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Use of mobile health technologies for postoperative care in paediatric surgery: A systematic review

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Abstract

Introduction: Mobile health (mHealth) is the use of mobile communication devices such as smartphones, wireless patient monitoring devices and tablet computers to deliver health services. Paediatric surgery patient care could potentially benefit from these technologies. This systematic review summarises the current literature on the use of mHealth for postoperative care after children's surgery.

Methods: Seven databases were searched by a senior medical librarian. Studies were included if they reported the use of mHealth systems for postoperative care for children <18 years old. Data extraction and risk of bias assessment were performed in duplicate.

Results: A total of 18 studies were included after screening. mHealth use was varied and included appointment or medication reminders, postoperative monitoring and postoperative instruction delivery. mHealth systems included texting systems and mobile applications, and were implemented for a wide range of surgical conditions and countries.

Discussion: Studies showed that mHealth systems can increase the postoperative follow-up appointment attendance rate ($p < 0.001$), decrease the rate of postoperative complications and returns to the emergency department and reliably monitor postoperative pain. mHealth systems were generally appreciated by patients. Most non-randomised and randomised studies had many methodological problems, including lack of appropriate control groups, lack of blinding and a tendency to devote more time to the care of the intervention group. mHealth systems have the potential to improve postoperative care, but the lack of high-quality research evaluating their impact calls for further studies exploring evidence-based mHealth implementation.

Keywords

Mobile health, paediatric surgery, postoperative care, attendance rate, complication rate

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Introduction

Mobile health (mHealth) is the use of mobile technologies, such as smartphones, to optimise the delivery of health care. Potential uses are multiple and include patient education, recovery monitoring and treatment-compliance improvement.[1] mHealth interventions can also increase access to health care and decrease costs.[2] Although mobile-phone ownership rates can vary depending on sex, education and age,[3] the gap has been closing between individuals from different socio-economic status (SES) strata,[4,5] and smartphone ownership has been on the rise throughout the world.[6]

The success of procedures in paediatric surgery is highly dependent on optimal postoperative management and follow-up. Non-optimal postoperative care can lead to long-term disability such as chronic pain,[7,8] as well as catastrophic outcomes such as organ rejection and death.[9,10] mHealth technologies could potentially

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facilitate postoperative care, monitor pain better, remind patients about appointments and provide postoperative education opportunities. However, mHealth interventions have to be adapted to the specific needs of the paediatric population, such as children's shorter attention span and the complex interactions between the patient, the caregivers and the health-care providers.[11]

Despite the rapid development and success of several mHealth interventions for different populations, diseases and settings,[12–16] no systematic review evaluating the effectiveness of mHealth interventions for postoperative care in paediatric surgery exists to date. The objective of this systematic review is therefore to evaluate the current state and use of mHealth interventions designed to provide postoperative care to paediatric surgery patients.

Methods

Data search

A systematic review was performed following the Preferred Reporting Items of Systematic reviews and Meta-Analyses (PRISMA) guidelines (Supplemental File S1).[17] The search was developed by a senior medical librarian. The following databases were searched from database inception until 15 August 2018: Medline (Ovid), Embase (Ovid), Cochrane (Wiley), Africa-Wide Information (EBSCO), Global Health (Ovid), Global Index Medicus (World Health Organization) and Web of Science (Clarivate Analytics). The strategy used variations in text words found in the title, abstract or keyword fields, and relevant subject headings to retrieve articles looking at mHealth combined with surgical procedures or common surgical anomalies as well as visual or diagnostic techniques, without language restrictions. Animal studies were excluded, and the search was limited to the paediatric population. The full search strategy is available in Supplemental File S2. Additionally, articles citing or cited by eligible articles found by the database search were also assessed for eligibility in a snowballing process. Details of the protocol for this systematic review were registered on PROSPERO (CRD42018111205; https://www.crd.york.ac.uk/prospero/display_record.php?RecordID = 111205).

Study eligibility

Study abstracts were independently screened in duplicate by two reviewers for eligibility using Rayyan QCRI software,[18] and were selected based on the independent review of the full-text articles. Conflicts were resolved by discussion between the reviewers and a third party if necessary. The inclusion criteria were: (a) patients $\geq$18 years old; (b) patients who underwent surgery; (c) interventions aiming to improve postoperative care; and (d) interventions using mHealth. The latter is defined by the Global Observatory for eHealth as the use of mobile communication devices to deliver health-care services,[19] designed to be used by the patients or their caregivers. The exclusion criteria were: (a) interventions without paediatric patients as their target (e.g. mHealth interventions for mothers delivering by caesarean section); (b) research protocols, conference presentations, reviews, editorials, case reports and case series; (c) publications dated before 15 August 2008; and (d) publications in languages other than English or French.

Data extraction, synthesis and bias assessment

A data extraction sheet was developed and piloted with four eligible studies. Data were collected in duplicate by two independent reviewers, and disagreements were resolved by discussion and a third party if necessary. Data items collected included participant characteristics (age, surgical condition, country), study design, mHealth intervention design (purpose, mHealth technology used, resources required, data handling), as well as health outcomes (reliability of monitoring, patient preference, compliance to follow-up and postoperative instructions, resource utilisation, complication rate, ease of implementation). Data were only analysed qualitatively due to the heterogeneity between studies, with the exception of a quantitative synthesis of the postoperative appointment follow-up rate. This was performed by combining the patients from mHealth groups in all relevant studies and comparing their postoperative attendance rate to all controls using a chi-square test with a level of significance set at $p < 0.05$.

The risk of bias was assessed using the Cochrane RoB 2.0 tool for randomised studies, which classifies studies as 'high risk', 'some concerns' and 'low risk', depending on an assessment of five bias domains.[20] The MINORS scale was used for non-randomised studies, with scores of >16 for non-comparative studies and >24 for comparative studies, and a gold standard score of 19.8 for comparative studies.[21]

Results

Study characteristics

The results of the literature search are shown in Figure 1, and the characteristics of the included studies are presented in Table 1. Ten non-randomised and eight randomised studies were included. Only three studies were excluded because they were published in languages other than English or French. Studies most commonly used mobile applications ('apps') designed for mHealth and

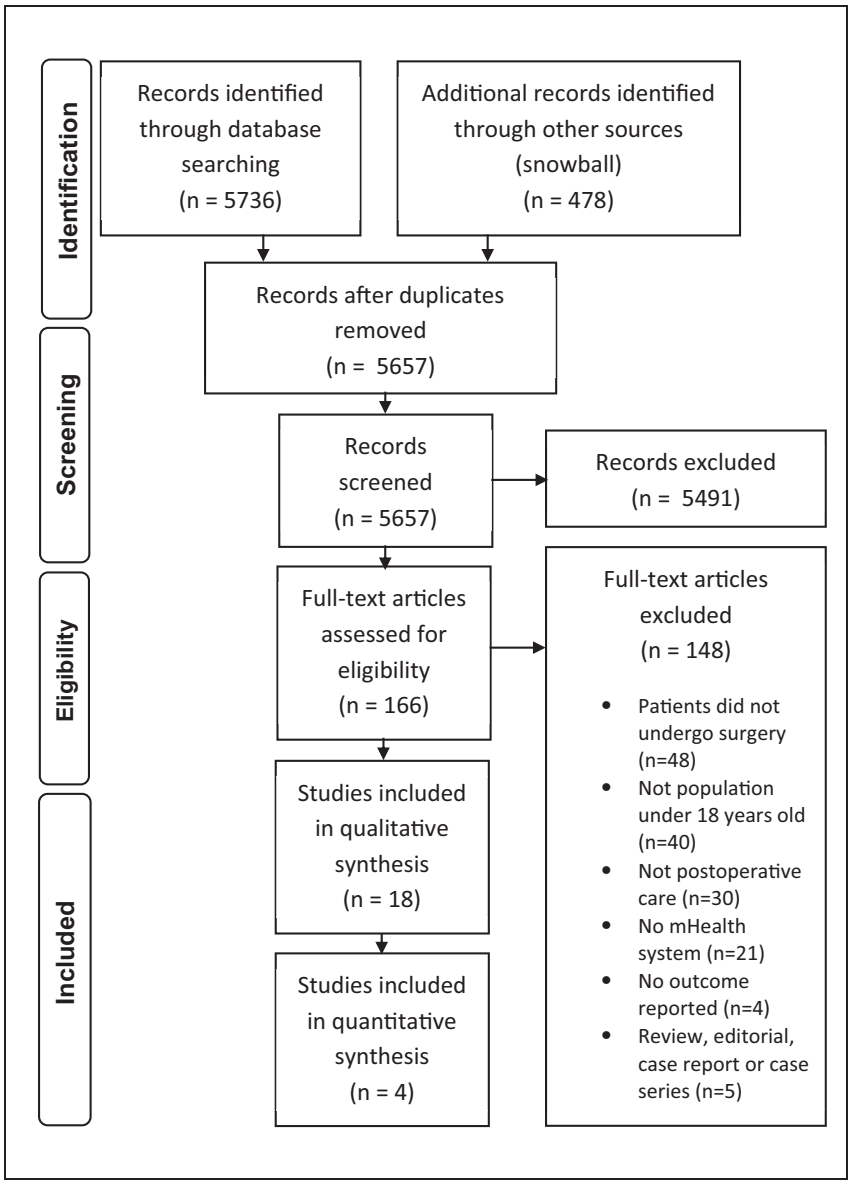

Figure 1. Prisma flow diagram.

short message services (SMS), and were primarily designed for regular mobile phones, smartphones and tablets.

The study populations were heterogeneous in terms of surgical interventions (Table 1). Participants were infants and preschoolers (0–6 years old) in seven studies, school-age children (6–12 years old) in one, adolescents (12–18 years) in one and paediatric patients of all ages in three studies; six studies did not report the participants' ages. One study took place in a lower-middle-income country, three in upper-middle-income countries and the rest in high-income countries. Patient follow-up was between one and four weeks in eight studies, more than one month in seven studies and missing in three studies.

Ease of implementation

Mobile devices were provided by the researchers in nine studies. However, in the nine other included studies, participants had to provide their own, and smartphone ownership was reported as an inclusion criterion in only three of these studies. A total of 11 smartphone applications were used: eight were developed for a single smartphone platform, and three were developed for multiple operating systems. Caregivers were trained in how to use the systems with written instructions in two studies, with an instructional video in one and in person in four studies. Among the 18 included studies, only two mentioned data security, with only one

Table 1. Study design and risk of bias of included studies.

First author (year)		Type of study	Country	Surgical procedure	*n*	Intervention: goal of study	MINORS or RoB 2.0 score[a]
Ali (2019)[40]		Non-randomised controlled trial	USA	Tonsillectomy	117	New app: Postop instructions	12/24
Black (2014)[29]		Historical controlled trial	USA	Single-ventricle repair	18	New app: Home recovery monitoring	15/24
Chen (2012)[41]		Single-arm trial	Australia	Tonsillectomy and adenoidectomy	26	SMS: Postop pain assessment	9/16
Chua (2017)[26]		Cohort study	Canada	Hypospadias repair	81	Smartphone photography: Home recovery monitoring	19/24
Foong (2012)[22]		Non-randomised controlled trial	Cambodia	Cleft-palate repair	22	Mobile phone distribution: Follow-up attendance	18/24
Newton (2016)[42]		Single-arm trial	USA	Tonsillectomy	5	SMS: Postop instructions	9/16
Newton (2018)[43]		Single-arm trial	USA	Tonsillectomy	85	SMS: Postop instructions	9/16
Shellmer (2016)[39]		Usability testing	USA	Organ transplant	7	New app: Drug adherence	13/16
Shirali (2016)[28]		Historical controlled trial	USA	Single-ventricle repair	30	New app: Home recovery monitoring	18/24
Stinson (2015)[31]		Usability testing	Canada	Cancer surgery	14	New app: Postop pain assessment	13/16
Sun (2018)[44]		Feasibility study	Canada	Multiple	29	New app: Postop pain assessment	10/16
Bingler (2018)[27]		Crossover RCT	USA	Single-ventricle repair	31	New app: Home recovery monitoring	H
Chang (2018)[23]		RCT	China	Cataract surgery	75	WeChat: Follow-up attendance	H
Lin (2012)[25]		RCT	China	Cataract surgery	135	SMS: Follow-up attendance	S
Liu (2018)[24]		RCT	China	Herniorrhaphy	209	WeChat: Postop instructions	S
Sun (2015)[30]	CAS trial	Crossover RCT	Canada	Multiple	68	Smartphone versions of CAS and FPS-R pain scales: Postop pain assessment	S
	FPS-R trial				75		H
Wood (2011)[32]		Crossover RCT	France	Not reported	166	Personal digital assistant version of FPS-R pain scale: Postop pain assessment	S
Yang (2016)[45]		RCT	South Korea	Tonsillectomy	27	SMS: Postop instructions	H

[a]MINORS score for non-randomised studies: score >16 for non-comparative studies and >24 for comparative studies; RoB 2.0 score for randomised studies: high risk (H), some concerns (S), low risk (L).
RCT: randomised controlled trial; SMS: short message service; FPS-R: Facial Pain Scale Revised; CAS: Color Analog Scale; Postop: postoperative.

mentioning conforming to data privacy and security legislation. Seven studies involved interactions between caregivers and health-care workers, and 11 were entirely automated, comprising automatic texting systems or similar technologies.

Postoperative follow-up appointment attendance rate

Four studies compared attendance rates at postoperative appointments in groups receiving a mHealth intervention to groups receiving traditional follow-up. All these studies found a statistically significant increase in attendance rate at follow-up appointments in the mHealth groups, although the clinical significance varied, as some studies had a very high attendance rate in both groups (Table 2). When pooled together, the studies found an attendance rate of 94% in patients in mHealth intervention groups compared to 81% in controls ($p < 0.001$). Foong et al. issued mobile phones to selected individuals to arrange a follow-up appointment within six months of cleft palate surgery.[22] Chang et al. and Liu et al. used WeChat, a popular Chinese multipurpose messaging application, to send text-message reminders for postoperative appointments and compared it to control groups who received no reminders and a written card with the appointment information, respectively.[23,24] In a randomised controlled study, Lin et al. compared attendance rates at four follow-up appointments after cataract surgery from one week to three months postoperatively in a group receiving text-message reminders and a control group who received no reminder for their appointments.[25]

Complication rate and resource utilisation

Using their intervention described above, Liu et al. found no statistically significant difference in the rate of postoperative complications after herniorrhaphy.[24] Chua et al. showed that patients sending smartphone pictures of their operative sites after hypospadias repair to a urology clinic nurse had a significant decrease in rate of return to the emergency department (ED) for wound checks compared to those who did not send pictures (relative risk = 0.14, $p = 0.01$), but no difference in ED visits for other reasons.[26] Three other studies evaluating complication rates in patients undergoing multistage single-ventricle repair procedures using wireless monitoring systems found no significant differences in the number of unplanned ED visits between the mHealth and control groups.[27–29] Among those, Shirali et al. had zero interstage deaths among the 30 patients using the CHAMP wireless monitoring system (a tablet app monitoring single-ventricle patients at home during their interstage period) compared to nine deaths among 53 historical controls (17% mortality, $p = 0.023$). There was, however, no improvement in unplanned readmissions, readmission days, intensive care unit (ICU) days or inpatient charges.[28] While using the same monitoring system, Bingler et al. found that the CHAMP system reduced ICU stay by six days per 100 interstage days when compared to traditional monitoring with binders ($p < 0.0001$), but did not significantly reduce the number of unplanned readmissions or the length of stay during unplanned hospital readmissions.[27] Of 23 unplanned readmissions, 13 (56%) were based on data obtained exclusively through CHAMP via instant alert or daily review by the team, as opposed to concern by caregivers at home, which resulted in five cardiac catheterisations and three other cardiac procedures.

Pain-scale reliability

Three studies evaluated the reliability of pain scales displayed on mobile devices. Sun et al. developed the Panda application, an electronic version of the Colored Analog Scale (CAS) and Faces Pain Scale-Revised (FPS-R) for mobile phones and tablets, and compared it on post-surgical wards to their respective paper versions in 66 and 62 patients for the CAS and FPS-R scales, respectively.[30] The Pearson correlation coefficient between the paper and mobile version was 0.87 for the CAS and 0.93 the FPS-R. Stinson et al. developed the Pain Squad mobile application, which uses a visual analogue scale to evaluate pain intensity in teenagers who underwent cancer surgery. The app was able

Table 2. Follow-up appointment attendance rate.

		Group size (*n*)		Attendance rate at follow-up appointment (%)		
First author (year)	Surgical procedure	Experimental group	Control group	Experimental group	Control group	*p*-Value
Chang (2018)[23]	Cataract surgery	75	88	93.6	80.5	<0.001
Foong (2012)[22]	Cleft-palate repair	23	14	73	21	0.005
Lin (2012)[25]	Cataract surgery	133	125	91.3	62.0	0.005
Liu (2018)[24]	Herniorrhaphy	209	209	99.46	96.43	0.04
Total		*440*	*436*	*94*	*81*	*<0.001*

to detect a significant decrease in pain intensity from the first to second week postoperatively ($p = 0.03$), but not the increase of pain from the week before surgery to one week after surgery ($p = 0.07$), or the pain variation throughout the day ($p = 0.22$).[31] Wood et al. designed a crossover study where 166 patients who underwent various surgical procedures evaluated their pain either on paper or with a personal digital assistant (PDA) version of the FPS-R, and then reassessed their pain 30 minutes later with the other version. The weighted kappa score between the paper and PDA version was 0.837 (95% confidence interval 0.777–0.897).[32]

Patient satisfaction

Eleven studies evaluated the satisfaction and preferences of patients towards mHealth interventions. Most study participants preferred the mHealth systems over traditional care, found the systems easy to use and would want to continue using them.

Risk of bias assessment

The risk of bias of the randomised studies is summarised in Figure 2. For non-randomised studies, the mean MINORS score was 10.5 ± 1.80 (range 9–13) over 16 for non-comparative studies and 15.75 ± 2.49 (range 12–18) over 24 for comparative studies (Supplemental File S3). Biased assessment of the study end points, lack of prospective calculation of the study size, lack of inclusion of consecutive patients and loss to follow-up were the main biases encountered in the non-randomised studies. The use of historical controls was also common in the comparative studies.

Discussion

mHealth has been gaining popularity as a tool to improve health-care delivery. Our systematic review found 18 studies examining the impact of mHealth on paediatric postoperative care. The data we have reviewed suggest that mHealth systems can increase postoperative follow-up appointment attendance rates, decrease complication rates, reliably measure postoperative pain and decrease resource utilisation.

mHealth intervention impacts

Postoperative follow-up appointment attendance rate. Results show that mHealth interventions, especially SMS appointment reminders, can increase postoperative follow-up appointment attendance rates in the paediatric population. However, the wide variability of results between studies might reflect an important site- or procedure-dependent effect. Another consideration is the variability between the follow-up methods used in the control groups.

Complication rate and resource utilisation. Although mHealth systems can reduce ICU length of stay and return to ED for wound checks after surgery, the mHealth systems used required significant involvement of health-care workers, who had to analyse the data and manage the patients appropriately, thus increasing the functional cost of these systems. These studies show that mHealth might improve real-time monitoring and allow caregivers and health-care providers to identify postoperative complications earlier compared to traditional monitoring. No other significant change in complication rates, such as length of hospital stay or number of unplanned ED visits, has been observed. The studies evaluated included as few as five patients and might therefore be underpowered to detect relatively uncommon complications.

Pain-scale reliability. The three studies that adapted paper pain scales to mobile devices found that mobile versions of pain scales could be used instead of their paper versions and reliably yield similar results. Although more studies in different settings and with different patient populations are required to confirm this finding, using mobile versions of pain scales appears appropriate and yields reliable data.

Patient satisfaction. Patients were very satisfied overall with mHealth interventions and often preferred them over more traditional follow-up approaches. The most commonly cited reasons for patient preference were ease of use, usefulness and reduction of perioperative anxiety. However, confounding factors such as novelty bias, selection bias for patients who answered the satisfaction surveys and the intention to please researchers might also have played a role. Most studies also asked the patient to make a dichotomous choice between mHealth and traditional interventions for their preference, which might force patients to pick the mHealth option, even if they had no preference or if the perceived benefit was minimal. Some studies also provided minimal care to individuals in the control group, making mHealth the only viable option by default.

mHealth intervention implementation barriers

Patient data privacy and security are regulated by various legislation throughout the world, such as the Health Insurance Portability and Accountability Act of 1996 in the USA and the Personal Information Protection and Electronic Documents Act in Canada.[33] However, this legislation has no clear

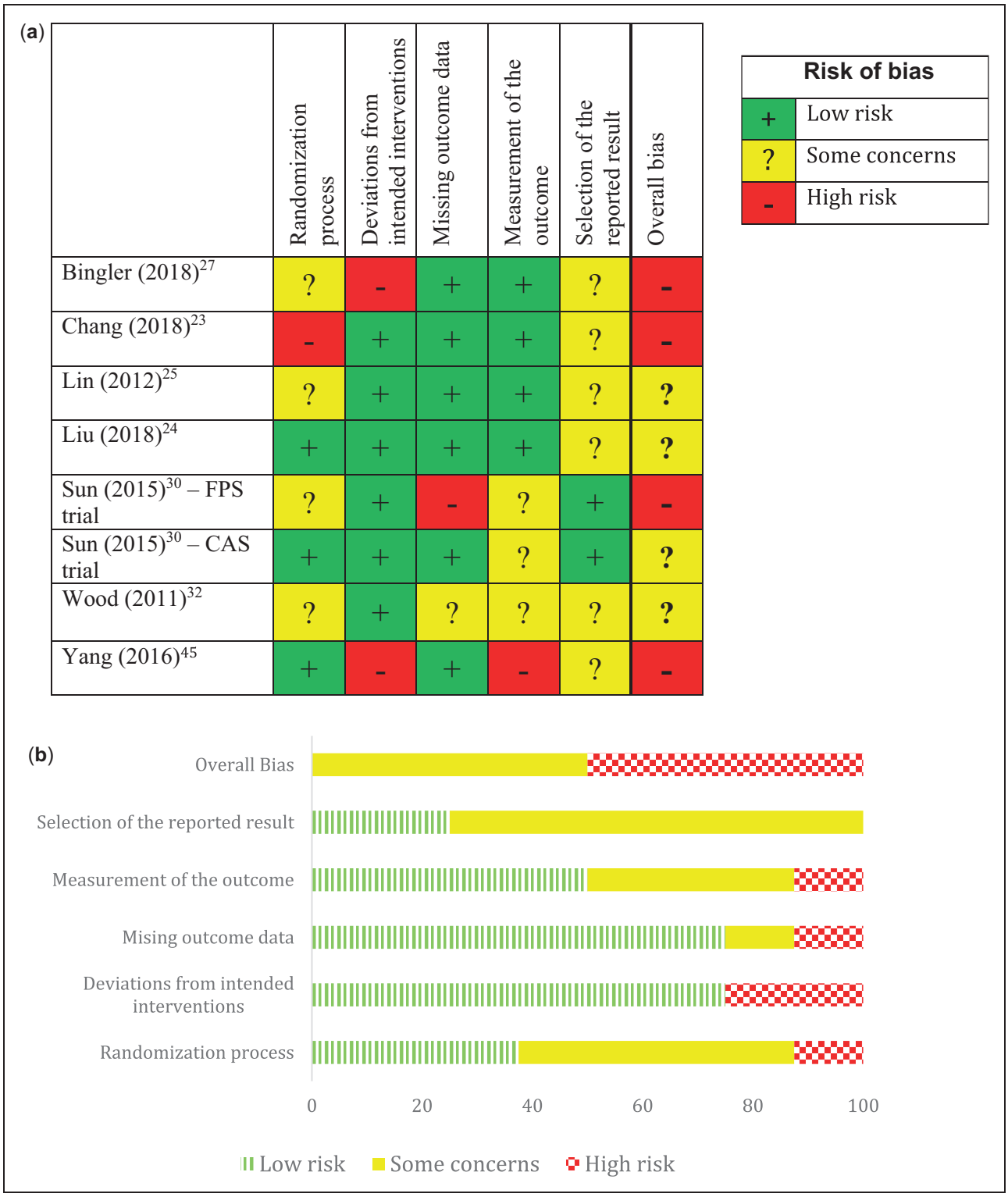

Figure 2. Risk of bias assessment of included randomised studies with the Cochrane RoB 2.0 tool.

regulations for newer technologies such as mHealth systems.[34,35] mHealth data security can be threatened by the use of shared networks, non-encrypted data transmission, data storage on unsecured clouds and shared access to mobile devices. Although general guidelines such as the one published by the American Telemedicine Association exist to ensure proper data security, standardised regulations and procedures to

ensure data security are still lacking.[36] Of note, in our review, data security was discussed in only two studies. Although ethical approval and informed consent were reported in most of the included studies as the mHealth systems were part of research processes, most commercial mHealth apps do not appear to have obtained such approval and consent. Even though mHealth creates a risk for health data privacy, commercial mHealth apps often fail to inform patients of this risk adequately.[37] Great care should be given to obtain proper informed consent, particularly regarding issues pertaining to patient data such as the usage of the collected information, data ownership and access and data security.[38]

Another limitation to the widespread implementation of mHealth is the variable access to mobile devices across various populations. Although mobile-phone ownership is growing yearly, it is far from being universal in several developing economies. In addition, a large proportion of individuals owning mobile phones in such countries have mobile phones that are not smartphones, therefore limiting the potential of the interventions for which they can be used. For instance, 64% of Indian adults own a mobile phone, but only 24% own a smartphone.[6] In this review, only 4/18 included studies took place in low- and middle-income countries. Most included studies either provided mobile phones to the participants or used mobile-phone ownership as an inclusion criterion. Yet, no study reported mobile-phone ownership rates in their setting or if mobile-phone accessibility was even an issue. Mobile-phone accessibility has therefore not been properly assessed. mHealth measures thus have to be tailored to the needs and resources of the population, including mobile-phone and smartphone accessibility.

Additionally, paediatric patients are the centre of a complex ecosystem involving one or several caregivers and the health-care workers, with different relationships evolving as the child develops. Most mHealth systems in the included studies were designed to be used by caregivers – only Teen PocketPath, an app developed by Shellmer et al. to increase medication adherence, was designed for both caregivers and paediatric patients. This system allows transfer of control of the medication list from the caregiver to the patient when the teenager is ready to take control of it.[39] None of the mHealth systems examined discussed the issue of patient confidentiality for caregivers of teenage patients. Other potential problems in the implementation of mHealth systems include the lack of a proper system for health-care worker remuneration when providing care through these systems, lack of communication between different mHealth systems and therefore data decentralisation, and the lack of proper data-driven development of commercial mHealth systems. None of these issues have been addressed in the included studies.

Limitations of the studies

Most studies showed a moderate to high risk of bias, had small sample sizes, had no appropriate control groups and were carried on for short periods of time. Substantial risk of bias came from the fact that most mHealth interventions could not be blinded for participants. Most studies did not mention whether the investigators were blinded while treating individuals and analysing the data. This lack of blinding led to potentially increased attention and care being given to the experimental group in several studies and is a significant potential cause of observer bias. Some studies also provided training to the experimental group to help them use the mHealth application and then compared the intervention to a control group who did not receive training, potentially allowing the intervention subjects' education to increase the perceived efficacy of the application. In some non-randomised studies, participants could decide whether they wanted to be part of the experimental or control group, which can result in selection bias – such as people who are more comfortable with technology being overrepresented in the mHealth group. Historical controls were also used in some studies and are a potential cause of bias. Other common potential sources of bias encountered include the loss of significant proportion of patients to follow-up and the lack of inclusion of consecutive patients.

Strengths and limitations of this review

We performed a systematic review of the existing literature through a database search designed by a senior medical librarian as well as a snowball search. The processes of abstract screening, full-text eligibility assessment and data extractions were all performed in duplicate. Although we only selected articles in English or French, only three studies were excluded on this basis.

However, the heterogeneous nature of the studies evaluated limited the assessment of their overall effectiveness and the ability to draw robust conclusions on the use of mHealth in paediatric surgery. Due to the heterogeneity of reported outcomes in the included studies, our review is at risk of outcome-reporting bias, as we did not include all possible outcome measures but rather only those most commonly reported. Finally, literature reviews are at risk of publication bias, as studies with negative results are potentially less likely to have been published.

Future research directions

This systematic review highlights the lack of quality and limited number of studies evaluating the effectiveness of mHealth interventions in paediatric postoperative care. Although the current results are promising, more high-quality studies are required to evaluate the potential of mHealth in paediatric postoperative care. Such studies would need to be longer in duration, include more patients and include contemporary control groups who receive standard-of-care postoperative instructions. Studies should also be carried out in different countries and clinical settings, for different paediatric populations and for different surgical conditions. Studies should evaluate the mHealth systems efficacy as well as their cost-effectiveness, and take into account mobile-phone accessibility. The results obtained from such studies would help to guide future developments in mHealth and would facilitate its implementation by providing critical data to key stakeholders.

Further development and validation of mHealth interventions will allow better identification of the advantages and limitations of mHealth, as well as clarification of the optimal ways to deliver such services in different settings. Potential areas of development include real-time communication and monitoring systems, online portals where patients can access their information and receive notifications, interactive educational platforms and systems facilitating the transition of adolescents from paediatric to adult medicine. The development of these systems should be done with a technical and technological framework that takes data privacy into account. In addition, the coronavirus disease 2020 pandemic will likely highlight current gaps and unmet needs in telemedicine. This might lead to initiatives that could be beneficial during usual patient care but could also help the medical community better prepare for future pandemics or other events where patient care must be performed remotely as much as possible.

Conclusions

The present study is the first to review systematically the literature on the use of mHealth interventions assisting in the postoperative care of paediatric surgical patients. Our results generally suggest that mHealth interventions are appreciated by patients, and that they can increase postoperative follow-up appointment attendance rates, decrease unnecessary postoperative ED visits and decrease complication and death rates in patients undergoing complex procedures requiring continuous monitoring. mHealth applications using validated pain scales can replace their respective paper versions while retaining comparable levels of reliability. Current evidence, however, does not show a decrease in postoperative complication rates for surgical procedures not requiring continuous monitoring. The reviewed studies were overall limited in terms of quantity and quality, and stronger evidence is needed to draw definitive conclusions on the efficacy of mHealth intervention in paediatric postoperative care.

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Supplemental material

Supplemental material for this article is available online.

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