Summary and analysis methods for digital pain manikin data in adults with personal pain experience: a scoping review

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Abstract

Background: A digital pain manikin is measurement tool that presents a diagram of the human body where people can mark the location of their pain to produce a pain drawing. Digital pain manikins facilitate collection of more detailed spatial pain data compared to questionnaire-based methods and are an increasingly common method for self-reporting and communicating pain. However, an overview of how digital pain drawings, collected through digital pain manikins, are analysed and summarised is currently missing.

Objective: To map the ways digital pain drawings were summarised and analysed, and which pain constructs these summaries attempted to measure. Specific objectives were to:
1) identify and characterise studies which used digital pain manikins for data collection;
2) identify (a) which individual drawing-level summary measures they reported, and (b) the methods by which these summaries were calculated;
3) identify if and how multi-drawing (e.g., time series) summary and analysis methods were applied.

Methods: We conducted a scoping review to systematically identify studies using digital pain manikins for data collection which reported any summary measures or analysis of digital pain drawings. We searched multiple databases using search terms related to “pain” and “manikin”. Two authors independently performed title, abstract and full text screening. We extracted and synthesised data on how studies summarised and analysed digital manikin pain data at the individual pain drawing-level as well as across multiple pain drawings.

Results: Our search yielded 6,189 studies, of which we included 92. The majority were clinical studies (n=51), and collected data cross-sectionally (n=64). Eighty-seven studies reported at least one individual drawing-level summary measure. We identified individual drawing-level manikin summary measures related to 10 distinct pain constructs, with the most common ones being pain extent (or, pain area) (reported in 53 studies), physical location (n=28), and widespreadness (n=21), with significant methodological variation within constructs. Forty-two studies reported at least one multi-drawing summary method, with five distinct categories. Heatmaps were most common (n=35), followed by the number or proportion of participants reporting pain in a specific location (n=14). Sixteen studies reported multi-drawing analysis methods, with the most common being an assessment of the similarity between pairs of pain drawings intended to represent the same individual at the same moment in time (n=6).

Conclusions: We found a substantial number of studies which reported manikin summary and analysis methods, with the majority being cross-sectional clinical studies. Studies commonly reported pain extent at the individual pain drawing-level and used heatmaps to summarise data across multiple drawings. Analysis methods which went beyond summarising pain drawings were much rarer. Methodological variation within pain constructs meant a lack of comparability of methods between studies and across manikins. This highlights a need for standardisation of methods to summarise and analyse digital pain drawings, which

are applicable across manikins.

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Keywords:

Digital pain manikin, digital pain drawing, digital pain body map, digital pain chart, pain measurement, patient-generated health data

Target journal: JMIR mHealth and uHealth

Abstract

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To map the ways digital pain drawings were summarised and analysed, and which pain constructs these summaries attempted to measure. Specific objectives were to:

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3) identify if and how multi-drawing (e.g., time series) summary and analysis methods were applied.

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We conducted a scoping review to systematically identify studies using digital pain manikins for data collection which reported any summary measures or analysis of digital pain drawings. We searched multiple databases using search terms related to “pain” and “manikin”. Two authors independently performed title, abstract and full text screening. We extracted and synthesised data on how studies summarised and analysed digital manikin pain data at the individual pain drawing-level as well as across multiple pain drawings.

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Our search yielded 6,189 studies, of which we included 92. The majority were clinical studies (n=51), and collected data cross-sectionally (n=64). Eighty-seven studies reported at least one individual drawing-level summary measure. We identified individual drawing-level manikin summary measures related to 10 distinct pain constructs, with the most common ones being pain extent (or, pain area) (reported in 53 studies), physical location (n=28), and widespreadness (n=21), with significant methodological variation within constructs. Forty-two studies reported at least one multi-drawing summary method, with five distinct categories. Heatmaps were most common (n=35), followed by the number or proportion of participants reporting pain in a specific location (n=14). Sixteen studies reported multi-drawing analysis methods, with the most common being an assessment of the similarity between pairs of pain drawings intended to represent the same individual at the same moment in time (n=6).

Conclusions

We found a substantial number of studies which reported manikin summary and analysis methods, with the majority being cross-sectional clinical studies. Studies commonly reported pain extent at the individual pain drawing-level and used heatmaps to summarise data across multiple drawings. Analysis methods which went beyond summarising pain drawings were much rarer. Methodological variation within pain constructs meant a lack of comparability of methods between studies and across manikins. This highlights a need for standardisation of methods to summarise and analyse digital pain drawings, which are applicable across manikins.

Introduction

The worldwide prevalence of chronic pain is estimated at around 30% [1], and is associated with a significant negative effect on psychological and physical function, quality of life, and work productivity [2–4].

It is necessary to measure pain for a variety of clinical and research purposes including aetiology, diagnosis, monitoring disease state, and measuring and understanding intervention effect. Pain measures are part of the diagnostic criteria and classification criteria for various conditions including fibromyalgia [5], chronic migraine [6], osteoarthritis [7] and rheumatoid arthritis [8]. Pain is also a common symptom for cancer, and the location of the pain is associated with the type and stage of the cancer [9]. Poor pain assessment has been identified as a significant barrier to adequate pain management in cancer patients [10]. Similarly, challenges regarding pain-assessment techniques and inadequate communication between patients and clinicians were identified as barriers to effective postoperative pain management [11].

Digital pain manikins, also known as pain drawings, pain charts or pain body maps, are an increasingly common tool used to gather self-report pain data. They are an outline diagram of a human body, typically with

a front and back view. Newer digital versions may provide more detail by using shading to indicate the breasts and chest cavity or the knee shape and structure. People self-report pain by marking or colouring the location of their pain, using a touchscreen or mouse [12]. A key feature of pain manikins compared to other pain instruments is that people can self-report pain spatially. This gives pain manikins unique potential as a pain measurement tool. Throughout this review we use the term “digital pain manikin” to refer to the tool, and “pain drawing” to refer to an instance of a report created using a digital pain manikin.

We categorised the summary and analysis of digital pain drawings as an individual drawing-level summary measure, a multi-drawing summary method, or a multi-drawing analysis method. Individual drawing-level summary measures quantify an aspect of an individual’s pain experience at a specific moment in time. For example, pain extent (also referred to as pain area) quantifies the area of pain as marked on a single pain drawing [13]. Multi-drawing summary methods give information about pain across a population, across time, or both. For example, heatmaps (images visualising an average of multiple pain drawings) can show the most common locations for an individual’s pain over time, or the average pain profile for a specific condition across a population [14]. Multi-drawing analysis methods provide direct interpretation of digital pain drawings rather than only compressing them, for example by using machine learning clustering methods to group similar pain drawings together and characterise the distribution of pain [15].

Previous systematic reviews have noted a lack of standardisation both in pain manikins and in summary measures derived from them [12,16], which may introduce problems with reproducibility of results and limit the ability to compare results meaningfully between studies. Understanding the current state of how digital pain drawings derived from digital manikins are summarised and analysed in the field is the first step towards building more robust, reproducible and scalable methods.

A 2019 systematic review of methodological milestones in pain manikins divided manikin-derived measures into “topographic” and “simple” measures, with “topographic” measures being those incorporating anatomical knowledge [12]. They found the most common “simple” measures to be those quantifying the size of the painful area, and widespreadness to be the most widely used “topographic” measure. However, mapping digital pain manikin summary measures and analysis methods was not a focus of the review. This means that the full picture of which manikin-derived summary measures and analysis methods are being used, and which pain constructs these relate to, is not currently established.

Therefore, this review maps the ways digital pain drawings are summarised and analysed, including the pain constructs measured using digital pain manikins.

Specific objectives were to:

1) identify and characterise studies which used digital pain manikins for data collection;

2) identify (a) which individual drawing-level summary measures they reported, and (b) the methods by which these summaries were calculated;

3) identify if and how multi-drawing (e.g. time series) summary and analysis methods were applied.

We expect this review to inform the direction of future work on developing more advanced manikin-derived summary measures and analysis methods that make best use of the spatial information manikins provide. Ultimately, this will contribute to harnessing the potential of digital manikins to support pain outcome measurement in both research and clinical care.

Methods

We reported this review in line with the PRISMA reporting guidelines for scoping reviews [17]. The completed PRISMA-ScR checklist can be seen in the appendix.

Information sources and search

We used the same search strategy as for a related review, which was registered on PROSPERO (an international database of prospectively registered systematic reviews in health and social care) [18].

We searched Medline, CINAHL and Embase via Ovid, Scopus, IEEE Xplore, and the ACM Digital Library, using search terms related to “pain” and “manikin”, including a range of common synonyms such as “pain drawing” and “pain body chart”. The full search strategy is included in the appendix. The search was not restricted based on publication date and was complemented by hand searching reference lists of included studies. We did not search additional sources for grey literature. We originally ran the search in November 2019 and updated the search in August 2023. The search strategy was developed by researchers with experience of conducting systematic reviews and supported by a qualified librarian.

Eligibility criteria

Papers were included if they had been published in English and met the following criteria:

Study population	Adults over 16 years old, including people with pain/a painful condition and healthy volunteers. Studies with a mixed sample of adults and children were included.
Digital pain manikin	Studies that used a digital pain manikin for data collection, defined as any human-shaped figure that facilitated interactive self-reporting of pain in any part or location of the body on a digital device, e.g. a desktop computer, tablet, smartphone, or custom device. Papers focusing on a specific body part were included.
Intended manikin users	Adults with current or previous personal pain experience. In other words, studies were included if manikins were intended to be used for self-reporting pain by the person who experienced the pain. This included healthy volunteers reporting induced pain. Studies which consisted solely of pain drawings created by healthcare professionals or researchers to record their observations of patients’ pain were excluded, but those with manikins completed by both patients and others were included.
Outcome of interest	We included studies that reported any summary of the data collected using digital pain

	manikins. This included methods for summarising the information from a single pain drawing (e.g., pain extent) and for aggregating information across pain drawings (e.g., a heatmap showing where study participants most commonly reported pain). We included summaries which were calculated automatically (e.g., pain extent extracted automatically by the manikin software) and those which were generated manually (e.g., a visual assessment of pain symmetry).
Publication type	Original research including peer-reviewed journals and full conference papers, excluding grey literature, pre-prints, protocols, reviews, commentaries, editorials and conference abstracts.

Selection of sources of evidence

After deduplication, we performed title and abstract screening to identify potentially relevant papers, followed by full text screening to confirm eligibility. Deduplication was performed by a single author. For both screening stages, all papers were screened independently by two authors, with disagreements resolved by discussion with a third author.

Data charting process

We recorded whether a study was a clinical study, where a manikin was used for data collection to answer a clinical research question, or a development/validation study where the primary aim of the study was the development and/or testing of a digital pain manikin. We also recorded whether a manikin was 2D, 3D, or pseudo-3D. We defined a 3D manikin to be a manikin with a rotatable model, as opposed to a pseudo-3D manikin with a fixed 2D perspective but with additional visual detail and shading that gave it a 3D appearance.

We developed a data charting form and pilot tested it on ten papers before starting full data charting. Data charting was performed for all included papers by one author (DM), with 25% in duplicate by a second author (SMA). Missing data on study, setting and population, and manikin characteristics was noted as “not reported” during data charting, or extracted from references to previous studies using the same manikin or dataset.

Data items

We extracted data items related to study characteristics, setting and population characteristics, manikin characteristics, individual drawing-level summary measures and the methods used to produce them, multi-drawing summary measures (i.e. cross-sectional pain drawings across multiple individuals, multiple pain drawings of an individual over time, or multiple pain drawings of multiple individuals over time) and other analysis methods. Data items on manikin characteristics included which location-specific pain aspects could be recorded on the manikin, including location-specific pain quality (e.g. burning, tingling) and location-specific intensity (typically on a scale of 1-10). This is distinct from additional non-manikin measures

collected at the same time (e.g. an overall pain intensity score, participant ratings of the usability of the manikin). The full list of data extraction items can be seen in the appendix.

Individual drawing-level manikin summary measures were defined as any variable extracted directly from a single pain drawing, compressing the high-dimensional pain drawing data into a single measurement, such as pain extent.

Multi-drawing summary methods were defined as any method of combining (or compressing) data from multiple individual pain drawings without first summarising the individual manikins, such as heatmaps showing the average of multiple pain drawings.

Multi-drawing analysis methods were defined as a method which produced new information about the data (e.g. the use of principal component analysis to assess the knee pain distribution), as opposed to *multi-drawing summary methods* which only compressed the data.

When a study reported descriptive summary statistics of individual summary measures we extracted this as an individual drawing-level summary measure and not a multi-drawing summary method. For example, if a study calculated the pain extent for each individual pain drawing, and then reported the average pain extent across participants at baseline and follow up, we recorded pain extent as an individual drawing-level manikin summary measure, and did not also record mean pain extent as a multi-drawing summary measure.

We defined automated measures as those which were extracted without human intervention on an individual drawing level. For example, if the calculation of pain extent required manual tracing of the pain area, this was counted as manual even if part of the process was performed automatically. If a measure was not explicitly stated to be manual or automated but we could derive it from contextual information, we recorded this as manual/automated (assumed). For example, measures in a study including many thousands of manikins were unlikely to have manual step so were assumed to be automated.

Synthesis of results

Guided by our objectives, we performed a narrative synthesis of the extracted data. For the synthesis of individual drawing-level summary measures (objective 2), we named and defined pain constructs after performing data extraction. A construct is an abstract concept which can not be directly measured. We recorded unique individual drawing-level summary measures within constructs when there were significant methodological variations in how that construct was measured (e.g. pain extent with region-based and pixel-based measures), or where there was minor conceptual variation within the construct (e.g. pain presence or absence inside a specific anatomical location versus pain presence or absence outside a specific anatomical location).

Results

Figure 1 shows that our search identified 5,981 papers after deduplication, with another 208 identified via our hand search (total n=6,189). Finally, we included 92. The main reasons for excluding full papers were that they used paper-based manikins (n=637) or did not use a manikin at all (n=132). Of the 92 included studies, 87 reported at least one individual drawing-level summary measure, 42 reported at least one multi-drawing summary, and 16 reported direct analysis of multiple pain drawings.

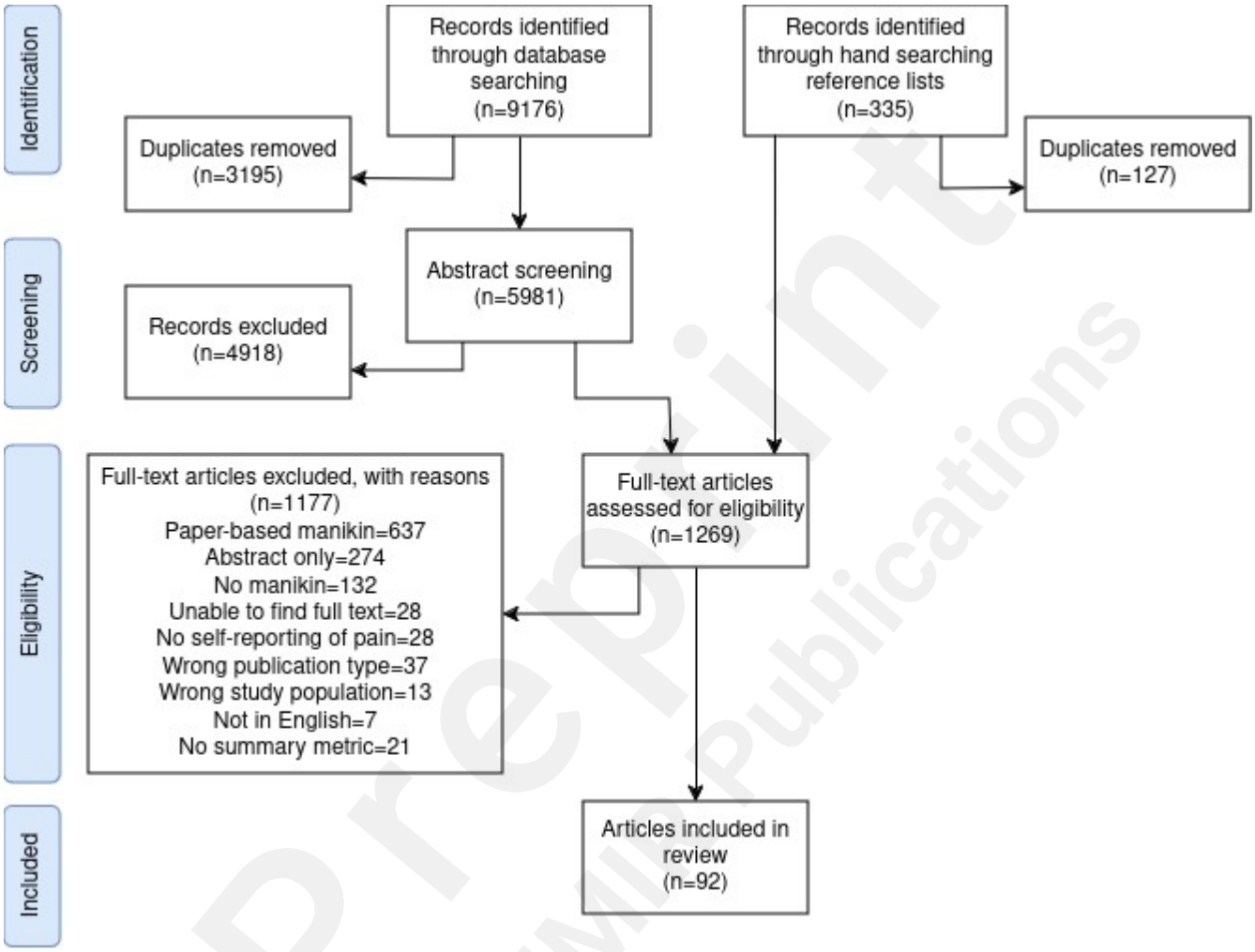

Figure 1: PRISMA diagram showing the screening process with the number of papers excluded at each stage

Study and manikin characteristics

Table 1 shows the characteristics of the included studies. Most studies were conducted in the USA (n=31) or Denmark (n=18), were clinical studies (n=51), and collected data cross-sectionally (n=64).

Across all studies, we identified 27 unique, named manikins. Almost a quarter of included studies used the Navigate Pain manikin (n=21), and 23 studies did not report details on which manikin they used. The majority of studies used a 2D (n=61) or pseudo 3D (n=21) manikin. Three studies reported using a 3D manikin and two compared manikins of different dimensions; these were all developmental/validation studies. Manikins were

used across a variety of conditions, primarily for chronic pain (n=52).

Manikins were most commonly either pixel-based manikins where participants could freely draw (n=56), analogous to paper-based manikins (such as the Navigate Pain manikin [19]), or manikins with non-overlapping pre-defined regions which participants can select (n=21) (e.g. the CHOIR manikin [20]). Exceptions to this include the Manchester Digital Pain Manikin, which used a grid [21]; the manikin used by Zuhdi *et al.* with overlapping predefined joints and areas [22]; an early iteration of the Iconic Pain Assessment Tool, which uses drag-and-drop icons [23]; and the manikin used by Miękisiak *et al.* where users clicked with a mouse to make individual marks rather than shading areas [24]. Example manikin images are shown in Fig 2.

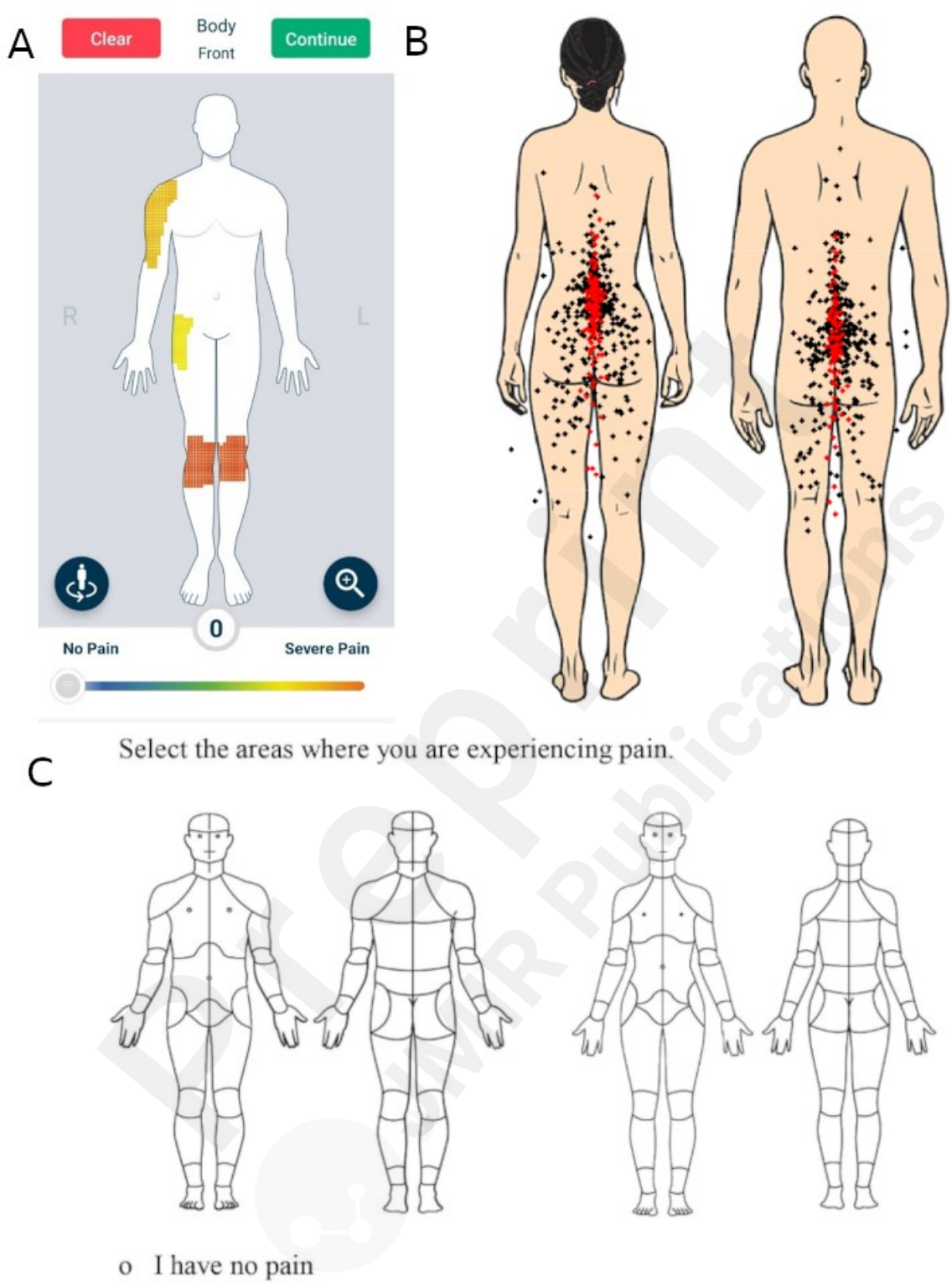

Figure 2: a) A screenshot of the Manchester Digital Pain Manikin app (copyright University of Manchester), where users marked the location and intensity of pain on a grid (as described in [25]);
b) The Collaborative Health Outcomes Information Registry (CHOIR) body map, from Scherrer *et al. (*2021), where users marked the location and intensity of pain on pre-defined body regions [26];
c) The manikin used by Miękisiak *et al.* (2021), where users made individual marks indicating pain location [24]

Table 1:

Summary of the characteristics of studies included in the review, including characteristics of the manikins used by those studies.

Characteristics	*Number (%) of studies (total=92, 100%)*
STUDY CHARACTERISTICS	
Country	
USA	31 (34)
Denmark	18 (20)
Spain	7 (8)
UK[1]	6 (7)
France	5 (5)
Germany	5 (5)
Canada	4 (4)
Poland	4 (4)
Other[2]	12 (13)
Condition	
Chronic pain	52 (57)
Musculoskeletal pain	16 (17)
Acute pain	9 (10)
Neurological pain	6 (7)
Dental/facial pain	4 (4)
Not reported	5 (5)
Study population	
Participants with specific condition (e.g. arthritis)[3]	46 (50)
Non-specific pain patients (e.g. recruited at a pain clinic)[4]	26 (28)
Healthy participants	7 (8)
Participants with previous injury and healthy controls	3 (3)
Specific demographic group (e.g. residents of one area)	2 (2)
Musicians	2 (2)
Athletes	2 (2)
Not reported	4 (4)
Study type	
Clinical	51 (55)
Development/validation	32 (35)

Both	9 (10)
Cross sectional	64 (70)
Longitudinal	26 (28)
Not reported	2 (2)
MANIKIN CHARACTERISTICS	
Detail level	
Pixels	56 (61)
Predefined regions	21 (23)
Grid	4 (4)
Squares[4]	3 (3)
Scalable Vector Graphics[5]	3 (3)
Circles[6]	1 (1)
Icons	1 (1)
Not reported	3 (3)
Dimensions	
2D only	61 (66)
Pseudo 3D only	21 (23)
3D only	3 (3)
Multiple	2 (2)
Not reported	5 (5)
Location-specific pain aspects[7]	
None	59 (64)
Intensity	20 (22)
Quality	15 (16)
Depth[8]	4 (4)
Other	5 (5)
Not reported	3 (3)

1) One UK based study was Switzerland and UK

2) Australia, Belgium, Greece, Italy, Japan, Lebanon, Norway, Switzerland, Thailand

3) n with healthy controls = 4, n with clinician participants = 2

4) n with healthy controls = 4

5) Squares were added in the locations that the patient clicked and were not aligned to a grid

6) A method of storing image data that records individual markings and their spatial relationship to each other rather than recording the values of individual pixels

7) Patients marked location of worst pain with a small circle

8) Eight studies had multiple location-specific pain aspects, so these numbers do not add up to 100%

9) How deep into the body the pain was, e.g. surface level or in the muscle

Individual manikin summary measures

How studies summarised data from an individual manikin report

Table 2 lists the 31 unique individual drawing-level summary measures we identified and mapped to ten pain constructs. The construct definitions are included in Appendix 3. Five summary measures lacked sufficient information to classify them into a specific construct [27–31]. The measures could be split into spatial measures and non-spatial measures. We defined spatial measures to be those which used the physical location of the pain in some way, and non-spatial measures to be those which discarded location-specific information. Almost all the measures were spatial measures, including for assessing the size and shape of the painful area, or the spread of pain throughout the body. Only nine studies reported non-spatial measures, all of which were pain quality measures, which summarised the presence or number of pain quality descriptors, or the maximum or minimum pain intensity marked anywhere on the drawing.

Table 2:

Individual summary measures reported by included studies and the studies which reported them, grouped by pain construct.

Description (n of studies; n of reported measures calculated automatically/ manually/not reported)*	*Studies*
Pain extent (n=53; 51 automated, 5 manual, 3 not reported)	
Pain area in absolute number of pixels (n=24)	13–15,19,27,28,32–48
Pain area as percentage of marked pixels (n=13)	19,29,39,49–58
Pain area quantified using predefined anatomical regions (n=5)	13,32,59–61
Pain area quantified without the use of pixels or predefined regions (n=6)	13,21,62–65
Pain area quantified as the physical area (n=2)	66,67
Pain area for specific symptoms (n=3)	36,68,69
Unspecified (n=6)	24,30,70–73
Location (n=28; 14 automated, 9 manual, 7 not reported)	
Presence or absence in a specific anatomical location (n=5)	15,20,31,34,74
Presence or absence outside a specific anatomical location (n=5)	20,75–78
Description of pain location (n=5)	62,79–82
Which predefined areas have pain presence (n=5)	14,26,42,60,83
The area of pain in a specific location or locations (n=9)	39,78,84–90

Unspecified (n=1)	91
Widespreadness (n=21; 9 automated, 4 manual, 13 not reported)	
Widespread pain index (n=3)	29,58,92
Clinical/categorical definitions (n=5)	27,82,93–95
Number of predefined areas (number unspecified) (n=9)	14,26,27,75,80,82,91,96,97
Number of predefined areas (15 or lower) (n=3)	93,98,99
Number of predefined areas (16 to 69) (n=2)	13,95
Number of predefined areas (70 and above) (n=4)	93,100–102
Pain quality (n=9; 5 automated, 1 manual, 5 not reported)	
Presence or absence of a particular pain quality (n=5)	23,43,50,68,103
The number of pain quality or symptom descriptors used (n=2)	29,101
Maximum intensity reported anywhere on the drawing (n=3)	62,85,101
Minimum intensity reported anywhere on the drawing (n=1)	101
Laterality (n=7; 2 automated, 4 manual, 1 not reported)	
Whether pain is present on one or both sides of the body split vertically (n=7)	15,34,39,43,50,96,104
Symmetry (n=5; 2 automated, 3 manual, 1 not reported)	
The degree to which pain is mirrored on the vertical midline of the body (n=5)	15,24,34,43,51
Shape (n=5; 4 automated, 3 not reported)	
The length of the area of pain (n=4)	41,73,78,79
The width of the area of pain (n=1)	73
The product of the maximum width and length of the area of pain (n=2)	55,79
Location-specific intensity (n=4; 4 automated, 1 manual, 1 not reported)	
Weighted score for pain intensity using location-specific pain intensity information (n=4)	57,67,85,101
Overlap (n=3; 2 automated, 1 manual)	
The area of intersection of two distinct co-occurring sensations (n=3)	30,66,70
Mismatch (n=3; 2 automated, 1 manual)	
The area of non-intersection of two distinct co-occurring sensations (n=3)	30,33,70

* Individual summary measure counts may add up to more than the number of studies that reported the overarching construct due to some studies reporting the same construct measured using multiple methods

Pain extent (also called pain area) was the most widely measured construct, with 53 of the 87 studies reporting related individual summary measures. The main methodological variation within the assessment and reporting of pain extent regarded the granularity of the manikin data, as pain extent for pixel-based manikins was generally reported as the percentage or raw number of pixels, whereas for manikins using pre-defined

areas this was generally calculated by weighting the size of each marked pain area. In comparison, there were no clear differences between pixel- and region- based manikins in calculating pain location measures (n=28), despite the difference in the level of detail available.

Location measures were reported by 28 included studies, quantifying where the reported pain was physically located. Most commonly this was a binary variable quantifying whether pain was present inside (n=5) or outside (n=5) a predefined anatomical region. These measures were typically associated with conditions characterised by pain in a specific location, such as interstitial cystitis/bladder pain syndrome [77].

Widespreadness measures were reported by 21 included studies. The main variations within these measures were whether they were reported as categorical (e.g. widespread or not widespread) or as a count of the number of painful areas; whether or not additional criteria beyond the number of painful areas were required (e.g. four painful areas within one arm would not count, whereas a total of four painful areas distributed between the arms and back would); and the number of pre-defined areas the manikin was divided into (e.g. a manikin may be split into seven pre-defined areas or 70). There was some overlap in the use of the constructs of pain extent and widespreadness, and it was not always clear which of the two constructs a study intended to measure.

Pain quality (n=9) and *location-specific intensity* (n=4) measures were reported by 12 studies, despite 33 studies collecting data on location-specific pain aspects (such as location-specific pain intensity). Pain quality and location-specific intensity were the only constructs which used location-specific pain aspects. This means that 21 studies collected location-specific pain aspects and did not use them as part of individual drawing-level summary measures.

Laterality was reported by seven studies and *symmetry* by five studies; only one study which reported symmetry did not also report laterality. Similarly, *overlap* (n=3) and *mismatch* (n=3) were both reported by two of the three studies reporting each of them.

Methods used to calculate individual manikin summaries

There was significant methodological variation within similar summary measures. For example, we found four different approaches to measuring symmetry within the five papers which reported this measure [15,24,34,43,51], ranging from manual expert assessment to an automated algorithm comparing the pain extent on the left and right halves of the body. Four studies used location-specific pain intensity information to calculate a weighted score that combined pain extent with intensity [57,67,85,101]. The types of manikins and methods used to calculate the measures were different for each study.

Within the measures of pain extent, the most common method was calculating the number of pixels marked as painful, either as an absolute number or as a percentage (n=36). The methods which did not use pixels or predefined regions included calculating the area of the polygon with the smallest number of sides which could enclose each stroke of a scalable vector graphics image [13], or calculating the proportion of available squares shaded with pain intensity above 1 [21]. Pain extent

measures derived from 3D manikins reported the total number of marks made on the diagram [62], the percentage of the surface area marked as painful [85], or the surface area marked as painful based on the number of predefined regions selected [61].

Automation of Manikin Summary Measures

Overall, we found that mostly simpler summary measures were calculated using automated methods. For example, of the 53 studies reporting pain extent, 46 reported (assumed) automated measures (Table 2). In contrast, three of the five studies used a manual method for symmetry measures. An example of an automated summary measure which made good use of the spatial information available was the symmetry measure developed by Boudreau *et al*, which involved mirroring a pain drawing from one knee and translating the mirrored image on the opposite knee to the location with maximum overlap [34]. This avoided the potential problem of an automated symmetry measure giving a low symmetry score to a pain drawing that a human expert would assess as symmetrical due to minor differences in the location of the pain areas. Many studies (n=50) had at least one reported measure that was not clearly stated to be manual or automated.

Multi-drawing summary methods

Table 3 shows the five multi-drawing summary methods we identified. Of the 42 papers summarising data from multiple pain drawings, 38 reported cross-sectional summaries of populations; two reported a summary of one individual over time, and three reported summaries of populations over time. Four studies made use of location-specific pain aspects in multi-drawing summary methods, those being the site and symptom specific methods (n=2) and the maximum symptom methods (n=2). 35 studies presented a heatmap. This included pixel-wise averages of multiple individual manikins (n=23) (Figure 3), the region-based equivalent showing the proportion of reports selecting each individual region (n=7), and pixel-wise averages with some kind of additional processing, such as a minimum threshold for the number of participants reporting pain in a particular location (n=4). The majority of heatmaps were cross-sectional summaries of populations (n=32).

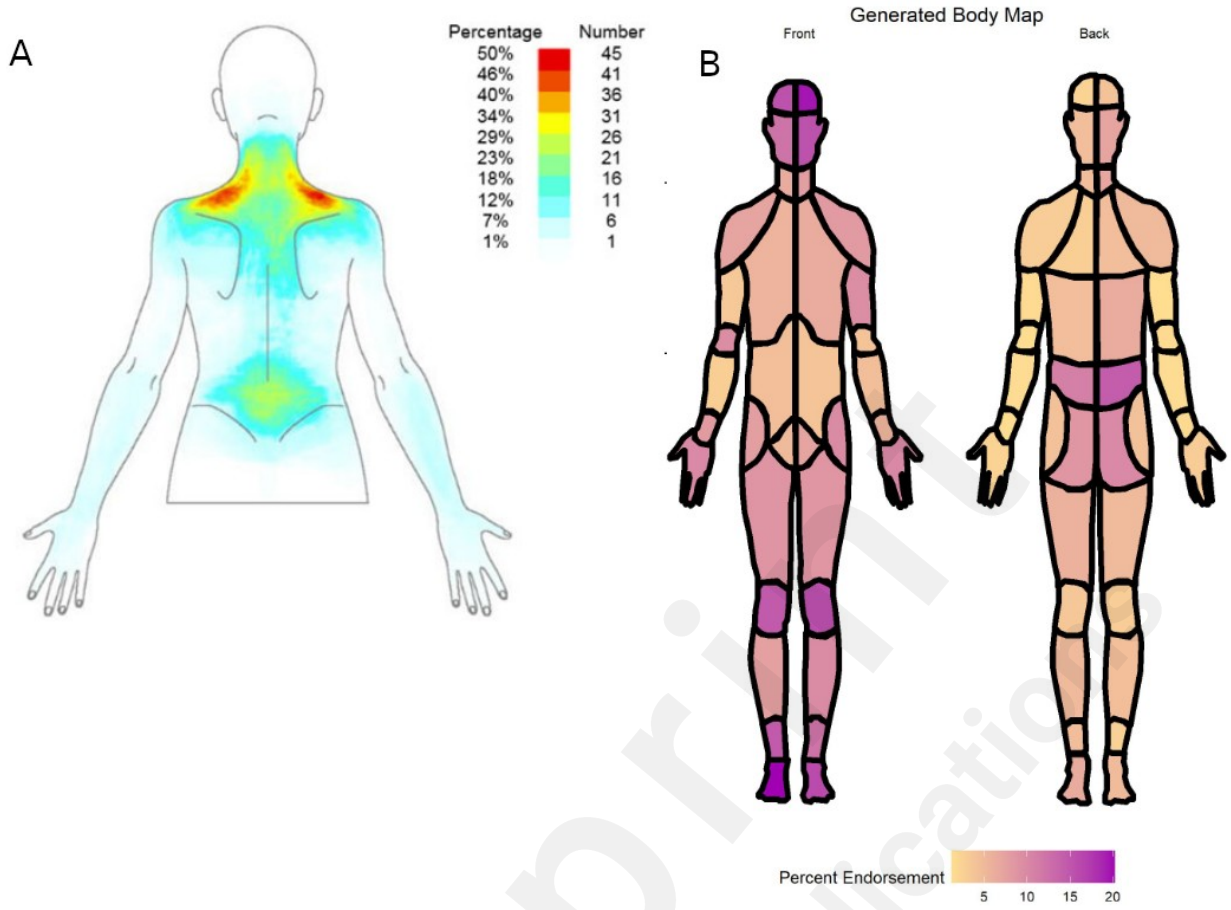

Figure 3: Heatmaps reproduced as examples of different digital pain manikin heatmaps
a) Cruder *et al.* (2018) generated a pixel average of overlaid pain drawings [14]
b) Cramer *et al.* (2022) generated a region-based average of overlaid pain drawings [105]

Studies which reported the number of participants with pain in a particular location (n=14) for pixel-based manikins (n=9) calculated this by overlaying predefined regions and counting the number of participants who marked pain within each region; the other five studies reporting this measure used region-based manikins. Two studies reported site and symptom specific summaries; one gave the number of participants who reported a specific pain quality at a specific site (e.g. throbbing, pulsing) [103], the other gave the average Numeric Rating Scale score for specific symptoms (frequency of interference, intensity, influence on playing) at a specific site [22].

Table 3:

The methods used to summarise multiple pain drawings (i.e. multi-drawing summary methods). Heatmap summaries are split into multiple rows to capture the variation in methods.

Name	*General definition(s)*	*Population/time period/ both**	*Studies*
Heatmap (n=35)	Simple pixel average of overlaid pain drawings (includes Scalable Vector Graphics) (n=21)	Population	14,15,33,34,37,38,40–42,44,50,53–56,59,72,78,87,106

	Simple pixel average of overlaid pain drawings at different points in time (n=2)	Both	45,79
	Not described (pixel average of pain drawings from multiple players over time) (n=1)	Not reported (both)	69
	Simple region-based average of overlaid pain drawings, with or without histogram (n=7)	Population	20,32,42,56,89,94,100,105
	Pixel average of overlaid pain drawings with additional processing, such as mirroring and/or a minimum threshold for number of participants reporting pain in that location (n=4)	Population	29,43,51,71
	Unclear (n=2)	Population	58,107
Location frequency (n=14)	The number or percentage of participants reporting pain in specific predefined locations (n=14)	Population	14,22,31,32,42,44,51,59,71,84,87,89,95,96
Site and symptom specific (n=2)	The number of participants reporting specific symptoms in specific locations (n=1)	Population	103
	Average symptom at specific body site (n=1)	Population	22
Maximum symptom (n=2)	Highest value for a specific symptom over a period of time (n=2)	Time	79,98
Variation over time (n=1)	Daily range in number of sites reported (n=1)	Time	98

* Whether methods summarised a cross-section of a population (“population”), an individual over time (“time period”), or a population over time (“both”)

Multi-drawing analysis methods

The most common analysis performed directly on pain drawings was an assessment of similarity between linked pairs of pain drawings, including pairs generated by researchers copying an example drawing [21] and patient-clinician pairs where the clinician completed a pain drawing based on the patient’s verbal description of their pain [55] (n=6). Of the six studies which assessed similarity, three calculated the Jaccard index, two counted the number of pixels coloured in both pairs, and one performed manual assessment. Other studies used the Jaccard index as a measure of similarity as part of other analysis methods, for example by Galve Villa *et al* to assess change over time [46], and by Alter *et al* to identify subgroups in a population using a machine learning clustering technique [100]. Van der Veer *et al* used the Jaccard index as part of their assessment of test-retest reliability [21].

Of the 15 papers reporting a multi-drawing analysis method, nine were developmental/validation papers, five were clinical, and one was both clinical and developmental/validation. All similarity analysis methods (n=6) were part of development/validation studies for the purpose of evaluating the validity of the derived scores.

Studies also used multi-drawing analysis methods to assess change over time (n=3), cluster similar drawings together (n=2), categorise drawings by diagnosis (n=2), or correlate pain location information with other data (n=2). Clustering is a machine learning technique for grouping similar examples together, and requires a measure of similarity to be successful. Of the clustering studies, Boudreau *et al* (2018) used Principal Component Analysis for dimensionality reduction then clustered using k-means clustering [15], and Alter *et al*

performed hierarchical clustering using the Jaccard index as a measure of similarity [100]. The Boudreau *et al* study was the only included study which characterised different patterns of pain distribution within an otherwise homogenous diagnosis, in comparison to other studies which simply summarised pain extent or widespreadness [15]. Preserving the spatial information allowed them to identify three sub-groups within patellofemoral pain which would not have otherwise been distinguishable. Of the studies which analysed change over time, one investigated the difference between consecutive pairs of pain drawings [46], and two reported the area under the pain area-time curve, in order to quantify the change in pain extent over time [73,79].

Ellingsen *et al* performed pixel-wise correlation with a pain catastrophizing score, which they defined as "a pain-targeted psychosocial construct comprised of helplessness, pessimism, and magnification of pain-related symptoms and complaints" [50].

Table 4:

The methods used to analyse reports from multiple pain drawings (i.e. multi-drawing analysis methods)[1]

Type of analysis	*Method*	*Population/ time period/ both/pairs*[2]	*Clinical/ developmental*	*Studies*
Similarity (n=6)	Manual assessment of similarity (n=1)	Pairs	Clinical	80
	Number of pixels coloured in both of a pair of body maps (pain drawings) (n=2)	Pairs	Clinical	33,37
	Jaccard index (n=3)	Pairs	Clinical	21,29,55
Change over time (n=3)[3]	Area under pain area-time curve (n=2)	Time	Clinical	73,79
	Jaccard index calculated between consecutive pairs of pain drawings (n=1)	Time	Both	46
Clustering (n=2)	PCA and k-means clustering (n=1)	Population	Clinical	15
	Hierarchical clustering using Jaccard index as similarity measure (n=1)	Population	Clinical	100
Categorisation (n=2)	Simple decision model categorising drawings into "patient" or "healthy" based on number of marks made (n=1)	Population	Developmental	64
	Discriminant analysis[4] based on proportion of area marked in specific regions (n=1)	Population	Developmental	88
Location correlation (n=2)	Pixel-wise correlation with pain catastrophizing score (presented as heatmap) (n=1)	Population	Clinical	50
	Inter-group comparisons with categorical location variable using z-tests (n=1)	Population	Developmental	105

1) Excluding studies which first calculated individual level summary measures (e.g., pain extent) and then reported a descriptive summary statistic of those measures (e.g., mean pain extent across a sample)

2) Whether methods analysed a cross-section of a population ("population"), an individual over time ("time period"), a population over time ("both"), or pairs of manikin reports ("pairs"). Examples of pairs of manikin reports include a clinician and a patient each filling in a manikin to describe that patient's pain, or consecutive pairs of manikins from a set one patient filled in over time.

3) Change over time only refers to direct analysis of manikin reports across a time period and does not include studies which compared individual level manikin measures at different time points

4) Discriminant analysis is a statistical classification technique

Discussion

Summary of findings

This scoping review identified 92 studies which used digital pain manikins for data collection. The majority of studies were cross-sectional clinical studies using manikin derived summary measures to answer a clinical question, although a large minority of studies were methodological work on the development or validation of digital pain manikins. Most studies used a 2D or pseudo-3D manikins, and manikins were most commonly pixel-based. We identified ten pain constructs expressed by individual drawing-level summary measures, with significant methodological variation between summary measures for the same pain construct.

Pain extent was the most commonly measured pain construct. It does not make as much use of the available spatial information when compared to other measures such as widespreadness and symmetry. For example, a hypothetical manikin report where alternate pixels were reported as painful would have the same pain extent score as one where every pixel in the lower half of the body is marked as painful, but widespreadness measures would distinguish between these two pain drawings. All studies reporting pain location either used region-based manikins or overlaid pre-defined areas onto pixel-based manikins to calculate these measures.

Heatmaps and location frequency were the most common multi-drawing summary methods. Multi-drawing analysis methods were less commonly used than summary methods and were mostly concerned with different ways to quantify the similarity between pairs of manikins (often for development/validation studies), the change over time in one person, or grouping similar manikins together.

There was a general lack of clarity around methodology in the literature, with many studies missing basic information such as whether a manikin was pixel- or region- based. It was often difficult to determine what construct was intended to be measured, or whether two measures used equivalent methods. We observed many studies reporting the number they calculated for a summary measure without explaining the process in sufficient detail for it to be reproduced. The issue of missing information was present in the descriptions of the acquisition methods, as well as of the summary and analysis methods.

Relation to other studies

We are not aware of any previous work which classified manikin-derived measures by pain construct, but two previous reviews looked at manikin-derived summary measures. Ali *et al*'s 2020 systematic review of digital pain manikin smartphone apps found nine manikin-derived summary measures, fewer than the 31 found by our review [16]. Although their review only included manikins available in app stores, all measures they reported

were also found by our review. They suggested there is a need to assess the measurement properties of smartphone-based pain manikins. Our mapping of pain constructs may help future work in this area as assessing the validity of measure requires an understanding of the construct it purports to measure.

One aspect of Shaballout *et al*'s 2019 systematic review of methodological milestones for the development of pain manikins was manikin-derived measures, which they split into "simple measures" and "topographic measures" [12]. They highlighted the need for standardisation and the difficulty of comparing results between studies, advocating for the adoption of a common body template. They noted that digital pain manikins have the potential to record more pain attributes (e.g. intensity or depth) when compared to paper manikins, and that they expect further development in manikin-derived measures and analysis methods in future. Our study extends their work describing manikin-derived measures with an updated search which included more recent studies, and a more detailed mapping of manikin-derived measures. Based on our findings, we concur with their suggestion that there is a need for standardisation.

Study limitations

One limitation of our review is that we aimed to extract detailed data on methodological aspects of included studies, whereas manikin methods were often not their focus. This meant there was a lack of detail on the data items extracted for many included studies, but did make our review more comprehensive than if we had only included studies with a focus on methodology.

Another limitation is that we restricted our search to published literature and did not include grey literature, or apps and software not reported in literature, so we may have missed measures and analysis methods from that part of the landscape. However, as all measures found by Ali *et al*'s app review were also identified in our review, this suggests that we managed to identify a comprehensive set of manikin-derived pain constructs [16].

Lastly, we were unable to investigate measurement properties of manikin-derived summary measures as originally planned in our registered protocol because the high level of heterogeneity among (methods to calculate) constructs did not allow a meaningful synthesis. The current review focused on identifying manikin-derived pain constructs (part two of the protocol's objective 3a). All remaining objectives were addressed elsewhere [108,109].

Implications for research

Manikin summary and analysis methods which make better use of location-specific pain aspects (such as location-specific pain intensity) should be developed. While 33 of the included studies used manikins that captured location-specific pain aspects, only 12 of the reported individual level summary measures, four of the multi-manikin summary methods, and none of the multi-manikin analysis methods used this data. For clinical studies with no plan to use location-specific pain aspects, the benefit of having this data available should be weighed against the additional burden to the patient in reporting it, in line with Aiyegbusi *et al's* 2024 consensus statement of recommendations to address respondent burden associated with patient-reported outcome (PRO) assessment. Aiyegbusi *et al* also highlighted the need to consider the complexity and completion time of PRO measures [110], which is particularly relevant when selecting a digital pain manikin for data collection.

Summary measures should be chosen with consideration of the underlying pain construct they attempt to measure, and its relevance to the disease or clinical area being studied. Summary measures inherently lose

spatial information, and very few studies used analysis methods which made use of this information. Different summary measures lose different parts of the spatial information; pain extent preserves the area but not the location of the pain, widespreadness attempts to preserve an aspect of the location but not the area. This links to our previous recommendation to only capture location-specific information when there is a specific reason to do so. We recommend first identifying the pain construct(s) to be measured, then selecting appropriate summary measures for that construct, and finally selecting a pain manikin from which those summary measures can be derived with the minimum participant burden. Through our review, it becomes evident that new methods may need to be developed to summarise multiple constructs simultaneously.

Our results suggest a need for standardisation in pain manikin measures, whether this means settling on a single manikin or developing measures that are comparable between manikins. Due to the variety of methods and manikins used, even widely-reported measures were not generally comparable between studies, meaning it would not be possible to assess measurement properties or validity across digital pain manikins as a whole. The lack of standardisation may also lead to confusion in the context of clinical care. For example, a pain extent of 57% on one manikin is not necessarily the same as 57% on a different manikin, which could cause issues when translating results from research to clinical practice, or when seeing patients who are using various different manikins. We contrast this with the standard methods of validating and developing questionnaires, where it is widely accepted that new questionnaires should not be developed if there is an existing validated questionnaire available. We recommend consideration of whether there is a suitable existing manikin before developing a new manikin. Efforts should also be made to standardise reporting of manikin studies and to agree terminology so that terms like “pain extent” and “widespreadness” are used consistently within the field; our review provides a strong foundation for this standardisation.

We also suggest that it is not realistic that the field will settle on one manikin, particularly as different manikins may be appropriate for different research questions, and that efforts should be focused on developing methods to compare findings across manikins. One approach to this could be defining translations of multiple different manikins to one underlying representation, so that data collected on different manikins can then be summarised and analysed in a consistent way. This is analogous to the problem of magnetic resonance imaging (MRI) dataset harmonisation, where the specific machine used to collect MRI scans makes applying machine learning techniques across datasets challenging [111]. One approach to analysing MRI scans is building a graph representation where the links between anatomical areas are an explicit part of the data format. A graph is a mathematical concept consisting of nodes which are linked by edges. For example, in a map of a social network, nodes would represent individual user accounts and edges would represent whether those users are connected. In a graph-based manikin, the nodes would represent individual anatomical locations, and would be linked by edges only if they are anatomically adjacent. Future work could employ a similar strategy of developing a graph-based manikin representation to solve the problem of standardisation, by defining translations of multiple manikins to the same graph representation. A graph-based representation would also open the door to novel summary and analysis methods making use of the additional anatomical structure encoded in the format.

Conclusions

Our review identified a substantial number of studies which used digital pain manikins for data collection, with the majority reporting relatively simple measures and methods of summarising pain drawings. Only a few studies went beyond only summarising to perform a direct analysis of the spatial data. The fact that information on pain location and other location-specific pain aspects (such as pain intensity or pain quality) collected through digital pain manikins was often not used in summary measures and methods suggests that the rich information available from pain drawings is currently not being fully harnessed. Our findings also

showed a need for better reporting and standardisation of pain constructs and methods through which they are measured. Future work should focus on developing more advanced summary and analysis methods that harness the spatial nature of pain drawings, by better incorporating anatomical and clinical knowledge.

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Conflicts of Interest

SAB is the co-founder of AglanceSolutions ApS (Denmark) which licenses a software for collecting digital pain diagrams.

Abbreviations

PRISMA - Preferred Reporting Items for Systematic reviews and Meta-Analyses
PRISMA-ScR - Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews
PROSPERO - International Prospective Register of Systematic Reviews
CINAHL - Cumulative Index to Nursing and Allied Health Literature
IEEE - Institute of Electrical and Electronics Engineers
ACM - Association for Computing Machinery
2D - Two Dimensional
3D - Three Dimensional
DM - Darcy Murphy
SMA - Syed Mustafa Ali
USA - United States of America
CHOIR - Collaborative Health Outcomes Information Registry
UK - United Kingdom
PCA - Principal Component Analysis
MRI - Magnetic Resonance Imaging

SAB - Shellie Ann Boudreau

Data Availability

The full data extraction spreadsheet is provided in the supplementary materials.

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Appendix 1 - full search strategy

Medline and Embase via Ovid online (22nd August 2023)

1. exp MANIKINS/

2. exp Visible Human Projects/

3. exp Medical Illustration/

4. manikin*.tw.

5. mannequin*.tw.

6. (pain adj3 drawing*).tw.

7. (pain adj diagram*).tw.

8. (pain adj3 map*).tw.

9. (pain adj3 chart*).tw.

10. (body chart*).tw.

11. (body drawing*).tw.

12. (body map*).tw.

13. (body diagram*).tw.

14. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13

15. exp PAIN/

16. exp Pain Measurement/

17. exp Pain Management/mt [Methods]

18. pain*.tw.

19. 15 or 16 or 17 or 18

20. 14 and 19

21. animals/ not (humans/ and animals.mp.)

22. 20 not 21

23. limit 22 to english languageCINAHL Plus (3rd November, 2020; 378 titles)

1. MH manikin

2. MH visible human project

3. MH medical illustration

4. TX manikin*

5. TX mannequin*

6. TX pain adj3 drawing*

7. TX pain adj3 diagram*

8. TX pain adj3 map*

9. TX pain adj3 chart*

10.TX body chart*

11.TX body drawing*

12.TX body map*

13.TX body diagram*

14. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13

15. MH pain

16. MH pain management

17. MH pain measurement

18 TX pain

19. 15 OR 16 OR 17 OR 18

20. 14 AND 19

Scopus (22nd August 2023)

((TITLE-ABS-KEY (pain W/5 mannequin)) OR (TITLE-ABS-KEY (pain W/5 manikin)) OR (TITLE-ABS-KEY (pain W/5 chart)) OR (TITLE-ABS-KEY (pain W/5 drawing)) OR (TITLE-ABS-KEY (pain W/5 diagram)) OR (TITLE-ABS-KEY (pain W/5 map))) AND NOT (INDEX (medline) OR INDEX (embase))

IEEE Xplore (22nd August 2023) [Result of the Command Search that uses free text and nested concepts; maximum 7 wildcards allowed per search]

(((“manikin*” OR “mannequin*” OR “pain NEAR drawing*” OR “pain NEAR map*” OR “pain NEAR diagram*” OR “pain NEAR chart*” OR “body NEAR drawing” OR “body NEAR map” OR “body NEAR diagram” OR “body NEAR chart”)))ACM Digital Library (3rd November, 2020; full text: 1095 titles]

“manikin*” OR “mannequin*” OR "pain drawing*" OR "pain map*" OR "pain diagram*" OR "pain chart*" OR "body drawing*" OR "body map*" OR "body diagram*" OR "body chart*"

Appendix 2 - full list of data extraction items

Objective 1		
Study characteristics	Country	
	Publication year	

	Clinical purpose (e.g. aetiology, understanding pain prevalence/patterns in particular groups, diagnosis, identifying deterioration/change in disease status, assessing recovery/response to treatment)
	Study aim (as reported by the authors)
	Cross sectional or longitudinal
Setting and population characteristics	Pain type (induced/natural)
	Clinical area (e.g. lower back pain, fibromyalgia)
	Population description (e.g. healthy volunteers, people with arthritis)
	Race/ethnicity
	Number of participants included in the analysis
	Age
	Gender/sex
Objective 2a	
Manikin characteristics	Name
	Dimensions (e.g. 2d/3d)
	Body area (e.g. whole body, head only)
	Views (e.g. front, side)
	Detail level (e.g. pixel, grid based, predefined areas)
	Location-specific pain aspects (e.g. intensity, quality)
Individual manikin summary measures	Name
	Description/definition of measure
Objective 2b	
Methods	*How is measure calculated (automated/manual/combination/not reported)
	Description of method (analysis methods/algorithm, assessment criteria)
	Measure built into manikin (yes/no)
Objective 3	
Other analysis methods	Name
	Description of method
	Level of analysis (population, time period)

*We defined “manual” methods to be any methods requiring human intervention on an individual manikin basis.

**For example, a study reporting pain area in absolute number of pixels without describing the method, but which used a manikin described in other work as being able to automatically calculate this measure, was recorded as “not reported (automated)” (15).

Appendix 3 - construct definitions

Construct	**Definition**
Pain extent (n=53)	The area of pain, regardless of the location
Location (n=28)	Quantification or description of the physical location of pain
Widespreadness (n=21)	The extent to which pain is present throughout the body rather than concentrated in a specific location
Pain	The pain qualities included in a pain drawing, regardless of the location

quality (n=9)	
Laterality (n=7)	Whether pain is present on one or both sides of the body split vertically
Shape (n=5)	Spatial measures of the area of pain such as the length, width, or product thereof
Location-specific intensity (n=4)	Weighted score for pain intensity using location-specific pain intensity information
Overlap (n=3)	The area of intersection of two distinct co-occurring sensations
Mismatch (n=3)	The area of non-intersection of two distinct co-occurring sensations

Appendix 4 - PRISMA scoping review checklist

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.	
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.	2-3

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
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.	3-4
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.	4
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.	4
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.	4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	4-5
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.	5
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	5-6, appendix
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).	n/a
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	6
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.	7
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	7-11
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
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.	11-18
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	11-18
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.	18-19
Limitations	20	Discuss the limitations of the scoping review process.	19-20

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
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.	20-21
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.	21

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.

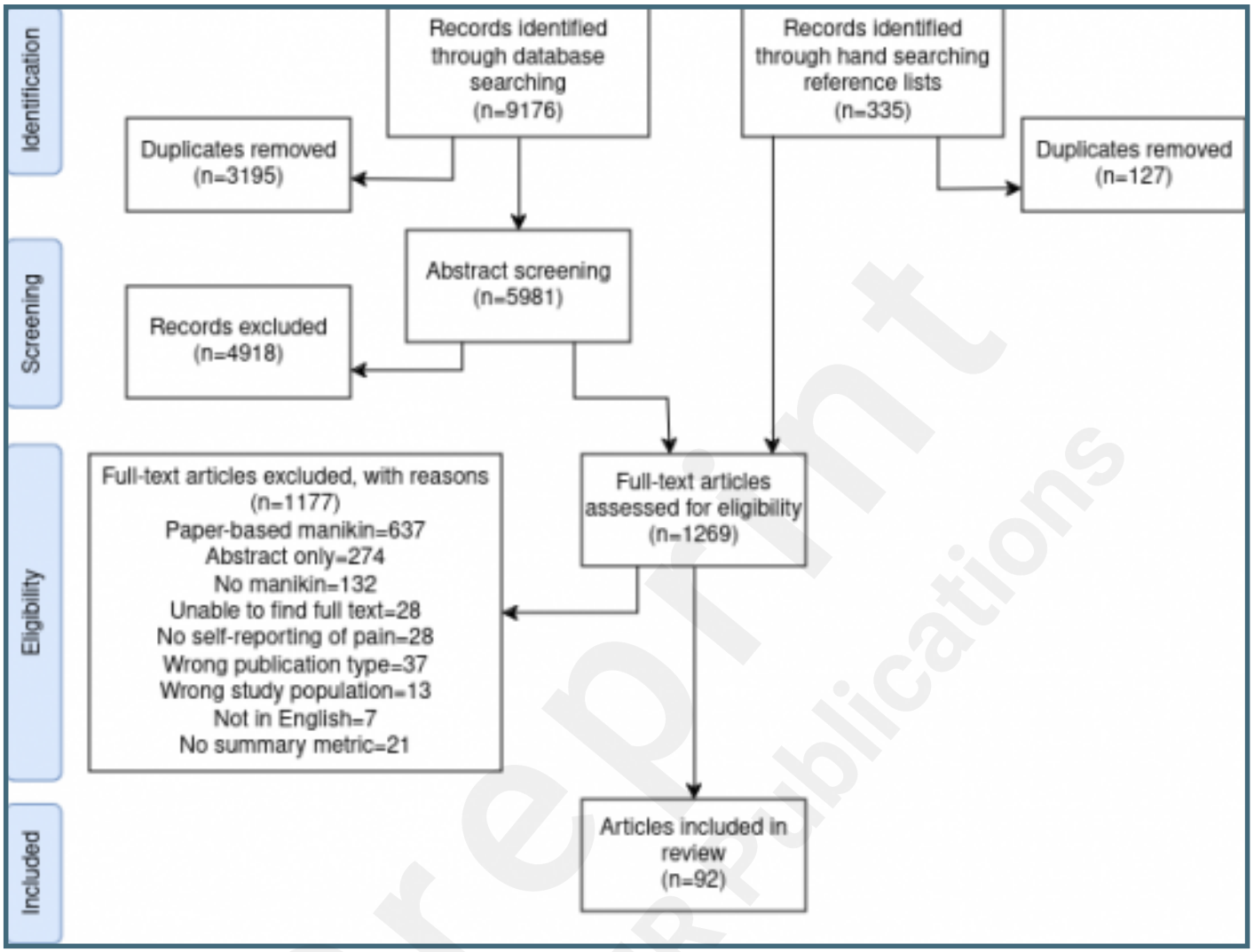
§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge 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 (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

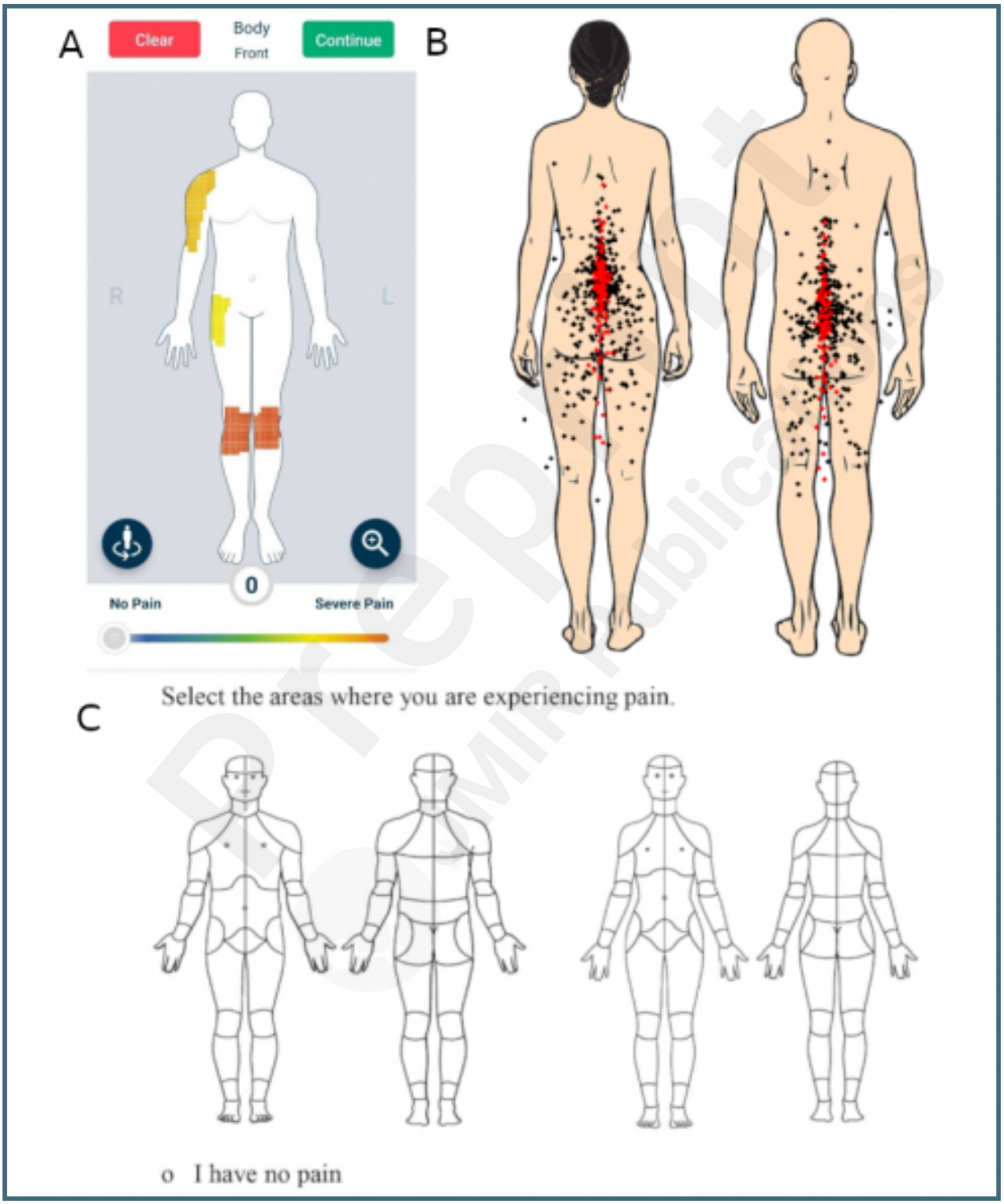
Supplementary Files

Figures

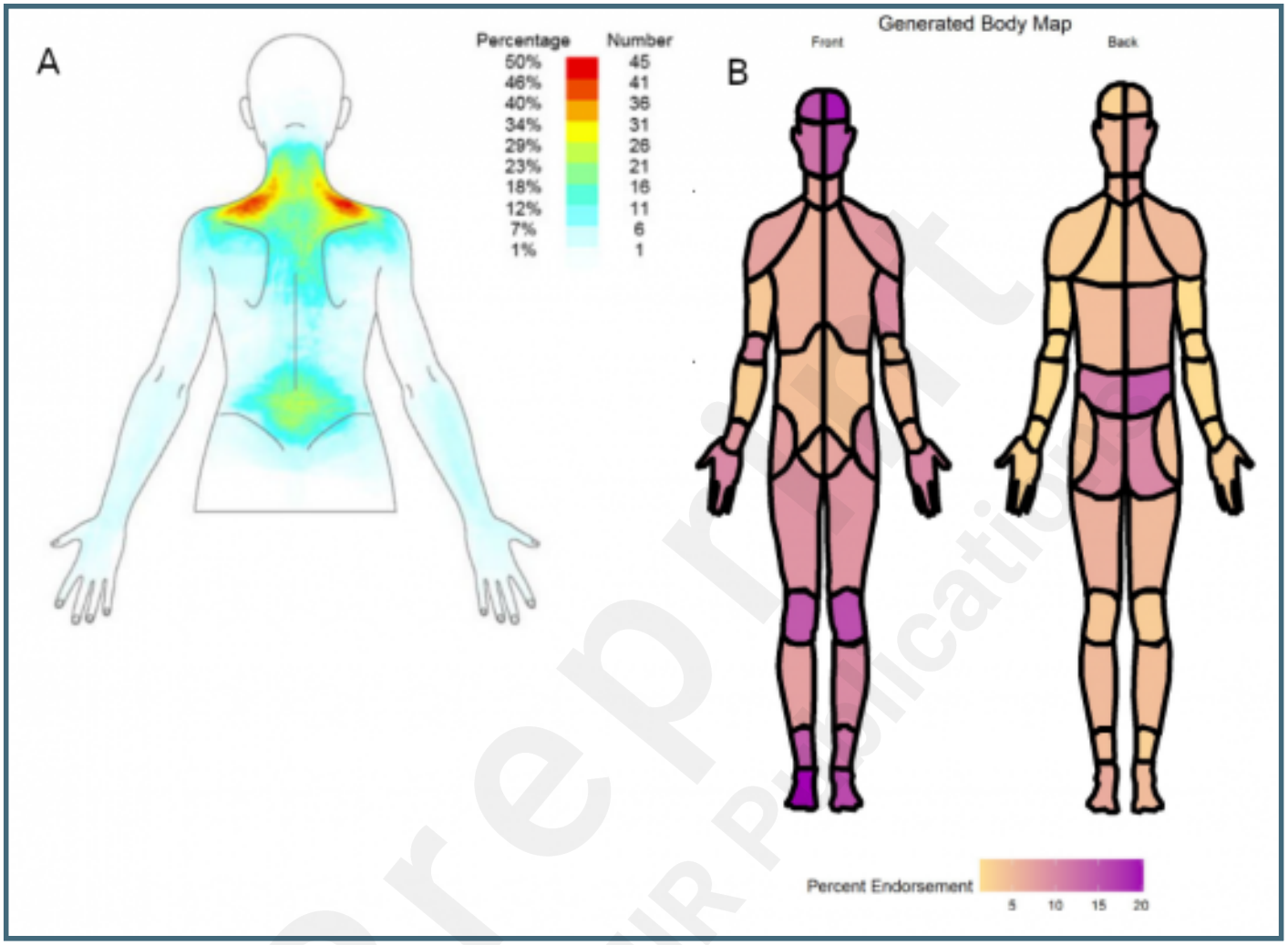
PRISMA diagram showing the screening process with the number of papers excluded at each stage.



a) A screenshot of the Manchester Digital Pain Manikin app (copyright University of Manchester), where users marked the location and intensity of pain on a grid (as described in 25); b) The Collaborative Health Outcomes Information Registry (CHOIR) body map, from Scherrer et al. (2021), where users marked the location and intensity of pain on pre-defined body regions 26; c) The manikin used by Mi?kisiak et al. (2021), where users made individual marks indicating pain location 24.



Heatmaps reproduced as examples of different digital pain manikin heatmaps a) Cruder et al. (2018) generated a pixel average of overlaid pain drawings 14 b) Cramer et al. (2022) generated a region-based average of overlaid pain drawings 105.



Multimedia Appendixes

Full data extraction spreadsheet.
URL: http://asset.jmir.pub/assets/5ccdb0c1255f49376320eaed6f93ffde.xlsx