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Effects of Smart Garments on the Wellbeing of Athletes: A Scoping Review Protocol

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3 1 **Title: Effects of Smart Garments on the Wellbeing of Athletes: A Scoping**

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5 2 **Review Protocol**

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5 28 **Title: Effects of Smart Garments on the Wellbeing of Athletes: A Scoping**

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7 29 **Review Protocol**

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9 30 **ABSTRACT**

10
11 31 **Background:** With the advancements in wearable electronics, electronically
12 32 integrated smart garments started to transpire in our daily lives. Smart garment
13 33 technologies are incorporated into sportswear applications to enhance the wellbeing
14 34 and performance of athletes. Smart garments applications in the sports sector are
15 35 proliferating, and the variety of smart garment applications available in the literature
16 36 is overwhelming. Therefore, it is essential to compare the wide variety of
17 37 technologies incorporated in smart garments for athletes and also to understand the
18 38 knowledge gaps for future studies. The protocol paper aims to examine the latest
19 39 developments of smart garments used in the sports domain to enhance the health and
20 40 wellbeing of athletes.

21 41 **Methods and analysis:** Relevant studies will be retrieved using pre-defined search
22 42 terms, and the retrieved articles will be filtered, incorporating a two-stage screening
23 43 process consisting of a title and abstract screening and full-text screening. The
24 44 included articles will be primary studies published in the English language within the
25 45 last ten years. Subsequently, the included articles will be further studied to extract
26 46 data using a data extraction form. The extracted data will undergo a thematic analysis,
27 47 followed by a narrative review. Also, quantitative analysis will be carried out using
28 48 descriptive statistics.

29 49 **Discussion:** The protocol was developed adhering to the preferred guidelines for
30 50 Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-
31 51 ScR). Results of this scoping review will provide a comprehensive understanding of
32 52 smart garment concepts used in the sports domain, which enhance the wellness and

1
2
3 53 health of athletes. The study findings will be disseminated through scientific
4
5 54 publications.

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8 55 **Ethics and Dissemination:** Ethical approval is not required for this study. The
9
10 56 findings of this review will be disseminated through a peer-reviewed publication and
11
12 57 a conference presentation.

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14
15 58 **Protocol registration number:** DOI 10.17605/OSF.IO/34MF2 (<https://osf.io/34mf2>)

16 59
17 60 **Keywords:** Smart garments, Athletes, Wellness, Sports, Health, Heat illnesses

18
19 61 **Strengths and limitations of the study**

- 20
21
22 62 • The proposed study uses existing scoping review methodology to identify the
23
24 63 effects of smart garments on the wellbeing of athletes.
- 25
26 64 • The study will provide an in-depth understanding of the current state of smart
27
28 65 sportswear for athletes.
- 29
30 66 • The review will investigate a large volume of literature from the last ten years.
- 31
32 67 • The scoping review will not consider the grey literature and studies published
33
34 68 in English will be reviewed.

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37
38 69 **BACKGROUND**

39
40 70 Smart garments are clothing items that have been integrated with technology such as
41
42 71 sensors and may connect with an app or wearables such as Fitbit or smart watch.[1]
43
44 72 These wearable computers evolved from basic monitoring devices such as heart rate
45
46 73 monitor, fitness monitors and smart wristwatches to advance smart garments covering
47
48 74 a wide variety of markets. Smart garments enabled the integration of smart materials
49
50 75 into clothing for uplifting health, wellness and lifestyle of humans. Majority of smart
51
52 76 garment applications integrate sensors in garments, which can track/monitor
53
54 77 biological and environmental details. The ‘smart shirt’, which measure vital body
55
56 78 parameters and communicate with remote units is an example of a smart garment
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3 79 application in the healthcare sector. [2, 3] This development was conducted primarily
4
5 80 to ensure occupational wellness focusing on occupations such as military, firefighters,
6
7 81 healthcare professionals, and police officers.[2, 3] Innovative wound care biosensing
8
9 82 is another smart clothing application.[4] These bio-monitoring sensors can monitor
10
11 83 critical wounds to enable the development of advance wound care treatments.
12
13 84 Temperature monitoring using wearable sensors for patients, aging population and for
14
15 85 children is also an interesting, smart application, which can be integrated into
16
17 86 garments.[5] Some studies elaborate on the smart cooling garment concepts, which
18
19 87 can provide intelligent cooling to the public to enhance cooling comfort and wellness.
20
21 88 [6, 7]
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25
26 89 Sports wellness is another vital domain addressed by smart garments. Sportswear
27
28 90 started getting subjected to unique demands of athletes, to protect the wearer from,
29
30 91 rigorous physical activities as well as from extreme environmental conditions. Hence,
31
32 92 to address complex sportswear requirements, smart garment concepts started to
33
34 93 outspread into the sportswear market. Existing studies elaborate on the use of sensors
35
36 94 in sportswear for applications such as body fluid measurement, physiological
37
38 95 parameters monitoring, posture controlling. [8, 9] Furthermore, smart textiles are used
39
40 96 in snowboarding activity where textile pressure sensors were used to recognise the
41
42 97 activities performed by users.[9] Another study developed a smart shirt and leggings
43
44 98 to measure heart and muscle activity, breathing rate and temperature. [10] With these
45
46 99 examples, it is evident that the smart garment technology can be incorporated into
47
48 100 sportswear applications to enhance the wellbeing and performance of sports
49
50 101 consumers. As mentioned in market reports, smart garment applications in the sports
51
52 102 sector are expected to exhibit high growth. [11]
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103 **Rationale**

104 Several review papers have been published in the domain of wearable technology and
105 smart garment technology. [12-15] However, most of these papers are focusing on
106 medical or health care applications giving less priority to the wellness of athletes. [14,
107 16, 17] Furthermore, the variety of smart garment applications available in the
108 literature is overwhelming. Therefore, the current review is essential to compare the
109 wide variety of technologies incorporated in smart garments for athletes and also to
110 understand the knowledge gaps for future studies. [18, 19]

111 Some of the existing reviews discuss smart garment technologies that can be applied
112 in the sportswear domain, yet they are either outdated [8, 9] or not comprehensive
113 enough to provide an in-depth understanding of the current state of smart sportswear.
114 [20] Due to the fast-evolving nature of smart garment applications, researchers
115 frequently introduce novel technologies and materials. [21, 22] One such novel
116 application in smart garment domain is the introduction of highly flexible, high-
117 energy textile lithium battery, which can offer a stable, durable and safe energy
118 supply for wearable electronics. [21] Gas detecting textiles, metatextiles, which can
119 offer adaptable thermal comfort and energy harvesting Triboelectrics materials and
120 are few other new smart garment applications. [21, 22]. These latest technologies can
121 fulfil a wide variety of sportswear requirements shifting smart sports garments to a
122 new dimension.

123 Considering requirements described above, a comprehensive review, which follows a
124 systematic approach and covers the latest smart sports garment applications is
125 essential to ensure effective use of latest technologies in future smart garment design
126 projects and also to understand the gaps in the literature. Therefore, this study will
127 provide a comprehensive review and a technology mapping of the latest smart sports
128 garment technologies that can guide future research projects. The objectives of this

1
2
3 129 review are to identify a) the functions offered by the smart garments, b) the types of
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5 130 technologies used in smart garments, c) effects (beneficial and harmful) of those
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7 131 garments on the performance of athletes and their experience in using such garments.
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9

10 132 **METHODS**

11
12 133 We follow the scoping review methodology proposed by Arksey and O'Malley, and
13
14 134 we further refined it by the methodology developed by the Joanna Briggs
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16 135 Institute.[23, 24] This protocol consists of six phases namely; 1. identifying the
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18 136 research question, 2. identifying relevant literature, 3. study selection, 4. charting the
19
20 137 data, 5. collating, summarising and reporting the articles and 6. consulting and
21
22 138 translating knowledge (optional). Also, this protocol follows the guidelines for the
23
24 139 Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for
25
26 140 Scoping Reviews (PRISMA-ScR) to optimise the quality of reporting (see additional
27
28 141 file 1).[25] The study has been registered in the Open Science Framework (OSF) on
29
30 142 June 25, 2020 (<https://osf.io/34mf2>).
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38 144 **Stage 1: identifying the research question**

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41 145 The objective of this scoping review is to assess the existing studies to understand the
42
43 146 existing smart garment technologies, which are developed to enhance the health and
44
45 147 wellbeing of athletes. Also, this review will generate input requirements for the
46
47 148 research, which will carry out to develop a smart garment for endurance athletes. The
48
49 149 review is expected to address the below question and sub-questions.
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- 54 150
- 55 • What functions do smart garments offer for athletes?
 - 56 151 • What are the tools and technologies incorporated into those smart
 - 57 152 garments?
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3 153 • How effective are those smart garments to enhance the health and
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6 154 wellbeing of athletes and experience of athletes in using them?
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10 156 **Stage 2: identifying relevant studies**

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12 157 The search strategy was developed by the research team after reviewing related
13
14 158 literature, and an iterative approach was adhered to finalise the strategy (see
15
16 159 additional file 2). The search strings were generated by incorporating Boolean logic
17
18 160 and operators. These strings consist of search terms, which were finalised after getting
19
20 161 agreement from the research team. The search terms are "sensor garments",
21
22 162 "electronic garments", "smart garments", "smart apparel", sports, athletes.
23
24
25

26 163 The databases, which were selected to collect literature are Scopus, Web of Science,
27
28 164 Science Direct, PubMed, and IEEE Xplore, and these databases were selected with
29
30 165 the help of an expert university librarian. Due to rapid technological changes, smart
31
32 166 garment applications are quickly becoming outdated; hence only the studies which
33
34 167 were published within the last ten years were considered for the review. Furthermore,
35
36 168 to ensure the credibility of the studies, we only considered peer-reviewed journal
37
38 169 articles. Also, only the studies in the English language will be included in the
39
40 170 analysis. The research team will review the first 50 search results from each database
41
42 171 before proceeding with the full search to ensure the accuracy of the search strategy.
43
44 172 However, during the execution of search strategy authors of primary studies or
45
46 173 reviews will be contacted for further information, if required. The latest search was
47
48 174 executed on 24/05/2020. The articles retrieved from the search will be imported into
49
50 175 the Covidence software, which will remove duplicated articles automatically from the
51
52 176 system.
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3 **178 Stage 3: study selection: inclusion and exclusion criteria**
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5 179 We will carry out study selection incorporating two-step method. Initially, titles and
6
7 180 abstracts will be reviewed against the selection criteria and will be marked as
8
9 181 'include', 'exclude' or 'uncertain'. Two reviewers will conduct this screening
10
11 182 independently and a discussion will be conducted within the research team to resolve
12
13 183 any discrepancy and to fine-tune selection criteria. This screening and discussion
14
15 184 process will continue until we reach a consensus. [26] Subsequently, for the included
16
17 185 studies, the full-text review will be carried out against the selection criteria following
18
19 186 the same screening procedure. Grey literature will not be considered for this review.
20
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24 187 This two-stage study selection process will be conducted incorporating a review
25
26 188 form (see additional file 3). Only the studies with electronic integrated smart sports
27
28 189 garment, which focus on health and wellbeing of athletes will be included for the
29
30 190 review. To simplify the screening process review form incorporates a few questions to
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32 191 determine the inclusion decision;
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- 40 192 • Does the article is a peer-reviewed primary study?
41
42 193 • Does the article is published within the last ten years (2010-2019) in the
43
44 194 English language?
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46 195 • Does the article involve smart garments
47
48 196 • Does the article focus on the health and wellbeing of athletes?
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53 197 The citations of the included studies will be evaluated against selection criteria
54
55 198 following the same two-stage study selection process to select the additional studies
56
57 199 to be added.
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3 **200 Step 4: charting the data**
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7 201 All included studies will be reviewed and charted using a data extraction form (see
8
9 202 additional file 4). The details which will be extracted from the studies are study
10
11 203 citation, publication type, authors, study location, study year, target market, sample
12
13 204 characteristics (number of participants, demographics), garment type, number of
14
15 205 functions, function type (i.e., biomonitoring, coaching, warning, posture control),
16
17 206 technology characteristics (sensor type, method of power supply,
18
19 207 communication/feedback mechanism and interconnection), evaluation protocol
20
21 208 adhered, user acceptability of the concepts and outcome of the study (quantitative
22
23 209 results, qualitative themes, recommendations, key learnings, limitations).
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29 210 These details will be changed based on the studies included, and after a reviewer
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31 211 carries out the charting, another reviewer will independently validate the charted
32
33 212 details.
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39 **214 Stage 5: collating, summarising and reporting the results**
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42
43 215 The filtered studies will be analysed regarding the location which the study was
44
45 216 conducted, year of publication, market characteristics, garment type, technology
46
47 217 components incorporated such as sensors, power supply, conductive materials,
48
49 218 microprocessors and actuators, evaluation protocol adhered, user acceptability of the
50
51 219 concepts and the outcome of the study. These details will be presented using tables,
52
53 220 charts, and graphs and will be followed by a narrative review.
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57 221 Also, to understand the key themes related to the technology components, to consider
58
59 222 for the underlined research, a thematic analysis will be conducted for the review
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3 223 results. The scoping review discussion will be designed, considering themes that will
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5 224 emerge. Furthermore, the research findings will be shared in relevant national and
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8 225 international conferences/peer-reviewed journals.
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12 13 227 **DISCUSSION**

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17 228 The primary objective of this scoping review is to obtain an understanding of smart
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19 229 garment applications in the sports domain, which were developed to enhance the
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21 230 wellbeing of athletes. The search terms and strings for the study were developed, and
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23
24 231 suitable databases were selected, referring to the related literature. The inclusion
25
26 232 criteria for the review were determined based on the objectives of the study.
27

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29
30 233 Even though the defined scoping review protocol is endorsed with preferred scoping
31
32 234 review protocol guidelines, we want to admit some of the limitations in the study.
33
34 235 Including the studies, which are published only in the English language, restrict the
35
36 236 objectivity of the review. Also, the review will not include studies, which are review
37
38
39 237 papers.
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41
42 238 The proposed scoping review will provide a comprehensive understanding of the
43
44 239 existing smart garment applications in the sports domain. Additionally, the results of
45
46 240 this review will offer foundational know-how on sports smart garment applications
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48
49 241 that can inform new research.
50

51 52 242 **Additional files**

53 243 Additional file 01: PRISMA-ScR Checklist. doc

54
55 244 This document includes the PRISMA-ScR protocol checklist.

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57 245 Additional file 02: Search Strategy. doc
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3 246 This document includes the search strategy that will be incorporated to execute the
4
5 247 search.

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7
8 248 Additional file 03: Review Form.xls

9
10 249 This form includes the criteria for screening the sources for the scoping review.

11
12 250 Additional file 04: Data extraction Form.xls

13
14
15 251 This form includes the format that will facilitate the charting of scoping review data
16
17 252 to enable analysis.

18
19 253

20
21 254 **Declarations**

22
23
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25
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29
30 258 Not applicable

31
32
33 259 **Availability of data and materials**

34
35 260 Not applicable

36
37 261 **Author contribution**

38
39
40 262 AAM and TIW contributed to plan the study and prepare the manuscript. All the
41 263 authors (AAM, TIW and BK) read and approved the final manuscript.

42
43 264

44
45 265 **Ethics approval and consent to participate**

46
47 266 Not applicable.

48
49 267 **Consent for publication**

50
51 268 Not applicable

52
53 269 **Competing interest**

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56 270 The authors declare that they have no competing interests

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58 271 **Author details**

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3 272 Not applicable
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REFERENCES

- 11
12 276 1. Ariyatun B, Holland R, Harrison D, et al. The future design direction of smart
13 277 clothing development. *Journal of the Textile Institute* 2005;**96**(4):199-210.
14 278 2. Georgia Tech Wearable Motherboard. Secondary.
15 279 <http://www.gtwm.gatech.edu/>.
16 280 3. Özyangan V, Abdulova V. Utilization of Smart Textiles in Healthcare.
17 281 *International Journal of Electronics, Mechanical Mechatronics Engineering*
18 282 **5**(4):1025-33.
19 283 4. Smart textiles with biosensing capabilities. *Advances in Science and*
20 284 *Technology*; 2013. Trans Tech Publ.
21 285 5. Li H, Yang H, Li E, et al. Wearable sensors in intelligent clothing for measuring
22 286 human body temperature based on optical fiber Bragg grating. *Optics*
23 287 *express* 2012;**20**(11):11740-52.
24 288 6. Battery powered heating and cooling suit. IEEE Long Island Systems,
25 289 Applications and Technology (LISAT) Conference 2014; 2014 2-2 May
26 290 2014.
27 291 7. Wearable individual adapting cooling system using smartphone and heart beat
28 292 sensor. 2016 55th Annual Conference of the Society of Instrument and
29 293 Control Engineers of Japan (SICE); 2016 20-23 Sept. 2016.
30 294 8. Textile-Based Wearable Sensors for Assisting Sports Performance. 2009 Sixth
31 295 International Workshop on Wearable and Implantable Body Sensor
32 296 Networks; 2009 3-5 June 2009.
33 297 9. Textile pressure sensors for sports applications. SENSORS, 2010 IEEE; 2010.
34 298 IEEE.
35 299 10. Design of smart garments for sports and rehabilitation. IOP Conference
36 300 Series: Materials Science and Engineering; 2018. IOP Publishing.
37 301 11. Hanuska A, Chandramohan B, Bellamy L, et al. Smart clothing market
38 302 analysis: Technical Report, 2016.
39 303 12. Tang SLP, Stylios G. An overview of smart technologies for clothing design
40 304 and engineering. *International Journal of Clothing Science Technology*
41 305 2006.
42 306 13. Papi E, Koh WS, McGregor AH. Wearable technology for spine movement
43 307 assessment: A systematic review. *Journal of Biomechanics* 2017;**64**:186-
44 308 97.
45 309 14. Patel S, Park H, Bonato P, et al. A review of wearable sensors and systems
46 310 with application in rehabilitation. *Journal of NeuroEngineering and*
47 311 *Rehabilitation* 2012;**9**(1):21.
48 312 15. Stoppa M, Chiolerio A. Wearable electronics and smart textiles: a critical
49 313 review. *sensors* 2014;**14**(7):11957-92.
50 314 16. Moral-Munoz JA, Zhang W, Cobo MJ, et al. Smartphone-based systems for
51 315 physical rehabilitation applications: A systematic review. *Assistive*
52 316 *Technology* 2019:1-14.

- 1
2
3 317 17. Kirk MA, Amiri M, Pirbaglou M, et al. Wearable Technology and Physical
4 318 Activity Behavior Change in Adults With Chronic Cardiometabolic
5 319 Disease: A Systematic Review and Meta-Analysis. *American Journal of*
6 320 *Health Promotion* 2019;**33**(5):778-91.
- 8 321 18. Fernández-Caramés TM, Fraga-Lamas P. Towards the Internet of smart
9 322 clothing: A review on IoT wearables and garments for creating intelligent
10 323 connected e-textiles. *Electronics* 2018;**7**(12):405.
- 11 324 19. Sayem ASM, Teay SH, Shahariar H, et al. Review on Smart Electro-Clothing
12 325 Systems (SeCSs). 2019.
- 14 326 20. Rajput M, Singh R. Study of smart textile in sports and designing a smart
15 327 jersey for athletes health issue. *International Research Journal of*
16 328 *Engineering and Technology* 2017;**04**(06).
- 17 329 21. The Hong Kong Polytechnic University. Highly flexible high-energy textile
18 330 lithium battery to cope with surging demand for wearable electronics.
19 331 Secondary Highly flexible high-energy textile lithium battery to cope with
20 332 surging demand for wearable electronics 2019.
21 333 <https://www.sciencedaily.com/releases/2019/05/190524102744.htm>.
- 23 334 22. Kapfunde M. 5 innovations that could help smart clothing go mainstream.
24 335 Secondary 5 innovations that could help smart clothing go mainstream
25 336 2019. [https://www.wearable.com/smart-clothing/smart-clothing-](https://www.wearable.com/smart-clothing/smart-clothing-technology-innovations-7284)
26 337 [technology-innovations-7284](https://www.wearable.com/smart-clothing/smart-clothing-technology-innovations-7284).
- 28 338 23. Arksey H, O'Malley L. Scoping studies: towards a methodological framework.
29 339 *International journal of social research methodology* 2005;**8**(1):19-32.
- 30 340 24. Joanna Briggs Institute. The Joanna Briggs Institute reviewers' manual 2015:
31 341 Methodology for JBI scoping reviews. *Joanne Briggs Inst* 2015:1-24.
- 32 342 25. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews
33 343 (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018;**169**:467-
34 344 73.
- 36 345 26. Orwin R, Decisions E, Cooper I, et al. *The Handbook of Research Synthesis*
37 346 1994:150-1.
- 38 347

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	5-6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	5-6
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	Click here to enter text.
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	7-9
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	7-8
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	8-9
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	9-10
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	9-10
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	NA
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	10



SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	NA
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	NA
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	NA
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	NA
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	NA
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	NA
Limitations	20	Discuss the limitations of the scoping review process.	3
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	NA
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	11

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: 10.7326/M18-0850.



Smart Garments to Enhance Health and Wellbeing of Athletes

database	Search string	Number of entries	date	Source type/s	Data	Time frame
Scopus	ALL (("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*) AND (health OR well-being OR wellness OR illnesses)) AND (LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (DOCTYPE , "ar"))	50	05/06/2020	Journals	ALL*	2010-2019
IEEE	(("Full Text & Metadata":sensor garment OR sensor garments OR electronic garment OR electronic garments OR smart garment OR smart garments OR smart apparel) AND "Full Text & Metadata":sport% OR athlet%) Filters Applied: 2010 - 2019	84	05/06/2020	Journals	Full text + Meta data (<i>Abstract, title and indexing terms</i>)	2010-2019

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4	Web of Science	TS=(("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*)) Refined by: DOCUMENT TYPES: (ARTICLE) Timespan: 2019-2010	1	05/06/2020	Article	TS=Topic Searches title, abstract, author keywords, and more
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13	Science Direct	(sensor OR smart OR electronic) AND (garment OR garments) AND (sport OR sports OR athlete OR athletes) Timespan: 2019-2010	415	05/06/2020	Research articles	Full text
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23	PubMed	("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*) Year-2010-2019	5	25/06/2020	Books and Documents Clinical trials Randomised control trial	Full text
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**SCOPUS ALL: Entering ALL("heart attack") will return documents with "heart attack" in the article title, source title, language, author, editor, affiliation, abstract, keywords, references, DOI, ISBN, ISSN, CODEN, issue, volume, publication year, sequence bank, sequence bank number, article number, chemical name, CAS registry number, manufacturer, publisher, or conference fields*

Language Filter was not used for the pilot search strategy

SCOPUS

Advance search query:

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ALL ( ( "sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel" ) AND (
sport* OR athlet* ) AND ( health OR well-being OR wellness OR illnesses ) )
) AND ( LIMIT-TO ( SRCTYPE , "j" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND
LIMIT-TO ( PUBYEAR,2018)
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OR LIMIT-TO ( PUBYEAR,2019)

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IEEE

For peer review only

Step 01

Advanced Search ?

Advanced Search | Command Search | Citation Search

Enter keywords, select fields, and select operators

Search Term in ?

AND in ↑ × +



Step 02

Filtering year range & filtering the source types: Journals and conferences

Year ^

Single Year **Range**

2010 2019

From To

2010 2019

For peer review only

Showing 1-25 of 117 for
 ("Full Text & Metadata":sensor garment OR sensor garments OR electronic garment OR electronic garments OR smart garment OR smart garments OR smart apparel) AND "Full Text & Metadata":sport% OR athlet%
 health OR well-being OR wellness OR illnesses

Filters Applied: 2010 - 2019

- Conferences (74)
- Journals (25)
- Magazines (8)
- Books (6)
- Standards (3)
- Early Access Articles (1)

Apply

Feedback

Web of Science

Advance search query:

TS=(("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*))

Refined by: DOCUMENT TYPES: (ARTICLE)

Timespan: 2019-2010

Science Direct

Advance search query:

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2
3 (sensor OR smart OR electronic) AND (garment OR garments) AND (sport OR sports OR athlete OR
4 athletes)
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9 **Year:** 2010-2019
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14 **Article Types:** Research articles
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27 **Advance search query:**
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29 ("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport*
30 OR athlet*)
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Article Types:

- Books and Documents
- Clinical trials
- Randomised control trial

For peer review only

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Paper ID	Title	Inclusion/exclusion criteria
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For peer review only

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Decision

For peer review only

BMJ Open

Effects of Smart Garments on the Wellbeing of Athletes: A Scoping Review Protocol

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-042127.R1
Article Type:	Protocol
Date Submitted by the Author:	26-Sep-2020
Complete List of Authors:	Al Mahmud, Abdullah ; Swinburne University of Technology, School of Design; Faculty of Health, Arts and Design Wickramarathne, Tharushi; Swinburne University of Technology, Centre for Design Innovation Kuys, Blair; Swinburne University of Technology, School of Design; Faculty of Health, Arts and Design
Primary Subject Heading:	Health informatics
Secondary Subject Heading:	Health informatics, Public health, Health services research, Health policy, Sports and exercise medicine
Keywords:	Health informatics < BIOTECHNOLOGY & BIOINFORMATICS, Information technology < BIOTECHNOLOGY & BIOINFORMATICS, Information management < BIOTECHNOLOGY & BIOINFORMATICS, World Wide Web technology < BIOTECHNOLOGY & BIOINFORMATICS

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3 1 **Title: Effects of Smart Garments on the Wellbeing of Athletes: A Scoping Review**
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5 2 **Protocol**
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3 27 **Title: Effects of Smart Garments on the Wellbeing of Athletes: A Scoping Review**
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5 28 **Protocol**
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7 29 **ABSTRACT**
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10 30 **Introduction** With the advancements in wearable electronics, electronically integrated
11
12 31 smart garments started to transpire in our daily lives. Smart garment technologies are
13
14 32 incorporated into sportswear applications to enhance the wellbeing and performance of
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16 33 athletes. Smart garments applications in the sports sector are increasing, and the variety
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18 34 of smart garment applications available in the literature is overwhelming. Therefore, it
19
20 35 is essential to compare the vast array of technologies incorporated in smart garments
21
22 36 for athletes to understand the knowledge gaps for future studies. The protocol paper
23
24 37 aims to examine the smart garments used in the sports domain to enhance the health
25
26 38 and wellbeing of athletes.
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30 39 **Methods and analysis** Relevant studies will be retrieved using pre-defined search
31
32 40 terms from Scopus, Web of Science, Science Direct, PubMed, and IEEE Xplore. The
33
34 41 retrieved articles will be eliminated in two phases: title and abstract screening and full-
35
36 42 text screening. The included articles will be primary studies published in the English
37
38 43 language within the last ten years. Subsequently, the included articles will be further
39
40 44 studied to extract data using a data extraction form. The extracted data will undergo a
41
42 45 thematic analysis. Also, quantitative analysis will be carried out using descriptive
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44 46 statistics.
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48 49 **Ethics and Dissemination** The results of this review will provide a comprehensive
49
50 51 understanding of smart garment concepts used in the sports domain. The findings of
51
52 52 this scoping review will be shared through a journal publication and a conference
53
54 53 presentation. Ethical approval is not needed for this scoping review.
55
56 54
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58 51 **Protocol registration number:** DOI 10.17605/OSF.IO/34MF2 (<https://osf.io/34mf2>)
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3 53 **Keywords:** Smart garments, Athletes, Wellness, Sports, Health, Heat illnesses
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5 54 **Strengths and limitations of the study**
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- 7
8 55 • The proposed study uses existing scoping review methodology to identify the
9
10 56 effects of smart garments on the wellbeing of athletes.
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12 57 • The study will give an in-depth understanding of the current state of smart
13
14 58 sportswear for athletes.
15
16 59 • The review will investigate literature from the last ten years.
17
18 60 • The scoping review will consider studies published in the English language.
19
20 61 • To capture a broad spectrum of smart garment applications incorporated in
21
22 62 professional sportswear, we will consider all the studies that reported the effects
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24 63 of smart garments designed for professional athletes.
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29 64 **INTRODUCTION**

30
31 65 Smart garments are clothing items that are made with intelligent materials or electronic
32
33 66 technologies, which can sense, react or adapt behaviour to the circumstances. [1] These
34
35 67 smart garments are also known as a branch of wearable computers that evolved from
36
37 68 the essential monitoring devices such as heart rate monitors, fitness monitors, and smart
38
39 69 wristwatches like Fitbit. Smart garments can be worn like regular clothing, and they
40
41 70 can measure a broad spectrum of biomechanical and physiological metrics and provide
42
43 71 advanced functions like posture controlling to support the health and wellbeing of the
44
45 72 athlete.[2-4]
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50 73 The majority of smart garment applications integrate sensor technology that enables
51
52 74 wireless health monitoring.[5] One such example is Hexoskin, which is a clinically
53
54 75 validated smart shirt that can measure biological/physical parameters like cardiac,
55
56 76 respiratory, sleep, and activity data. [6] Temperature monitoring using wearable sensors
57
58 77 and smart cooling are some other smart applications that can be integrated into clothing
59
60

78 to enhance the comfort and wellness of an individual. [7-9] Smart monitoring and other
79 related functions offered by some of the existing smart garments are listed in Table 1.

80 Table 1: Some examples of smart garment applications

Smart Function	Smart Garment Applications
Smart monitoring	<ul style="list-style-type: none"> • Biomonitoring: Heart rate, body temperature, breathing [10-12] • Posture monitoring [12-14] • Micro-climate temperature and humidity monitoring [15, 16]
Other smart functions	<ul style="list-style-type: none"> • Smart cooling [12, 16, 17] • Smart compression [18]

81

82 Sportswear started getting subjected to the unique demands of athletes, to protect the
83 wearer from extreme environmental conditions. Also, researchers explored sensor
84 technologies as a means of enhancing the health and wellbeing of athletes.[19]
85 Considering these, to address complex sportswear requirements and to improve the
86 wellbeing of athletes, smart technologies with integrated sensors started to outspread
87 into the sports market. Some of the existing studies explored the use of sensors to
88 measure biological parameters (i.e., heart rate, muscle and oxygen saturation) and
89 safety-related parameters (i.e., position, motion and impact) to enhance health,
90 wellness, and performance of athletes. [20-22] Another study investigated the use of
91 smart textiles in snowboarding activity where textile pressure sensors were utilised to
92 recognise the activities performed by users.[21] Also, researchers developed a smart
93 shirt and leggings to measure heart and muscle activity, breathing rate, and temperature.

1
2
3 94 [11] With these examples, it is evident that smart technology can be incorporated into
4
5 95 sportswear applications to enhance the wellbeing and performance of athletes.
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9
10 97 Sportswear manufacturers started stretching the boundaries of smart wearables by
11
12 98 integrating technology into garments. [4] As mentioned in market reports, smart
13
14 99 garment applications in the sports sector are expected to exhibit high growth. [23]
15
16
17 100 However, most of the commercialised sport smart garments offer standard functions
18
19 101 like smart monitoring, communication, compression and coaching. These garments
20
21 102 consist of non-textile electrical/electronic devices/components to inbuild intelligent
22
23 103 functions to the clothing inhibiting user experience. Researchers started exploring e-
24
25 104 textiles and designed smart technologies into textiles.[24, 25] Also, some studies
26
27 105 examined creative, smart applications to improve user experience. The smart garment
28
29 106 that reacts to the wearer mood is one such example. [26] These studies provide an
30
31 107 opportunity for future smart sports garments that can improve the health and wellbeing
32
33 108 of athletes. A technology mapping and review of existing smart garments designed for
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35 109 athletes will assist in understanding how these smart garments may inform the new
36
37 110 product development and guide further research.
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43 **Rationale**

44 112 Several researchers have reviewed the applications of wearable technology and smart
45
46 113 garment technology. [19, 22, 27-30] However, most of these papers are focusing on
47
48 114 medical or healthcare applications giving less priority to the wellness of athletes. [29,
49
50 115 31, 32] Furthermore, the variety of smart garment applications available in the literature
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52 116 is overwhelming. Therefore, the proposed review is essential to compare the vast array
53
54 117 of technologies incorporated into smart garments for athletes and also to understand the
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56 118 knowledge gaps for future research. [33, 34]
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3 119 Some of the existing reviews discuss smart garment technologies that can be applied in
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5 120 the sportswear domain. Yet, they are either outdated [20, 21] or not comprehensive
6
7 121 enough to provide an in-depth understanding of the current state of smart sportswear
8
9 122 [35] or focusing only on smart monitoring. [22] Due to the fast-evolving nature of smart
10
11 123 garment applications, researchers frequently introduce novel technologies and
12
13 124 materials. [36, 37] One such novel application is recently introduced wearable textile
14
15 125 electronics that can uplift the performance of future smart sports clothing. [36]
16
17 126 Metatextiles that offer adaptable thermal comfort and energy harvesting Triboelectrics
18
19 127 materials that can be used to optimise power consumption of smart sports garments are
20
21 128 few other new smart technology applications. [36, 37]. These latest technologies can
22
23 129 fulfil a wide variety of sportswear requirements shifting smart sports garments to a new
24
25 130 dimension.

26
27 131 Considering the requirements described above, a comprehensive review, which follows
28
29 132 a systematic approach and covers the latest smart sports garment applications is
30
31 133 essential to ensure effective use of the latest technologies in future smart garment
32
33 134 design projects. Therefore, this paper presents a protocol for conducting a scoping
34
35 135 review that can provide a comprehensive evaluation and a technology mapping of the
36
37 136 latest smart sports garment technologies to guide future research. The objectives of this
38
39 137 review are to identify a) the functions offered by the smart garments, b) the types of
40
41 138 technologies used in smart garments, c) effects (beneficial and harmful) of those
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43 139 garments on the performance of athletes and their experience in using such garments.
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144 **METHODS**

145 We follow the scoping review methodology proposed by Arksey and O'Malley. [38]

146 This protocol consists of six phases namely; 1. identifying the research question, 2.

147 identifying relevant literature, 3. study selection, 4. charting the data, 5. collating,

148 summarising and reporting the articles and 6. consulting and translating knowledge

149 (optional). PRISMA-ScR checklist (see Additional file 1) will be used throughout the

150 proposed scoping review to ensure adherence.[39] The study has been registered in the

151 Open Science Framework (OSF) on June 25, 2020 (<https://osf.io/34mf2>).

152

153 **Stage 1: identifying the research question**

154 The objective of this study is to assess the existing studies to understand the current

155 smart garment technologies, which are developed to enhance the health and wellbeing

156 of athletes. Also, this review will generate input requirements for developing improved

157 smart garment for athletes. To concretise the focus of this review, we will concentrate

158 on smart garment studies related to professional athletes. The review is expected to

159 address the below questions.

- 160 • What functions do smart garments offer for professional athletes?
- 161 • What are the technologies incorporated into those smart garments?
- 162 • How effective are those smart garments to enhance the health and
- 163 wellbeing of athletes?

164

165 **Stage 2: identifying relevant studies**

166 The research team developed the search strategy after reviewing related literature, and

167 an iterative approach was adhered to finalise the strategy (see Additional file 2). The

168 search strings were generated by incorporating Boolean logic and operators. These

1
2
3 169 strings consist of search terms, which were finalised after getting agreement from the
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5 170 research team. The search terms are "sensor garments", "electronic garments", "smart
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8 171 garments", "smart apparel", "sports", and "athletes".
9

10 172

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12 173 The databases, which were selected to collect literature are Scopus, Web of Science,
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14 174 Science Direct, PubMed, and IEEE Xplore, and these databases were chosen with the
15
16
17 175 help of an expert university librarian. Due to the rapid technological changes, smart
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19 176 garment applications are quickly becoming outdated; hence only the studies published
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21 177 within the last ten years will be considered for the review. Furthermore, to ensure the
22
23 178 credibility of the studies, we only considered peer-reviewed journal articles. Also, only
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26 179 the studies in the English language will be included for review. The research team will
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28 180 review the first 50 search results from each database before proceeding with the full
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31 181 search to ensure the accuracy of the search strategy. However, during the execution of
32
33 182 search strategy authors of primary studies or reviews will be contacted for further
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35 183 information, if required. The latest search was executed on 24/05/2020. The articles
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37 184 retrieved from the search will be imported into the Covidence software, which will
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40 185 remove duplicated items automatically.
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42 186

43 44 45 187 **Stage 3: study selection: inclusion and exclusion criteria**

46 188 We will carry out study selection incorporating two-step method. Initially, titles and
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48 189 abstracts will be reviewed against the selection criteria and will be marked as 'include',
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51 190 'exclude' or 'uncertain'. Two reviewers will conduct this screening independently, and
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53 191 a discussion will be undertaken in the research team to resolve any discrepancy and to
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55 192 fine-tune selection criteria. This screening and discussion process will continue until
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58 193 we reach a consensus. [40] Subsequently, for the included studies, the full-text review
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194 will be carried out against the selection criteria following the same screening procedure.

195 Grey literature will not be considered for this review.

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

- 201 • Is the article a peer-reviewed primary study?
- 202 • Is the article published within the last ten years (2010-2019) in the English
203 language?
- 204 • Does the article involve smart garments?
- 205 • Does the article focus on the health and wellbeing of professional athletes?

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

209 **Step 4: charting the data**

210 All included studies will be reviewed and charted using a data extraction form (see
211 Additional file 4). The details, which will be extracted from the studies are study
212 citation, publication type, authors, study location, study year, target market, sample
213 characteristics (number of participants and demographics), garment type, number of
214 functions, function type (i.e., biomonitoring, coaching, warning, and posture control),
215 technology characteristics (sensor type, method of power supply,
216 communication/feedback mechanism and interconnection), evaluation protocol

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3 217 adhered, user acceptability of the concepts and outcome of the study (quantitative
4
5 218 results, qualitative themes, recommendations, key learnings, and limitations). The
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7
8 219 charting of the extracted information will be conducted by two reviewers.
9

10 220

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12 221 **Stage 5: collating, summarising and reporting the results**

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14 222 Initially, we will conduct a quantitative analysis for extracted data using descriptive
15
16 223 statistics (e.g., frequencies). This analysis will provide numerical summaries of a) smart
17
18 224 sports garment applications designed focusing on professional athletes, b) the functions
19
20 225 offered by those smart garments, c) the types of technologies used in smart garments
21
22 226 and d) effects (beneficial and harmful) of those garments on the performance of athletes
23
24 227 and their experience in using such garments. These details will be presented using
25
26 228 tables, charts, and graphs and will be followed by a brief summary. Afterwards, we will
27
28 229 analyse all the extracted data thematically to identify emerging themes. Two reviewers
29
30 230 will independently identify the emerging themes, and those themes will be reviewed
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32 231 later by both reviewers to determine the final themes.
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39 232 **Patient and public involvement**

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42 233 This scoping review protocol does not include patients or the public.
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47 235 **ETHICS/DISSEMINATION**

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50 236 This protocol reports a comprehensive methodology derived from the standard and
51
52 237 well-established best practices to guide a scoping review that will be conducted to
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54 238 understand the existing smart sports garments applications. The proposed study will
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56 239 provide a comprehensive review and a technology mapping of the latest smart sports
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58 240 garment technologies that were developed to enhance the wellbeing of athletes. The
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3 241 scoping review findings will offer foundational know-how on sports smart garment
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5 242 applications emphasising the technology and design gaps to assist new product
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7 243 development and to inform further research. In future work, we are planning to
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9 244 disseminate the results of this scoping review at relevant conferences and journals.
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12 245 Ethical approval is not needed for this scoping review, as we will not collect any
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14 246 primary data.
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17 247 **Additional files**

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20 248 Additional file 01: PRISMA-ScR Checklist.pdf

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22 249 This document includes the PRISMA-ScR protocol checklist.

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24 250 Additional file 02: Search Strategy.pdf

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26 251 This document includes the search strategy that will be incorporated to execute the
27
28 252 search.

29
30 253 Additional file 03: Review Form.pdf

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32 254 This form includes the criteria for screening the sources for the scoping review.

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34 255 Additional file 04: Data extraction Form.pdf

35
36 256 This form includes the format that will facilitate the charting of scoping review data
37
38 257 to enable analysis.

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40 258

41 42 43 44 45 259 **Declarations**

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47 260

48 49 261 **Acknowledgments**

50
51 262 Not applicable

52 53 263 **Patient and Public Involvement**

54
55 264 No patients and or public will be involved to conduct this study or to design the
56
57 265 protocol.
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3 266 **Funding**
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5 267 Not applicable
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8 268 **Availability of data and materials**
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10 269 Not applicable
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12 270 **Author contribution**
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14 271 AAM and TIW contributed to plan the study and prepare the manuscript. All the authors
15 272 (AAM, TIW and BK) read and approved the final manuscript.
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19 274 **Ethics approval and consent to participate**
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21 275 Not applicable.
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23 276 **Consent for publication**
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25 277 Not applicable
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27 278 **Competing interest**
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29 279 The authors declare that they have no competing interests
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31 280 **Author details**
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33 281 Not applicable
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REFERENCES

- 40
41
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43
44 285 1. Ariyatum, B., et al., *The future design direction of smart clothing*
45 286 *development*. Journal of the Textile Institute, 2005. **96**(4): p. 199-210.
46 287 2. *Nike granted patent for smart shoe with in-built fitness tracking*, in *The*
47 288 *Sunday Morning Herald*. 2016.
48 289 3. Draper, S. *Top 5 Smart Clothes for Workout Freaks in the Market Right*
49 290 *Now*. 2018; Available from: [https://www.wearable-](https://www.wearable-technologies.com/2018/08/top-5-smart-clothes-for-workout-freaks-in-the-market-right-now/)
50 291 [technologies.com/2018/08/top-5-smart-clothes-for-workout-freaks-in-](https://www.wearable-technologies.com/2018/08/top-5-smart-clothes-for-workout-freaks-in-the-market-right-now/)
51 292 [the-market-right-now/](https://www.wearable-technologies.com/2018/08/top-5-smart-clothes-for-workout-freaks-in-the-market-right-now/).
52 293 4. Sawh, M. *The best smart clothing*. 2018; Available from:
53 294 <https://www.wareable.com/smart-clothing/best-smart-clothing>.
54 295 5. Koh, A., et al., *A soft, wearable microfluidic device for the capture, storage,*
55 296 *and colorimetric sensing of sweat*. Science translational medicine, 2016.
56 297 **8**(366): p. 366ra165-366ra165.
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58
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60

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3 298 6. HEXOSKIN *HEXOSKIN SMART GARMENTS SPECIFICATIONS*. n.d.; Available
4 299 from: <https://www.hexoskin.com/>.
- 5
6 300 7. Paul, G., E. Gim, and D. Westerfeld. *Battery powered heating and cooling*
7 301 *suit*. in *IEEE Long Island Systems, Applications and Technology (LISAT)*
8 302 *Conference 2014*. 2014.
- 9 303 8. Suzuki, Y., et al. *Wearable individual adapting cooling system using*
10 304 *smartphone and heart beat sensor*. in *2016 55th Annual Conference of the*
11 305 *Society of Instrument and Control Engineers of Japan (SICE)*. 2016.
- 12 306 9. Li, H., et al., *Wearable sensors in intelligent clothing for measuring human*
13 307 *body temperature based on optical fiber Bragg grating*. *Optics express*,
14 308 2012. **20**(11): p. 11740-11752.
- 15 309 10. Paiva, A., et al. *Design of a Smart Garment for Cycling*. 2019. Cham:
16 310 Springer International Publishing.
- 17 311 11. Paiva, A., et al. *Design of smart garments for sports and rehabilitation*. in
18 312 *IOP Conference Series: Materials Science and Engineering*. 2018. IOP
19 313 Publishing.
- 20 314 12. Durbhaka, G.K. *Adaptive wearable smart fabric based on body posture and*
21 315 *temperature*. in *2016 2nd International Conference on Advances in*
22 316 *Computing, Communication, & Automation (ICACCA) (Fall)*. 2016.
- 23 317 13. Wang, Q., et al. *Smart Rehabilitation Garment for posture monitoring*. in
24 318 *2015 37th Annual International Conference of the IEEE Engineering in*
25 319 *Medicine and Biology Society (EMBC)*. 2015.
- 26 320 14. Wang, Q., et al. *Zishi: a smart garment for posture monitoring*. in
27 321 *Proceedings of the 2016 CHI Conference Extended Abstracts on Human*
28 322 *Factors in Computing Systems*. 2016.
- 29 323 15. Linti, C., et al. *Sensory baby vest for the monitoring of infants*. in
30 324 *International Workshop on Wearable and Implantable Body Sensor*
31 325 *Networks (BSN'06)*. 2006. IEEE.
- 32 326 16. Jahangir, M., et al. *Design and Testing of Cooling Jacket using Peltier Plate*.
33 327 in *2019 International Conference on Applied and Engineering Mathematics*
34 328 *(ICAEM)*. 2019. IEEE.
- 35 329 17. Wickramarathne, T.I., A.A. Mahmud, and B. Kuys, *Exploring Smart Cooling*
36 330 *Garments for Endurance Cycling Athletes*, in *Proceedings of the 31st*
37 331 *Australian Conference on Human-Computer-Interaction*. 2019, Association
38 332 for Computing Machinery: Fremantle, WA, Australia. p. 563–567.
- 39 333 18. Belbasis, A. and F.K. Fuss, *Muscle Performance Investigated With a Novel*
40 334 *Smart Compression Garment Based on Pressure Sensor Force Myography*
41 335 *and Its Validation Against EMG*. 2018. **9**(408).
- 42 336 19. Choi, J., et al., *Skin-interfaced systems for sweat collection and analytics*.
43 337 *Science advances*, 2018. **4**(2): p. eaar3921.
- 44 338 20. Coyle, S., et al. *Textile-Based Wearable Sensors for Assisting Sports*
45 339 *Performance*. in *2009 Sixth International Workshop on Wearable and*
46 340 *Implantable Body Sensor Networks*. 2009.
- 47 341 21. Holleczeck, T., et al. *Textile pressure sensors for sports applications*. in
48 342 *SENSORS, 2010 IEEE*. 2010. IEEE.
- 49 343 22. Seshadri, D.R., et al., *Wearable sensors for monitoring the internal and*
50 344 *external workload of the athlete*. *NPJ digital medicine*, 2019. **2**(1): p. 1-18.
- 51 345 23. Hanuska, A., et al., *Smart clothing market analysis*. 2016, Technical Report.
- 52
53
54
55
56
57
58
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2
3 346 24. IDTechEx. *Introducing the latest in textiles: Soft hardware*. 2018; Available
4 347 from:
5 348 [https://www.wearabletechnologyinsights.com/articles/15079/introduci](https://www.wearabletechnologyinsights.com/articles/15079/introducing-the-latest-in-textiles-soft-hardware)
6 349 [ng-the-latest-in-textiles-soft-hardware](https://www.wearabletechnologyinsights.com/articles/15079/introducing-the-latest-in-textiles-soft-hardware).
7
8 350 25. Lugoda, P., T. Dias, and R. Morris, *Electronic temperature sensing yarn*.
9 351 *Journal of Multidisciplinary Engineering Science Studies*, 2015. **1**(1).
10 352 26. eScent. *PERSONALISED SCENT BUBBLE*. n.d.; Available from:
11 353 <https://www.escent.ai/smartsecondskin>.
12 354 27. Tang, S.L.P. and G. Stylios, *An overview of smart technologies for clothing*
13 355 *design and engineering*. *International Journal of Clothing Science*
14 356 *Technology*, 2006.
15 357 28. Papi, E., W.S. Koh, and A.H. McGregor, *Wearable technology for spine*
16 358 *movement assessment: A systematic review*. *Journal of Biomechanics*, 2017.
17 359 **64**: p. 186-197.
18 360 29. Patel, S., et al., *A review of wearable sensors and systems with application in*
19 361 *rehabilitation*. *Journal of NeuroEngineering and Rehabilitation*, 2012.
20 362 **9**(1): p. 21.
21 363 30. Stoppa, M. and A. Chiolerio, *Wearable electronics and smart textiles: a*
22 364 *critical review*. *sensors*, 2014. **14**(7): p. 11957-11992.
23 365 31. Moral-Munoz, J.A., et al., *Smartphone-based systems for physical*
24 366 *rehabilitation applications: A systematic review*. *Assistive Technology*,
25 367 2019: p. 1-14.
26 368 32. Kirk, M.A., et al., *Wearable Technology and Physical Activity Behavior*
27 369 *Change in Adults With Chronic Cardiometabolic Disease: A Systematic*
28 370 *Review and Meta-Analysis*. *American Journal of Health Promotion*, 2019.
29 371 **33**(5): p. 778-791.
30 372 33. Fernández-Caramés, T.M. and P. Fraga-Lamas, *Towards the Internet of*
31 373 *smart clothing: A review on IoT wearables and garments for creating*
32 374 *intelligent connected e-textiles*. *Electronics*, 2018. **7**(12): p. 405.
33 375 34. Sayem, A.S.M., et al., *Review on Smart Electro-Clothing Systems (SeCSs)*.
34 376 2019.
35 377 35. Rajput, M. and R. Singh, *Study of smart textile in sports and designing a*
36 378 *smart jersey for athletes health issue*. *International Research Journal of*
37 379 *Engineering and Technology*, 2017. **04**(06).
38 380 36. The Hong Kong Polytechnic University. *Highly flexible high-energy textile*
39 381 *lithium battery to cope with surging demand for wearable electronics*.
40 382 2019; Available from:
41 383 <https://www.sciencedaily.com/releases/2019/05/190524102744.htm>.
42 384 37. Kapfunde, M. *5 innovations that could help smart clothing go mainstream*.
43 385 2019; Available from: [https://www.wearable.com/smart-clothing/smart-](https://www.wearable.com/smart-clothing/smart-clothing-technology-innovations-7284)
44 386 [clothing-technology-innovations-7284](https://www.wearable.com/smart-clothing/smart-clothing-technology-innovations-7284).
45 387 38. Arksey, H. and L. O'Malley, *Scoping studies: towards a methodological*
46 388 *framework*. *International journal of social research methodology*, 2005.
47 389 **8**(1): p. 19-32.
48 390 39. Shamseer, L., et al., *Preferred reporting items for systematic review and*
49 391 *meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation*.
50 392 *Bmj*, 2015. **349**.
51 393 40. Orwin, R., et al., *The Handbook of Research Synthesis*. , 1994: p. 150-1.
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Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3-6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	6
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	NA
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	7
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	7
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	7-8
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	9
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	9-10
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	NA

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	10
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	NA
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	NA
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	NA
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	NA
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	NA
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	NA
Limitations	20	Discuss the limitations of the scoping review process.	10
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	NA
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	NA

JB1 = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: 10.7326/M18-0850.



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Smart Garments to Enhance Health and Wellbeing of Athletes

Database	Search string	Number of entries	date	Source type	Data	Time frame
Scopus	ALL (("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*) AND (health OR well-being OR wellness OR illnesses)) AND (LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (DOCTYPE , "ar"))	50	05/06/2020	Journals	ALL*	2010-2019
IEEE	((("Full Text & Metadata":sensor garment OR sensor garments OR electronic garment OR electronic garments OR smart garment OR smart garments OR smart apparel) AND "Full Text & Metadata":sport% OR athlet%) Filters Applied: 2010 - 2019	84	05/06/2020	Journals	Full text + Metadata (<i>Abstract, title and indexing terms</i>)	2010-2019
Web of Science	TS=(("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*)) Refined by: DOCUMENT TYPES: (ARTICLE) Timespan: 2019-2010	1	05/06/2020	Article	TS=Topic Searches title, abstract, author keywords, and more	2010-2019

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Science Direct	(sensor OR smart OR electronic) AND (garment OR garments) AND (sport OR sports OR athlete OR athletes) Timespan: 2019-2010 <i>Cannot use more than 8 Boolean operators and wildcards , hence the results are not filtered for below:</i> <i>(health OR well-being OR wellness OR illnesses)</i>	415	05/06/2020	Research articles	Full text	2010-2019
PubMed	("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*) Year-2010-2019	5	25/06/2020 Verified again- 21/09/2021	All the studies except reviews	Full text	2010-2019

**SCOPUS ALL: Entering ALL("heart attack") will return documents with "heart attack" in the article title, source title, language, author, editor, affiliation, abstract, keywords, references, DOI, ISBN, ISSN, CODEN, issue, volume, publication year, sequence bank, sequence bank number, article number, chemical name, CAS registry number, manufacturer, publisher, or conference fields*

Language Filter was not used for the pilot search strategy

SCOPUS

Advance search query:

ALL (("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*) AND (health OR well-being OR wellness OR illnesses))
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IEEE

Step 01

Advanced Search ?

Advanced Search

Command Search

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Enter keywords, select fields, and select operators

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Step 02

Filtering year range & filtering the source types: Journals and conferences

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health OR well-being OR wellness OR illnesses x

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| <input type="checkbox"/> Standards (3) | <input type="checkbox"/> Early Access Articles (1) | | |

Apply

Feedback

Web of Science

Advance search query:

TS=(("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*))

Refined by: DOCUMENT TYPES: (ARTICLE)

Timespan: 2019-2010

Science Direct

Advance search query:

(sensor OR smart OR electronic) AND (garment OR garments) AND (sport OR sports OR athlete OR athletes)

Year: 2010-2019

Article Types: Research articles

PubMed

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("sensor garment*" OR "electronic garment*" OR "smart garment*" OR "smart apparel") AND (sport* OR athlet*)

Year: 2010-2019

Article Types:

All the studies except reviews

For peer review only

