Handheld computer devices to support clinical decision-making in acute nursing practice: a systematic scoping review

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Abstract

Background: Nursing care is increasingly supported by computerised information systems and decision-support aids. Since the advent of Handheld Computer Devices (HCDs) there has been limited exploration of their use in nursing practice.

Objective: To understand the professional and clinical impacts of nurse use of mobile health applications to assist clinical decision-making in acute care settings. To explore the scope of published research and identify key nomenclature with respect to research into this emerging field within nursing practice.

Methods: This scoping review involved a tripartite search of electronic databases (CINAHL, EMBASE, MEDLINE, Google Scholar) using (1) preliminary, (2) broad, and (3) comprehensive search terms. Included studies were hand-searched for additional citations. Two researchers independently screened studies for inclusion and appraised quality using structured critical appraisal tools.

Results: Of the 2,309 unique studies screened, 28 were included in final analyses: randomized controlled trials (n = 3); and quasi-experimental (n = 9), observational (n =10), mixed-methods (n = 2), qualitative-descriptive (n = 2), and diagnostic accuracy (n = 2) studies. Studies investigated the impact of HCDs on nurse decisions (n = 12, 42.9%), the effectiveness, safety, and quality of care (n = 9, 32.1%), and HCD usability, uptake, and acceptance (n = 14, 50%), and were judged to contain moderate-to-high risk of bias. The terminology used to describe HCDs was heterogenous across studies, comprising 24 unique descriptors and 17 individual concepts that reflected three discrete technology platforms (‘PDA technology, ‘Smartphone / tablet technology’, ‘Healthcare-specific technology’). Study findings varied, as did the range of decision-making modalities targeted by HCD interventions. Interventions varied according to the level of clinician versus algorithmic judgment: unstructured clinical judgment; structured clinical judgment; computerised algorithmic judgment.

Conclusions: The extant literature is varied but suggests that HCDs can be used effectively to support aspects of acute nursing care. However, there is a dearth of high-level evidence into this phenomenon and studies exploring the degree to which HCD implementation may affect acute nursing care delivery workflow. Additional targeted research using rigorous experimental designs is needed in this emerging field to determine their true potential in optimising acute nursing care.

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HANDHELD COMPUTER DEVICES TO SUPPORT CLINICAL DECISION-MAKING IN ACUTE NURSING PRACTICE: A SYSTEMATIC SCOPING REVIEW

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Keywords: Handheld computer devices; Smartphones; Mobile computing; Mobile health; Nursing; Acute care; Decision-making; Clinical decision making; Scoping review.

Introduction

The commercial release of smartphones in 2007 initiated a revolution in handheld device ownership facilitating multimodal instant communication options and the rapid evolution of mobile health applications that provide instantaneous access to online information and resources [1]. Handheld computer devices (HCDs) with internet connected functionality are now widely employed to support health practitioner communication, documentation, education, research and clinical decision making across healthcare systems, including acute practice settings. The use of HCDs may offer advantages over fixed bedside information systems through their portability, rapid deployability [2] and cross-platform integration across care settings [3]. However, to effectively promote the quality and safety of care, the rapidly evolving landscape of HCDs in clinical practice requires a strong evidence-based foundation [4, 5]. Yet presently, the development and use of HCD-based applications at the point-of-care has outpaced their empirical testing, such that their overall effect on patient outcomes remains unclear [4, 6, 7].

HCDs provide nursing staff with a powerful and accessible mobile platform for a range of decision-support applications. Tiffen, Corbridge, & Slimmer (2014) defined nurses' clinical decision making as, "the process of choosing between alternatives or options through the gathering and evaluation of data, from which a decision, judgement or intervention is formulated." (p.399) [8]. HCDs may support best nurse decision making at point of care through the provision of evidence-based prompts, and/or the use of mobile computing to quantify key clinical markers or produce an algorithmic judgment from a combination of available information [9]. Despite sharing common principles of evidence-based decision-making with other health disciplines [10], nursing-specific knowledge, training and scope of practice render the *processes* of nurse decision-making distinctive [11, 12]. Yet, there are strong theoretical and empirical reasons to expect improvements to nursing care if structured decision aids can be carefully integrated into nursing practice. Since the 1950's evidence from the psychological sciences has demonstrated that the incorporation of evidence-based, algorithmic judgments typically outperform unaided clinical judgments across a wide range of both medical and non-medical applications [13-15]. The use of HCDs in the clinical space reflects the application of current mobile technology to facilitate such judgments at the point-of-care.

Reviews of the extant literature have typically explored HCD use in non-nurses [16, 17][16, 17], did not differentiate between professions [18, 19], or have explored nurses' use of information and communication technology broadly, without specifically focusing on the beside use of HCDs in acute settings [20-23]. However, in 2014, Mickan et al. [9] reported the findings of a systematic review on the use of HCDs to support information access and clinical decision-making at the point of care. The authors noted that at that time, seven randomised controlled trials had explored this concept, finding that the use of handheld tools improved knowledge acquisition and safety with respect to point-of-care decision-making. However, all identified studies were based on earlier generation, 'Personal Digital Assistant (PDA) technology, and primarily evaluated physician *(n* = 5, 71.4%) rather than nurse usage. It has been argued that the nursing profession lags other health care practitioners in their acceptance of using such technologies. However, it's to be noted that nurses in some health care settings have been prohibited from independently digital tools to support clinical decision-making and practice delivery [24, 25]. Therefore, while this earlier review was conducted after the smartphone era, a new systematic review of the literature is required to capture the impact of recent technological innovations.

In this paper, we report the findings of a scoping review that sought to identify and evaluate the body of published empirical literature investigating the use and effectiveness of HCDs in supporting nurses' clinical decision-making in the acute healthcare settings. This review aimed to summarise the extent, quality, characteristics, and scope of published research and identify key nomenclature with respect to this emerging field.

Methods

Design

To address the above aims, we undertook a scoping review involving both systematic electronic database searches and hand searches of the reference lists of included studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews checklist (PRISMA-ScR) was used to guide review methodology and reporting [26].
We operationally defined HCDs as any portable computer device that can be held in one hand and controlled by the person's other hand, including PDAs, smartphones, and tablet devices, but not including ubiquitous computing devices. Studies were screened against inclusion/exclusion criteria by one reviewer (DG). Ambiguous papers were subjected to full-text review. Two reviewers (DG and AH) independently performed full-text review of screened papers, appraised the methodological quality of included studies using Joanna Briggs Institute critical appraisal tools [27] and undertook data extraction. Disagreements about inclusion, quality appraisal, and data extraction decisions were resolved via consensus.

Search strategy

Keywords denoting HCDs varied between studies. Consequently, we employed a strategy involving three successive literature searches (preliminary database search, broad search, comprehensive search) to generate productive search terms and provide multiple patterns of literature coverage. All searches were limited to English language publications.

Literature Search 1 – Preliminary database search

We undertook a preliminary scoping of literature published between 2001 and 2021 in CINAHL Complete, MEDLINE Complete, EMBASE and SCOPUS. MEDLINE and CINAHL were searched using a combination of Medical Subject Headings (MeSH), CINAHL subject headings and keywords: 'Nursing Staff, Hospital'; 'Acute Care Nurse Practitioner'; nurs*; 'Decision Making, Computer Assisted'; 'Decision Making, Clinical'; 'Decision Making'; 'Decision Making, Patient'; 'Nursing Care Plans, Computeri?ed'; clinical judgement; mobile application; and mhealth. EMBASE and SCOPUS searched with simple keywords: nurs*, decision*; "handheld computer*". Search terms were initially derived from the systematic literature review by Mickan et al. (2014) [9] and are reported in full in Online Supplement A.

Literature Search 2 – Broad database search

Results from the preliminary database search identified few studies on current generation HCDs such as smartphones, android, iOS and tablet devices. Therefore, a second search using a small number of broad search terms and limited to 2010-2021 was conducted to help identify additional keywords. We conducted this search in CINAHL Complete, MEDLINE Complete, EMBASE and Google Scholar using the following keywords: 'Decision Making, Computerised'; nurs*; acute; handheld (see Online Supplement B). It was noted that the reference lists of many relevant articles found in Search 2 noted publications from the journal; 'CIN: Computers, Informatics, Nursing', not retrieved from the bibliographic databases. Consequently, we hand searched articles published in this journal from 2010-2021.

Literature Search 3 – Comprehensive database search

A final, comprehensive search was conducted in MEDLINE, EMBASE, and CINAHL (2010-2021). This search was conducted to determine if a more structured and detailed search strategy derived from the results of Literature Search 1 and 2 would identify a more comprehensive list of relevant studies. Details of the search algorithm is provided in Online Supplement C.

Study inclusion/exclusion criteria

Studies were included according to the following criteria: (1) primary research study; (2) explored the effect, acceptability, or usability of HCDs with respect to nurses' clinical decision making; (3) study conducted in an acute care setting; and (4) peer-reviewed journal publication. Conference proceedings and dissertations, studies that did not include nurses in the evaluation, studies not conducted at the point of patient care, studies that explored the effect of HCD devices on nurse education or professional development were excluded from the review. As this was a scoping review, studies were not excluded on the basis of study design or methodological quality.

Data extraction and data analysis

Management of scoping review citations and study data was undertaken in the Covidence reference management platform (www.covidence.org). To categorise studies according to their objectives, they were analysed thematically. Two researchers (DG and AH) reviewed selected papers and devised independent coding frames based on emergent themes. The two researchers then discussed and refined the themes identified across the included studies until consensus on the final thematic structure was reached.

Study data was extracted and recorded on a spreadsheet, capturing: study characteristics – design, methodology, sample size context, type of computer technology used, information delivery mode, decision-support information provided; and study outcomes - outcome measures and findings.

Results

Number of studies identified by review

A total of 3,108 records were identified from the three literature searches and handsearches of reference lists. After removing duplicate records, 2,309 studies were screened by title and abstract and 558 underwent full-text review. A total of 2,281 studies failed to meet inclusion criteria and were excluded from the review. Figure 1 reports the number of studies identified, screened, and included in this scoping review.

Twenty eight studies were included for final analysis. These comprised of: randomised controlled trials (*n* = 3) [28-30] ; quasi-experimental studies (*n* = 9) using non-equivalent [31], cross-over [32, 33] and before-after designs with [34, 35] and without [36-39] controls; observational studies (*n* = 10) involving prospective [40, 41], retrospective [42] and cross-sectional [43-49] designs; qualitive-descriptive studies (*n* =2) involving in-depth[50] and focus group [6] interviews; and studies of diagnostic accuracy (*n* = 2) [51, 52]. Two mixed-method studies were also included in the review [53, 54]. Due to their prominent qualitative component, these were quality appraised using the Joanna Briggs Institute structured checklist for qualitative studies [27]. All judgments of risk of study bias made using the Joanna Briggs Critical Appraisal Tools (2021) [27] are detailed in Online Appendix D.

Three thematic areas of inquiry emerged from included studies (see Table 1): impact on clinical decision-making (*n* = 12, 42.9%); enhancing the efficiency, safety and quality of care (*n* = 9, 32.1%); and handheld device usability, uptake and acceptance (*n* = 14, 50%). Five studies evaluated the use of older computerised decision-support technology available on Personalised Digital Assistant (PDA) devices [35, 43, 45, 47, 53]. Most studies (n = 21, 75%) evaluated the use of digital applications delivered by modern smartphone or tablet devices. One used both PDA and tablet devices. [39] The remaining study evaluated the use of a mobile nursing information system that could be accessed at the bedside [54]. Overall, HCDs were described in included studies using 24 unique terms covering

17 individual concepts (see Table 2).

Impact of handheld device use on clinical decision-making

The characteristics and outcomes of the 12 studies that investigated HCDs as clinical decision-making supports are summarised in Table 3. Studies in this group investigated the extent to which HCDs could improve the quality of clinical assessment and management decisions or processes (*n* = 10) [28, 31-33, 35, 36, 40, 42, 51, 52] and enhance nurses' capacity for clinical decision-making (*n* = 2) [37, 38]. HCD interventions targeted processes of nurse clinical decision making using a range of modalities, which varied according to the predominance of clinician versus algorithmic judgment. These were: (1) clinical reference guides to support unstructured clinical judgments (*n* = 2) [37, 38]; (2) the use of aide mémoirs to structure clinical judgment (*n* = 3) [28, 31, 35]; and (3) fully computerised algorithmic assessments [32, 52], drug dosing [40] and clinical pathways [33, 36, 42, 51], with varying levels of clinician-override (*n* = 7). One study investigating the impact of HCD use on clinical decision-making employed PDAs [35], while the remaining 11 studies employed modern HCD technology. Studies within this theme were undertaken in emergency departments (*n* = 4) [31, 36, 42, 51], in various health and hospital settings (*n* = 3) [28, 37, 38], inpatient wards (*n* = 3) [35, 40, 53], an infectious paediatric ward (*n* = 1) [52], and in the context of a laboratory-based simulation (*n* = 1) [32].

Research investigating the impact of HCDs on the quality of clinical decisions or processes (*n* = 10) found significantly greater rates of diagnosis when using a HCD system for the assessment and management of obesity, tobacco use and depression [28]; improved prediction of serious illness [33] and clinical deterioration in hospitalised children using HCD-based assessment instruments [52]; more consistent nursing documentation following the implementation of HCD support system for patients' care plans and preferences [35]; lower odds of hospital admission and shorter hospital length of stay in paediatric patients and increased referrals to smoking cessation programs in child caregivers from computerised asthma management support [42]; faster calculation of Body Surface Area and intravenous fluid replacement rates in burns patients when using an automated tool [32]; faster treatment decision-making [31] and increased patient confidence [36] via the use of tablet-based, emergency department assessment applications. One study reported that an android tablet tool was able to successfully identify patients who required an ECG within 10 minutes of presentation [51]. Finally, the use of computerised decision-support for insulin dosing in Type 2 diabetes yielded a high level of agreement with standard clinical assessments (97%) and was perceived to precipitate a reduction in treatment decision-making errors [40].

Research examining the degree to which handheld technology may enhance nurses' self-rated decision-making capacity reported no significant impact from HCDs (*n* = 2). Specifically, Sedgwick, Awosoga and Grieg (2017) [37] found that the use of a nursing smartphone application ('PEPID') over the course of one month failed to significantly improve nurses' ratings of self-efficacy and the ability of new graduate nurses to make clinical decisions in a rural hospital setting. A later publication by the same authors (2019) [38] reported that the intervention was not associated with nurses' perceptions of improvements in their clinical decision-making processes. Notably, however, both studies had small sample sizes (*n* = 25 and *n* = 20), which limited their statistical power.

Enhancing efficiency, safety and quality of care

The characteristics and outcomes of the nine studies that investigated the effect of HCD decision support systems on the efficiency, quality and safety of care delivery are summarised in Table 3. Studies that addressed this theme examined the impact of HCDs on the flow of nursing activities (*n* = 5) [29, 30, 34, 38, 44], team communication (*n* = 2) [6, 45] and care safety (*n* = 2) [34, 54], and explored nurses' perceptions of the quality of their HCD-facilitated care in the clinical space (*n* = 1) [50]. The research targeted two decision-making modalities: (1) unstructured clinical judgment via

the use of electronic clinical reference guides with (*n* = 1) [50] or without (*n* = 4) [6, 34, 38, 45] medical calculator support; and (2) fully computerised, algorithmic judgments for drug dosing (*n* = 3) [29, 30, 54]. The authors of the remaining study did not specify the type of mobile computing applications accessed by nurses [44]. Apart from studies involving both PDA and tablet technology [45] and one of a standalone handheld drug and IV infusion calculator[54], this research investigated modern HCD technology. A range of acute care contexts were represented, including: rural hospitals (*n* = 2) [34, 38], paediatric emergency departments (*n* = 2) [29, 30]; and medical (*n* = 1) [45], gynaecological (*n* = 1) [6], orthopaedic (*n* = 1) [34], palliative care (*n* = 1) [34], neonatal and paediatric intensive care (*n* = 1) [54] units and cross-sectional studies across multiple clinical environments in acute care [44, 50].

Most published research that examined the flow of nursing activities reported a positive association between the use of HCDs in the clinical setting and nursing efficiency (*n* = 4, 80%). Research that found a positive clinical impact of HCDs in this respect were: two studies of a HCD-based medical dosing support system, which resulted in significantly reduced drug preparation time, time to drug delivery, and medication errors compared with usual care [29, 30]; and two studies investigating the use of electronic clinical reference guides, which found that HCDs were associated with self-reported time-saving [34, 44]. The remaining study [38], reported that the implementation of a nursing smartphone application did not significantly modify nurses' work efficiency, as measured by the distance walked each shift.

The literature suggested HCD interventions enhanced team communication and were safe, but the number of relevant studies was small. Authors reporting on post-implementation focus groups [6] and questionnaire [45] findings reported that HCD-based, electronic clinical reference guides improved nurse communication. and These interventions were also associated with nurse reports of increased quality and patient safety in acute care delivery [34]. A further study, which evaluated the safety of computerised medication dose calculations, reported that despite concerns with perceptions of risk with respect to the HCD device, there were no significant differences in the rate of medication administration errors when using the intervention, relative to usual care [54].

The final study within the theme of efficiency, safety and quality of care explored perceptions of HCD-facilitated care quality in 10 nurses [50]. Interviewees believed that the use of smartphone devices at the point-of-care with access to a disease directory, pharmacological treatment guidelines and a medical calculator improved their diagnostic accuracy and quality of patient care. Smartphones were also said to improve nurses' computer literacy skills and have utility in facilitating the delivery of patient and in-service education.

Handheld device usability, uptake and acceptance

Studies that evaluated the usability, uptake and acceptance of HCDs among clinical end-users are detailed in Table 3 (*n* = 14). These studies sought to; evaluate of the quality of data entry into, or retrieval from, HCD platforms (*n* = 5) [33, 34, 43, 44, 47]; assess usability with respect to heuristics, human factors or ergonomics (*n* = 5) [6, 49, 51, 53, 54]; describe patterns of HCD use in clinical staff (*n* = 3) [39, 46, 48]; and identify predictors of the use of HCD interventions (*n* = 1) [41]. Research within this theme investigated the usability, uptake or acceptance of: (1) electronic clinical reference guides [6, 34] or prompts [41] to supplement unstructured clinical judgments (*n* = 3); (2) decision-support algorithms to facilitate structured clinical judgment (*n* = 1) [46]; and (3) algorithmic clinical pathways [33, 49, 51, 53] and drug dosing [54] (*n* = 4). The remaining five studies on this theme explored the use of mobile phone [39, 44, 48] and PDA [39, 43, 47] technology involving no pre-specified HCD intervention.

Studies that explored HCD usability, uptake and acceptance varied by technology platform. Except for three PDA studies [43, 47, 53] and a study of a standalone handheld drug and IV infusion calculator, research on this theme examined modern smartphone and tablet technology (*n* = 10). Usability, uptake and acceptance studies were undertaken in acute hospital settings [39, 41, 44, 47-

49] including an emergency department [51], gynaecological ward [6], heart centre [53], regional hospital[43], orthopaedic and palliative care units [34], and paediatric inpatient settings [33, 46, 54]. Studies by Cato, Hyun and Bakken (2014) [41] and Doran et al., (2010) [39] also included patients from long-term, home care, and correctional organisations, as well as ambulatory settings, respectively. Analyses in these studies were not stratified according to acute care status.

The reviewed findings consistently suggested that HCD devices may facilitate improved processes for clinical data entry and retrieval at the point of care (n = 5). For example; recording children's physiological data was found to be faster and more accurate when using a handheld device compared to traditional written medical records [33]. and a further study revealed that nursing staff perceived the use of smartphone technology to improve their ability to access information [34, 44], as well as record notes and plan care [44]. Finally, nurses perceived PDAs to assist the retrieval, integration and interpretation of clinical data [43]. However Shen, Zang and Cong (2018) [47] found that nurse perceptions of utility varied according to the stability of the wireless network and the level of nurse education. Specifically, the authors reported that nurses with more education and years of clinical experience were more satisfied with using the device.

Studies of the usability of HCD interventions with respect to heuristics, human factors or ergonomics (n = 5) reported varied findings. Cognitive work analysis interviews undertaken with cardiac nurse co-ordinators (n = 9), suggested that the PDA-based decision-support aids were easier to use than their paper-based equivalents and yielded clearer and more consistent data collection by nursing staff [53]. In another study, nurses described an android-based application to aid decisions in suspected coronary syndrome as easy to use [51]. Despite these positive findings, other research highlighted barriers to HCD usability precipitated by device and design issues. These included the limitations of small device screen size and the perception that patients may view smartphone use in the clinical setting as unprofessional [6]; and performance and interface-related concerns that impacted upon both time efficiency and nurses' willingness to adopt the technology [54]. Studies reported that nurse operated HCDs had low cognitive and physical burden [49] and no significant difference in cognitive load or administration errors in HCDs versus usual care [54].

Descriptive research on nurses' patterns of HCD use (n = 3) reported on the frequency of self-initiated access of mobile phones and PDAs in the clinical space [39, 48] and identified the elements accessed in a paediatric electronic decision support tool [46]. While the data suggested it was common for nurses to use mobile devices and PDAs for clinical purposes [39, 48], a study of the predictors of HCD utilisation suggested that adoption of HCDs may vary according to a combination of nurse, patient and hospital characteristics [41]. The authors found that patient tobacco cessation screening was significantly more likely when nurses were advanced practice nurses, when patients were women or African Americans, and where the predominant payer was Medicare, Medicaid, or the State Children's Health Insurance Program (SCHIP).

Discussion

The social pervasiveness of HCD technology, coupled with its low cost, provides nurses with access to a set of tools capable of optimising patient care at the bedside. Despite the slow initial adoption of this technology [9], this systematic scoping review of the literature found that some has now been conducted in this emerging area (n = 28 studies). Positive impacts of HCD adoption were reported within the literature with a high degree of consistency. However, the low-to-moderate level of evidence characterised by observational and quasi-experimental designs, and the dearth of studies that investigated the degree to which HCD implementation may disrupt existing workflows, limits the strength of conclusions drawn about the overall clinical impact of HCDs at point-of-care.

This review identified that the literature investigating nurses' use of HCDs at point of care has targeted a variety of decision-making modalities ranging from the use of static guides supporting unstructured clinical judgments, to fully algorithmic decisions based upon computation of patient

characteristics. Presently, prevailing models of the psychology of decision making identify two qualitative distinct types of mental processing for decision-making: Type 1, ‘autonomous processing’, reflecting automatic, rapid, intuitive, or associative judgments; and Type 2, ‘effortful processing’, reflecting conscious, slow processing, that is, logical or hypothetical thinking [55, 56]. Structured clinical judgment and fully computerised judgment reduce and remove clinician input, and thus, the potential influence of cognitive biases typically associated with Type 1 thinking [57]. Notably, a very large volume of empirical research has identified the superiority of algorithmic versus human judgment [13-15]. Consequently, it seems likely that these mechanisms at least partially account for the finding that the HCD interventions, which formally structured or directed clinical judgment typically reported more positive outcomes compared with usual care.

While the current trend of implementing HCD support for more structured nursing applications may better leverage available mobile computing capabilities, many nursing tasks require rapid clinical judgments based on clinical experience [58]. Clinical reasoning is considered by professional nursing organisations to be fundamental to the very role of the nurse [59-61]. However at present, research offers little to support the effectiveness of, or strategies for, HCD supports for nurses’ routine workflows. Aside from studies that duplicated existing paper-based clinical information into an electronic format or allowed nurses to use HCDs to access the electronic resources they wished; there has been a lack of research into how HCDs could be used to support nurses’ routine work outside of the narrowly defined, technical nursing tasks investigated. While the findings did generally indicate improvement within these discrete areas, the assortment and availability of HCD applications appears to be rather piecemeal, such that the literature offers little guidance regarding the generalisability of these findings to other settings, or the total integration of individual applications within hospital information systems, or greater integration of HCD technology into nurses’ workflow. Thus, at present the empirical literature does not provide clarity on the worth and utility of HCD technology to nursing work and its transformative potential remains unclear.

This review found the most frequently undertaken domain of study on the bedside use of HCDs has concerned device usability, uptake, and acceptance. However, these issues have not been explored in depth, or study outcomes were specific to individual interventions with unclear generalisability to external health settings. There was a high degree of reliance upon subjective outcomes such as staff self-reports, which may result in biased outcomes because of perceived pressures to respond positively. While user uptake was a key component of several individual intervention studies, to-date, published research has not identified principle-based barriers and facilitators capable of guiding future HCD interventions. Furthermore, a serious gap in existing research was the absence of detailed investigation into the degree to which HCD implementation may disrupt existing workflows. Additional work in this area is critical to developing a more holistic understanding of the clinical value of HCD interventions to nursing care delivery in the acute healthcare setting.

Finally, this review identified significant heterogeneity in the descriptors used within the published literature to denote HCDs. Individual descriptors (n = 24) could be subsumed under three discrete labels with respect to the type and degree of technological development (‘PDA technology, ‘Smartphone / tablet technology’, ‘Healthcare-specific technology’). Despite this, there was a limited uniformity between the descriptors *within* these overarching labels, demonstrating a lack of standardised terminology. To assist future discovery and categorisation of studies in this field, efforts to standardise the language may prove fruitful. Initially, we recommend that future researchers include clear terms such as ‘smartphone’ and ‘tablet’ that readily communicate the technology platform being used.

Recommendations for future research.

The finding that the level of evidence within the body of empirical literature was insufficient to support meta-analyses indicates the critical need for additional research to investigate the impact of HCDs on clinical nursing care in the acute practice setting. Notably, the preponderance of small-

scale studies using observational designs highlighted the need for large, well designed experimental trials employing randomisation or cluster randomisation, where possible. Furthermore, as much of the extant literature has evaluated the impact of HCDs in pooled samples of multidisciplinary healthcare cohorts, there is a need to measure nurse-specific outcomes via nursing-specific studies, or multidisciplinary studies using stratified analyses. Finally, as the use of HCDs in nursing practice implicitly lends itself to data capture via large scale digital connectivity, future investigations in this field should attempt to leverage the potential of 'big data' involving sizable datasets from multiple users across multiple domains [62]. Despite the conceptual and technical challenge presented, there should also be an exploration of the degree to which applications using Bayesian or machine learning techniques could support nurses' clinical judgments. .

Many of the retrieved studies measured the nursing and patient impacts from digital tools focussed on multidisciplinary health assessment, diagnosis, and treatment modalities. However, this highlighted gaps in HCD-based applications designed to support decision-making for other nurse sensitive outcomes including the assessment of clinical deterioration, patient comfort, functional status, and pre-discharge self-efficacy. Moreover, given the dynamic, treatment-based focus of care delivery in the acute health care environment, there is also a need to develop digital tools that support decisions for nursing care organisation, including patient care prioritisation, workflow, and safety. Other aspects of clinical handheld device use also need further exploration, including the potential benefits to patient care quality and safety resulting from productivity gains and the point of care use of specific computerised resources. Research should also systematically test the utility of various handheld program user interface and interactivity designs to ensure that they assist, rather than impede the flow of care delivery. Research should be undertaken to guide the future development of context specific clinical HCD applications, to improve the utility, safety and value of such assistive devices to the particular requirements and demands of acute nursing care delivery.

Limitations

This scoping review had several limitations. First, as the primary focus was on published peer-reviewed literature, the grey literature was not comprehensively searched, and this may be an area of inquiry for future research. This would assist in determining the degree of positive publication bias present in the peer-reviewed literature. Second, this review was limited to studies undertaken in acute settings. Future research should investigate the degree to which impacts measured in non-acute settings may be generalisable and applicable across a range of health care settings. Third, this review was undertaken in the context of research for a minor thesis, without the resource to translate and include non-English publications.

Conclusion

This paper has described the complexities involved in conducting a systematic scoping review and the dearth of quality research on the use of handheld computer devices to support acute clinical nursing practice, highlighting the need for more targeted and rigorous research on this phenomenon. It is suggested that future research adopts a recognised nurse and patient sensitive outcomes framework and focuses explicitly on the integration of mobile computing technology into existing workflows and investigation of the impact of HCDs on patient care outcomes.

Conflicts of Interest

The authors have no conflicts of interest to disclose.

Tables

Table 1

Themes identified from included studies

Author	Impact on clinical decision-making			Enhancing efficiency, safety and quality of care			Handheld device usability, uptake acceptance		
	Identifies elements	Quantifies elements	Synthesises elements	Identifies elements	Quantifies elements	Synthesises elements	Identifies elements	Quantifies elements	Synthesises elements
Bakken et al., (2014) [28]	✓	✓							
Cato, Hyun, & Bakken (2014) [41]							✓		
Cleaver, Bird, & Francis (2021) [31]	✓								
Doran et al., (2010) [39]							*	*	*
Farrell (2016) [6]				✓			✓		
Godwin et al., (2015) [32]	✓	✓							
Hsiao & Chen (2012) [43]							*	*	*
Johansson et al., (2012) [34]				✓			✓		
Johansson et al., (2014) [44]				*	*	*	*	*	*
Kartika et al., (2021) [52]	✓	✓							
Kerns et al., (2021) [42]	✓	✓	✓						
Lin (2014) [45]				✓					
McCulloh et al., (2018) [46]							✓	✓	
Momtahan, et al., (2007) [53]							✓	✓	✓
Moore & Jayewardene (2014) [48]							*	*	*
O'Donnell et al., (2019) [51]	✓	✓	✓				✓	✓	✓
Reynolds et al., (2019) [54]				✓	✓		✓	✓	
Ricks et al. (2015) [50]				✓	✓				
Ruland (2002) [35]	✓								
Sedgwick et al., (2017) [37]	✓								
Sedgwick et al., (2019) [38]	✓			✓					
Sefton et al., (2017) [33]	✓	✓	✓				✓	✓	✓
Siebert et al., (2017) [29]				✓	✓				
Siebert et al., (2019) [30]				✓	✓				

Shen, Zang, & Kong (2018) [47]				*	*	*
Singh et al., (2017) [36]	☐	☐	☐			
Spat et al., (2017) [40]	☐	☐				
Yuan et al., (2013) [49]				☐	☐	☐

*Note.** specific HCD intervention not included in research or indicated by authors.

Table 2

Descriptors for 'handheld computer device' (HCD) in included studies (*N* = 28)

Term	Frequency *n* (%)	References
Personal Digital Assistant (PDA) technology	**6 (21.4%)**	
Personal Digital Assistant	3 (10.7%)	[10, 47, 53]
Mobile nursing information system	2 (7.1%)	[43, 45]
Handheld technology	1 (3.6%)	[35]
Smartphone / Tablet technology	**22 (78.6%)**	
Mobile device application / Mobile device app / Mobile-based application	3 (10.7%)	[29, 30, 52]
Mobile computerised decision support system / Mobile computing devices	2 (7.1%)	[40, 50]
Mobile devices / Advanced mobile devices	2 (7.1%)	[34, 44]
Mobile electronic clinical decision support / Mobile device-based electronic decision support tool	2 (7.1%)	[46]
Mobile health decision support system	2 (7.1%)	[28, 41]
Mobile technologies	2 (7.1%)	[37, 38]
Smartphone / iPhone	2 (7.1%)	[6, 48]
Tablet personal computer / Android tablet	2 (7.1%)	[39, 51]
Clinical decision support system	1 (3.6%)	[49]
Electronic physiological surveillance system	1 (3.6%)	[33]
Smart-device based application	1 (3.6%)	[32]
Tablet app	1 (3.6%)	[31]
Tablet based patient centred decision support	1 (3.6%)	[25]
Healthcare-specific technology	**1 (3.6%)**	
Handheld decision support device	1 (3.6%)	[54]

Table 3
Characteristics of included studies that explored clinical decision-making

Reference	Theme *(subtheme)* / study setting	Type of intervention	Outcome measure	Study Type / No of participants	Results
Bakken et al., (2014)[28]	Quality of clinical decision making *(Assessment / care decisions)* Various health settings	**Decision-support (aide-mémoire for structured clinical judgment)** Handheld decision-support tool, assessment and management of obesity, tobacco use and depression: screening prompts; standardised screens; selection of patient goals; clinical practice guidelines; recording treatment plans.	Number of encounters with a clinical practice guideline-related diagnosis. Number of care plan items in encounters with a clinical practice guideline-related diagnosis.	Randomised controlled trial 363 registered nurses undergoing nurse practitioner education	Significant effect of the intervention on diagnostic rates.
Cato, Hyun, & Bakken (2014) [41]	Usability, uptake acceptance *(Predictors of HCD use)* Acute and ambulatory care settings in the New York City metropolitan area	**Decision-support (aide-mémoire to initiate screening and select treatment)** Tobacco cessation screening and treatment prompt housed on mobile device(s).	Number of encounters resulting in: nurse screening for tobacco use; provision of smoking cessation advice; patient referrals for smoking cessation treatments	Observational study of the intervention arm of a randomised controlled trial 14,115 patient encounters involving 185 registered nurses	Screening more likely in patient encounters involving women (OR=1.14, 95% CI [1.03,1.25]) or African Americans (OR=1.18, 95% CI [1.01–1.38]. Screening higher in patients cared for by specialty nurses (OR=4.43, 95% CI [3.20, 6.13]) or in sites where the predominant payer was Medicare, Medicaid, or SCHIP (OR=1.88, 95% CI [1.57, 2.24]). In these sites, nurses were more likely to provide tobacco cessation teaching / counselling (OR=1.74, 95%CI [1.03, 2.94]) and less likely to provide treatment referrals for tobacco cessation (OR=0.439, 95% CI [.252, 0.764]). Patient encounters by nurses in FNP (OR=0.381, 95% CI [0.209,.693] or PNP (OR=0.314, 95% CI [0.109,0.906]) specialties were less likely to provide treatment referrals.
Cleaver, Bird, & Francis (2021) [31]	Quality of clinical decision making *(Assessment / care decisions)* Two metropolitan hospital ED's, London, UK	**Decision-support (aide-mémoire for structured clinical judgment)** Tablet based decision-support app to assist ED nurses to select investigations and treatments at initial patient assessment	Speed and accuracy of clinical decisions (including pt. acuity score rating) compared to control. Nurse assessment and subsequent expert panel evaluation.	Retrieval and analysis of stored device data on type and time of requests made by nurses c/w control nurse decisions and independent post event review by expert panel No. of nurse participants not specified; 529 patient assessments performed via app	Demonstrated time improvements in identification and actioning of appropriate pt. investigations, treatments and procedures. Need to improve some user design features identified.
Doran et al., (2010) [39]	Usability, uptake acceptance *(Patterns of use)* 29 acute, long-term, home care, and correctional organisations - Ontario, Canada	**No specific intervention – survey of staff perceptions of technology use** Mobile devices, include PDAs and tablet computers	Perceived impact of the mobile technologies on: barriers to research use; quality of care; job satisfaction.	Pre & post questionnaire 488 frontline nurses	Over 44.5% of nurses used mobile device at least once every few days
Farrell (2016) [6]	Enhancing efficiency, safety and quality of care *(Clinical /*	**Electronic clinical reference guide** iphone with clinical	To explore nurses' perspectives on iphone use within an acute care unit	20 registered nurses	iPhones accessible, portable, enhanced workplace communication. Negative findings; Small screen size inhibited use, esp. for patient teaching

	interdisciplinary communication) Usability, uptake acceptance *(Assess usability or identify heuristics / human factors / ergonomic considerations)* Acute gynaecological ward, Melbourne, Australia	resource and medication information apps - use by nurses in the acute care setting			and device use perceived to be unprofessional in direct patient care setting
Godwin et al., (2015) [32]	Quality of clinical decision making *(Assessment / care decisions)* Laboratory study	**Computerised measurement tool** Software app for Apple devices that facilitates calc of total Body surface Area of burns patients with fluid replacement formula ready reckoner and serial wound photography platform.	Accuracy off app vs traditional 'longhand' calculation tools	Repeat measures observation, with one week washout between method testing by participants 11 health clinicians, including ED nurses	App allowed faster calculation of BSA, fluid requirements and wound type evaluation c/w traditional methods, with no loss of accuracy
Hsiao & Chen (2012) [43]	Usability, uptake acceptance *(Quality of data entered or retrieved)* Regional hospital, Taiwan	**No specific intervention – survey of staff perceptions of technology use** 'm-NIS' available on PDA, notebook or 'panel' computer	Factors affecting 'fit between mobile nursing system and nursing tasks and task-technology fit and nursing performance	Pre & post questionnaire 310 clinical nurses recruited, with 210 questionnaires returned	Positive effect on: information acquisition, integration and interpretation. Nursing.
Johansson et al., (2012) [34]	Enhancing efficiency, safety and quality of care *(Impact on activity flow / perceived safety)* Usability, uptake acceptance *(Quality of data entered or retrieved)* Orthopaedic ward, palliative care unit and rural district hospital in Norway	**Electronic clinical reference guide** Use of mobile phones in clinical nursing practice for 15 weeks	To explore the usefulness, information retrieval, time saving, patient safety, quality of care, and work confidence for use of mobile device	Descriptive pre & post written survey Registered nurses (n= 14) and nursing students (n=7)	Mobile device perceived as useful, and time saving. Also contributed to improved patient safety and quality of care by improving access to information.
Johansson et al., (2014) [44]	Enhancing efficiency, safety and quality of care *(Impact on activity flow)* Usability, uptake acceptance *(Quality of data entered or retrieved)* Multiple health care agencies, Sweden	**No specific intervention – survey of staff perceptions of technology use** The use of mobile devices	views regarding the use of advanced mobile devices in nursing practice.	Cross sectional survey 62 graduate nurses working in acute care settings (of a larger sample of 107 nurses)	Participants regarded an advanced mobile device to be useful for access to resources, making notes, planning their work and saving time.
Kartika, Wanda & Nurhaeni (2021) [52]	Quality of clinical decision making *(Assessment / care decisions)* Infectious paediatric ward of a major	**Computerised risk assessment tool** Mobile computing application to assess the risk of clinical deterioration,	AUC/ROC Sensitivity / specificity of cutpoints	Test of diagnostic accuracy 108 paediatric patients	Analyses indicated that the mPEWS-InPro had a strong predictive ability: AUC=0.942 (95%CI 0.865 to 1.000; P = 0.001). Using a cutpoint of 4, the mPEWS-

	referral hospital, Indonesia	Modified Pediatric Early Warning System (mPEWS)-InPro.			InPro had a sensitivity of 92.3% and a specificity of 80%.
Kerns et al., (2021) [42]	Quality of clinical decision making *(Assessment / care decisions)* Emergency and inpatient departments in 75 freestanding Childrens or community Hospitals in the USA	**Decision-support (algorithmic clinical pathways)** Mobile 'mECDS tool' which provided evidence based clinical support for the management of paediatric asthma	Determine impact of tool on paediatric asthma care quality	Observational study (digital review of screen usage by practitioners) Tool used on 286 devices, 355 times for 4.191 digital events. (approximately 50:50 access events in ED versus inpatient settings)	Significantly reduced odds of hospital admission through use of the eECDS tool. Higher rates of caregiver smoking cessation referral rates through use of the tool. Shortened hospital length of stay
Lin (2014) [45]	Enhancing efficiency, safety and quality of care *(Clinical / interdisciplinary communication)* Major regional medical centre, Taiwan	**Electronic clinical reference guides** A mobile nursing 'Cart', PDA and tablet device providing access to a 'mobile nursing information systems (m-NIS) program (details of this program not provided)	factors affecting the 'fit 'between nursing tasks and mobile nursing information systems and nurse performance from the perspective of task-technology fit.	Post implementation questionnaire 219 surveys returned	m-NIS improved message exchange between healthcare professionals, communication with patients, increases efficiency of patient care duties, improves quality of care, increases professional image of nursing and im- proves the overall performance in nursing practices
McCulloh et al., (2018) [46]	Usability, uptake acceptance *(Patterns of use)* Inpatient paediatric settings, USA	**Decision-support (algorithm for structured clinical judgment)** Smartphone based evidence based 'PaedsGuide' electronic decision support tool	Tool development, distribution and usage patterns,	descriptive analysis (data analytics and on-line user feedback survey) 3,805 multi-disciplinary health care practitioner users (number of nurses not specified)	61% of total user screen time spent viewing clinical practice benchmarks, including hospital admission appropriateness, length of hospitalisation and diagnostic testing recommendations. Positive feedback on tool's usability.
Momtahan, K., Burns, C., Sherrard, H., Mesana, T., & Labinaz, M. (2007) [53]	Usability, uptake acceptance *(Assess usability or identify heuristics / human factors / ergonomic considerations)* Canadian acute heart centre	**Decision-support (algorithmic clinical pathways)** PDA (Personal Digital Assistant) cardiac patient symptom decision support tool	Viability and value of the digital handheld decision support tool c/w standard paper-based survey approach (retrospective cardiologist opinion on nurse evaluation)	'Cognitive work analysis' Semi-structured interviews following three-month trial 9 cardiac nurse coordinators	Data collection more complete and clearer with PDA assessment Nurses found PDA tool more helpful than paper-based tool. Cardiologists concurred with nurse assessment outcomes in 97% of cases
Moore & Jayewardene (2014) [48]	Usability, uptake acceptance *(Patterns of use)* 161 acute NHS trusts	**No specific intervention – survey of staff perceptions of technology use**	Questionnaire measuring: patterns of app use; factors affecting app use; perceived effects on patient care	Cross-sectional survey 82 nurses 334 doctors	Participant responses indicated a high level of users of textbooks, formularies, clinical decision tools and calculators.
O'Donnell et al., (2019) [51]	Quality of clinical decision making *(Assessment / care decisions)* Usability, uptake acceptance *(Assess usability or identify heuristics / human factors / ergonomic considerations)* Hospital Emergency Dept, Dublin, Ireland	**Decision-support (algorithmic clinical pathways)** Android tablet tool (AcSAP) determining probability of patients with suspected coronary syndrome, prompting ECG performance on pts within 10 mins	Efficacy of app to identification patients requiring an ECG Time until performance of ECG	Patient history audit of: time of presentation, triage action, first ECG and diagnosis Post-use Questionnaire on App usability AcSAP App activated 379 times by triage nurses (exact no of nurses unstated) 18 triage nurses returned post-use	App successfully identified patients who required an ECG within 10 mins of presentation. App assessed as easy to use by participants

				questionnaire	
Reynolds et al., (2019) [54]	Enhancing efficiency, safety and quality of care *(Perceived safety)* Usability, uptake acceptance *(Assess usability or identify heuristics / human factors / ergonomic considerations)* Neonatal and Paediatric intensive care units, across two hospitals in California, USA	**Medication dosing support** Nurse use of standalone customised handheld drug & IV infusion calculation aid	User acceptance and effect of device	Mixed methods; ethnographic observation, pre and post interviews, surveys 64 nurses	Device perceived to be worthwhile, risk perceptions and device usability limited device use. No significant difference in cognitive load or administration errors
Ricks, Benjamin & Williams (2015) [50]	Enhancing efficiency, safety and quality of care *(Nurses' perceptions of care quality)* Public hospital in Port Elizabeth, South Africa	**Electronic clinical reference guide / Medical calculator** Nurse use of a smart phone device at the point of care to access electronic resources: a disease directory; drug list treatment guidelines; and a medical calculator	To explore the experiences of registered nurses in using the device	Qualitative descriptive study N = 50 nurses, Purposive sampling of 10 nurses for in-depth interview	Improved computer literacy, useful for patient & in-service education, improves accuracy of diagnosis, increased practice delivery, improved quality of care.
Ruland (2002) [35]	Quality of clinical decision making *(Assessment / care decisions)* Acute medical care unit in Oslo, Norway	**Decision-support (aide-mémoire for structured clinical judgment)** 'Palm-pilot' handheld computerised support system ('CHOICE') that assists nurses to determine patient preferences to incorporate into care plan	Effects of the system on nurses' care priorities and preferences, patient satisfaction	Three group sequential survey design 28 nurses	Use of system resulted in improved consistency between patients' and nurses' care preferences
Sedgwick, Awosoga, & Grigg, (2017) [37]	Quality of clinical decision making *(Capacity for clinical decision-making)* Rural hospital, Lethbridge, Canada	**Electronic clinical reference guide** PEPID App (containing multiple nurse resources) on personal mobile device	Impact of mobile technologies on grad nurses' perceived decision-making abilities and self-efficacy	Quasi-experimental pre-test/ post-test design 25 Graduate student nurses (on clinical placement) recruited, 12 completed full questionnaire	Use of app did not enhance self-perceived efficacy or decision-making ability
Sedgwick, Awosoga, & Grigg (2019) [38]	Quality of clinical decision making *(Capacity for clinical decision-making)* Enhancing efficiency, safety and quality of care *(Impact on activity flow)* Rural hospital, Lethbridge, Canada	**Electronic clinical reference guide** Personal smartphone app 'PEPID professional Nursing Suite App' (providing access to multiple clinical nursing resources)	Effect on nurses walking distance and clinical decision-making ability	Pre and post survey 20 clinical nurses	No significant reduction in nurses clinical walking distance. No self-perceived effect on nurses decision-making ability. Increased confidence in using app over time.
Sefton et al.,	Quality of clinical decision making	**Computerised measurement tool**	Accuracy of vital sign readings and	Prospective mixed methods	Improved documentation speed, accuracy and clarity with use of

(2017) [33]	*(Assessment / care decisions)* Usability, uptake acceptance *(Quality of data entered or retrieved)* Paediatric hospital, United Kingdom	**with pathway decision-support** Handheld digital 'Paediatric Warning System' tool to identify development of serious illness (iPod Touch 4th gen)	time taken to document compared with paper-based method	23 RN's, student nurses, Health service attendants and medical students	digital device
Shen, Zang, & Kong (2018) [47]	Usability, uptake acceptance *(Quality of data entered or retrieved)* Various (nonspecified) clinical departments of major tertiary hospital in Beijing, China	**No specific intervention – survey of staff perceptions of technology use** Personal Digital assistant providing access to mobile nursing information system	Clinical nurse satisfaction with use of PDA	Cross-sectional descriptive survey 383 nurses	Nurses more satisfied with delivery of medical orders and documentation facility of device. Utility dependent on stability of network and higher satisfaction positively correlated with nurse education level
Siebert et al., (2017) [29]	Enhancing efficiency, safety and quality of care *(Impact on activity flow)* Pediatric emergency department, Switzerland	**Medication dosing support** Tablet-based app to support decision making for continuous infusion of medications	Drug preparation time. Time to drug delivery. Number of medication errors	Randomised controlled crossover trial 20 nurses	Intervention significantly reduced drug preparation time, time to drug delivery, medication errors.
Siebert et al., (2019) [30]	Enhancing efficiency, safety and quality of care *(Impact on activity flow)* Three regional pediatric emergency departments in Switerland	**Medication dosing support** Tablet-based app to support decision making for continuous infusion of medications	Drug preparation time. Time to drug delivery. Number of medication errors	Randomised controlled crossover trial 128 nurses	Intervention significantly reduced drug preparation time, time to drug delivery, medication errors.
Singh et al., (2017) [36]	Quality of clinical decision making *(Assessment / care decisions)* Emergency Department, Connecticut, USA	**Decision-support (algorithmic clinical pathways)** Use of a bedside tablet computer app to assess patients and guide decisions on the performance of a CT scan in patients with concussion.	Effects of tool on patient experience, clinician experience, health care utilisation and patient safety	Pilot study with pre and post survey of patient and clinician experiences 2 advanced practice nurses, 16 physicians, 11 physician assistants (41 patients enrolled)	Patients satisfied clarity of information and use enhanced trust in the physician, most clinicians perceived the app to be helpful for patients, to be usable. No clinically important brain injury was missed through use of the device.
Spat et al., (2017) [40]	Quality of clinical decision making *(Assessment / care decisions)* General hospital ward, Graz, Austria	**Medication dosing support** Customised Samsung Galaxy tablet computer designed to assist nurses and medical officers in determining appropriate insulin dose for patients with type 2 diabetes	Safety, efficacy and user acceptance of device/system	Feasibility study; field notes on use, pre and post written questionnaires 14 nurses and 12 physicians- time-1, 12 nurses, 3 physicians time-2, 12 nurses and 6 physicians, time-3	High usage of device, High confidence in use of tool over time, high level of device decisions agreeance by Health care providers. (97%). Perceptions that treatment errors prevention reduced through use of device.
Yuan et al., (2013) [49]	Usability, uptake acceptance *(Assess usability or identify heuristics / human factors / ergonomic considerations)* Hospital setting, Texas, USA	**Decision-support (algorithmic clinical pathways)** Bedside clinical decision support system housed on tablet devices	Number of heuristic violations. Number of successful case simulations Duration of simulated task	Heuristic evaluation A panel of evaluators comprising 3 licensed vocational nurses and 7 registered nurses	Simulation sessions resulted in: - 83 heuristic violations - 100% of successful completions (*n* = 30 sessions) - Average of 111 sec (SD=30 sec) to complete the simulated task NASA Task Load Index results indicated low cognitive and physical

	National Aeronautics and Space Administration (NASA) Task Load Index	burden.

Figures

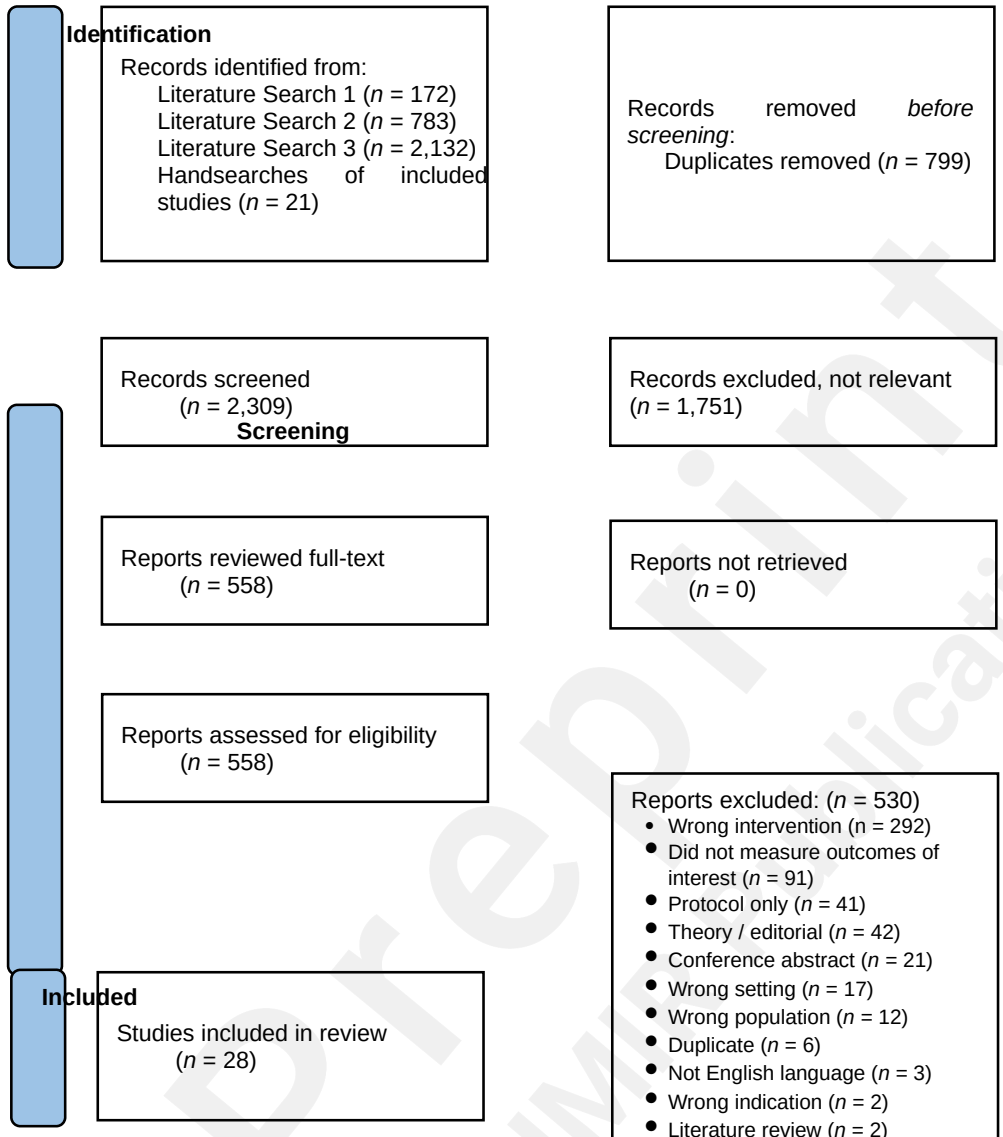

Figure 1. PRISMA Flow Diagram for Literature Searches 1 through 3

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Supplementary Files

Multimedia Appendixes

Untitled.
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