sportswear, we will consider all the studies that reported the effects of smart garments designed for professional athletes.

to support the health and well-being of the athletes.<sup>2-4</sup>

The majority of smart garment applications integrate sensor technology that enables wireless health monitoring.<sup>5</sup> One such example is Hexoskin, which is a clinically validated smart shirt that can measure biological/physical parameters like cardiac, respiratory, sleep and activity data.<sup>6</sup> Temperature monitoring using wearable sensors and smart cooling are some other smart applications that can be integrated into clothing to enhance the comfort and wellness of an individual.<sup>7-9</sup> Smart monitoring and other related functions offered by some of the existing smart garments are listed in [table 1](#).

Sportswear started getting subjected to the unique demands of athletes, to protect the wearer from extreme environmental conditions. Also, researchers explored sensor technologies as a means of enhancing the health and well-being of athletes.<sup>10</sup> Considering these, to address complex sportswear requirements and to improve the well-being of athletes, smart technologies with integrated sensors started to outspread into the sports market. Some of the existing studies explored the use of sensors to measure biological parameters (ie, heart rate, muscle



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**Table 1** Some examples of smart garment applications

Smart function	Smart garment applications
Smart monitoring	<ul style="list-style-type: none"> <li>▶ Biomonitoring: heart rate, body temperature, breathing<sup>14 33 34</sup></li> <li>▶ Posture monitoring<sup>34–36</sup></li> <li>▶ Microclimate temperature and humidity monitoring<sup>37 38</sup></li> </ul>
Other smart functions	<ul style="list-style-type: none"> <li>▶ Smart cooling<sup>34 38 39</sup></li> <li>▶ Smart compression<sup>40</sup></li> </ul>

and oxygen saturation) and safety-related parameters (ie, position, motion and impact) to enhance health, wellness and performance of athletes.<sup>11–13</sup> Another study investigated the use of smart textiles in snowboarding activity where textile pressure sensors were utilised to recognise the activities performed by users.<sup>12</sup> Also, researchers developed a smart shirt and leggings to measure heart and muscle activity, breathing rate and temperature.<sup>14</sup> With these examples, it is evident that smart technology can be incorporated into sportswear applications to enhance the well-being and performance of athletes.

Sportswear manufacturers started stretching the boundaries of smart wearables by integrating technology into garments.<sup>4</sup> As mentioned in market reports, smart garment applications in the sports sector are expected to exhibit high growth.<sup>15</sup> However, most of the commercialised sport smart garments offer standard functions like smart monitoring, communication, compression and couching. These garments consist of non-textile electrical/electronic devices/components to inbuild intelligent functions to the clothing inhibiting user experience. Researchers started exploring e-textiles and designed smart technologies into textiles.<sup>16 17</sup> Also, some studies examined creative, smart applications to improve user experience. The smart garment that reacts to the wearer mood is one such example.<sup>18</sup> These studies provide an opportunity for future smart sports garments that can improve the health and well-being of athletes. A technology mapping and review of existing smart garments designed for athletes will assist in understanding how these smart garments may inform the new product development and guide further research.

### Rationale

Several researchers have reviewed the applications of wearable technology and smart garment technology.<sup>10 13 19–22</sup> However, most of these papers are focusing on medical or healthcare applications giving less priority to the wellness of athletes.<sup>21 23 24</sup> Furthermore, the variety of smart garment applications available in the literature is overwhelming. Therefore, the proposed review is essential to compare the vast array of technologies incorporated into smart garments for athletes and also to understand the knowledge gaps for future research.<sup>25 26</sup>

Some of the existing reviews discuss smart garment technologies that can be applied in the sportswear

domain. Yet, they are either outdated<sup>11 12</sup> or not comprehensive enough to provide an in-depth understanding of the current state of smart sportswear<sup>27</sup> or focusing only on smart monitoring.<sup>13</sup> Due to the fast-evolving nature of smart garment applications, researchers frequently introduce novel technologies and materials.<sup>28 29</sup> One such novel application is recently introduced wearable textile electronics that can uplift the performance of future smart sports clothing.<sup>28</sup> Metatextiles that offer adaptable thermal comfort and energy harvesting triboelectric materials that can be used to optimise power consumption of smart sports garments are few other new smart technology applications.<sup>28 29</sup> These latest technologies can fulfil a wide variety of sportswear requirements shifting smart sports garments to a new dimension.

Considering the requirements described above, a comprehensive review, which follows a systematic approach and covers the latest smart sports garment applications is essential to ensure effective use of the latest technologies in future smart garment design projects. Therefore, this paper presents a protocol for conducting a scoping review that can provide a comprehensive evaluation and a technology mapping of the latest smart sports garment technologies to guide future research. The objectives of this review are to identify (A) the functions offered by the smart garments, (B) the types of technologies used in smart garments, (C) effects (beneficial and harmful) of those garments on the performance of athletes and their experience in using such garments.

### METHODS

We follow the scoping review methodology proposed by Arksey and O'Malley.<sup>30</sup> This protocol consists of six phases namely; (1) identifying the research question, (2) identifying relevant literature, (3) study selection, (4) charting the data, (5) collating, summarising and reporting the articles and (6) consulting and translating knowledge (optional). Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews checklist (see online supplemental file 1) will be used throughout the proposed scoping review to ensure adherence.<sup>31</sup> The study has been registered in the Open Science Framework (OSF) on 25 June 2020 (<https://osf.io/34mf2>).

#### Stage 1: identifying the research question

The objective of this study is to assess the existing studies to understand the current smart garment technologies, which are developed to enhance the health and well-being of athletes. Also, this review will generate input requirements for developing improved smart garment for athletes. To concretise the focus of this review, we will concentrate on smart garment studies related to professional athletes. The review is expected to address the below questions.

- ▶ What functions do smart garments offer for professional athletes?

- ▶ What are the technologies incorporated into those smart garments?
- ▶ How effective are those smart garments to enhance the health and well-being of athletes?

### Stage 2: identifying relevant studies

The research team developed the search strategy after reviewing related literature, and an iterative approach was adhered to finalise the strategy (see online supplemental file 2). The search strings were generated by incorporating Boolean logic and operators. These strings consist of search terms, which were finalised after getting agreement from the research team. The search terms are “sensor garments”, “electronic garments”, “smart garments”, “smart apparel”, “sports”, and “athletes”.

The databases, which were selected to collect literature are Scopus, Web of Science, Science Direct, PubMed and IEEE Xplore, and these databases were chosen with the help of an expert university librarian. Due to the rapid technological changes, smart garment applications are quickly becoming outdated; hence only the studies published within the last ten years will be considered for the review. Furthermore, to ensure the credibility of the studies, we only considered peer-reviewed journal articles. Also, only the studies in the English language will be included for review. The research team will review the first 50 search results from each database before proceeding with the full search to ensure the accuracy of the search strategy. However, during the execution of search strategy, authors of primary studies or reviews will be contacted for further information, if required. The latest search was executed on 24 May 2020. The articles retrieved from the search will be imported into the Covidence software, which will remove duplicated items automatically.

### Stage 3: study selection: inclusion and exclusion criteria

We will carry out study selection incorporating two-step method. Initially, titles and abstracts will be reviewed against the selection criteria and will be marked as ‘include’, ‘exclude’ or ‘uncertain’. Two reviewers will conduct this screening independently, and a discussion will be undertaken in the research team to resolve any discrepancy and to fine-tune selection criteria. This screening and discussion process will continue until we reach a consensus.<sup>32</sup> Subsequently, for the included studies, the full-text review will be carried out against the selection criteria following the same screening procedure. Grey literature will not be considered for this review.

This two-stage study selection process will be conducted, incorporating a review form (see online supplemental file 3). Only the studies with electronic integrated smart sports garment, which focus on health and well-being of professional athletes will be included for the review. The review form will incorporate the following inclusion criteria to simplify the screening process.

- ▶ Is the article a peer-reviewed primary study?
- ▶ Is the article published within the last 10 years (2010–2019) in the English language?

- ▶ Does the article involve smart garments?
- ▶ Does the article focus on the health and well-being of professional athletes?

The citations of the included studies will be evaluated against selection criteria following the same two-stage study selection process to select the additional studies if required.

### Step 4: charting the data

All included studies will be reviewed and charted using a data extraction form (see online supplemental file 4). The details, which will be extracted from the studies are study citation, publication type, authors, study location, study year, target market, sample characteristics (number of participants and demographics), garment type, number of functions, function type (ie, biomonitoring, coaching, warning and posture control), technology characteristics (sensor type, method of power supply, communication/feedback mechanism and interconnection), evaluation protocol adhered, user acceptability of the concepts and outcome of the study (quantitative results, qualitative themes, recommendations, key learnings and limitations). The charting of the extracted information will be conducted by two reviewers.

### Stage 5: collating, summarising and reporting the results

Initially, we will conduct a quantitative analysis for extracted data using descriptive statistics (eg, frequencies). This analysis will provide numerical summaries of (A) smart sports garment applications designed focusing on professional athletes, (B) the functions offered by those smart garments, (C) the types of technologies used in smart garments and (D) effects (beneficial and harmful) of those garments on the performance of athletes and their experience in using such garments. These details will be presented using tables, charts and graphs and will be followed by a brief summary. Afterwards, we will analyse all the extracted data thematically to identify emerging themes. Two reviewers will independently identify the emerging themes, and those themes will be reviewed later by both reviewers to determine the final themes.

### Patient and public involvement

This scoping review protocol does not include patients or the public.

### Ethics and dissemination

This protocol reports a comprehensive methodology derived from the standard and well-established best practices to guide a scoping review that will be conducted to understand the existing smart sports garments applications. The proposed study will provide a comprehensive review and a technology mapping of the latest smart sports garment technologies that were developed to enhance the well-being of athletes. The scoping review findings will offer foundational know-how on sports smart garment applications emphasising the technology and design gaps to assist new product development and to inform further research. In future work, we are planning



to disseminate the results of this scoping review at relevant conferences and journals. Ethical approval is not needed for this scoping review, as we will not collect any primary data.

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