Title: The effectiveness of web-based mobile health interventions in pediatric outpatient surgery: A systematic review and meta-analysis of randomized controlled trials

Running Title: Web-based mobile health interventions for children

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This article has been accepted for publication and undergone full peer review (not applicable for Editorials) but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/JAN.14381

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Author Contribution:
AR, JM, and TP were responsible for the study conception and design. AR performed the data collection. AR and TP were responsible for the quality assessment of the selected studies. JM, AR, and TP performed meta-analysis. AR performed the data synthesis. AR, JM, MP, and TP were responsible for drafting the manuscript. TP, JM, MP and HHG made critical revisions to the paper for important intellectual content. TP supervised the study. All authors have agreed on the final version and meet at least one of the following criteria [recommended by the ICMJE]

Acknowledgements
The authors wish to acknowledge the assistance of the information specialist Sirpa Grekula from Oulu University Medical Library.

Funding Information:
The research was carried out as part of the ICory (An Intelligent Customer-driven Solution for Orthopedic and Pediatric Surgery Care) project, which was funded by Business Finland, the Finnish Funding agency, between 2018 and 2020. This research was funded also by the Rosa Instrumentarium Foundation.
Aims: To evaluate the effectiveness of web-based mobile health interventions on pediatric patients and their parents in the day surgery context, where the primary outcome was children’s preoperative anxiety and secondary outcomes were postoperative pain and parents’ anxiety and satisfaction with entire course of the day surgery.

Design: A systematic review and meta-analysis of randomized controlled trials.

Data Sources: CENTRAL, CINAHL, Scopus, Ovid MEDLINE and Web of Science were systematically searched without time limits (up to December 2018).

Review Methods: Studies were appraised using the Cochrane risk of bias tool. A random effect meta-analysis of children’s preoperative anxiety was performed.

Results: Eight studies with a total of 722 patients were included in the analysis. The effectiveness of web-based mobile health interventions, including age-appropriate videos, web-based game apps and educational preparation games made for the hospital environment, was examined in preoperative settings. A meta-analysis (N=560 children) based on six studies found a statistically significant reduction in preoperative anxiety measured by the Modified Yale Preoperative Anxiety Scale with a moderate effect size. Three studies reported parental satisfaction.

Conclusion: Web-based mobile health interventions can reduce children’s preoperative anxiety and increase parental satisfaction. Web-based mobile health interventions could be considered as nonpharmacological distraction tools for children in nursing. There is not
enough evidence regarding the effectiveness of reducing children’s postoperative pain and parental anxiety using similar interventions.

**Impact:**

Web-based mobile health interventions reduce children’s preoperative anxiety and could therefore be considered as non-pharmacological distraction tools for children in nursing.

**Keywords:** anxiety, day surgery, distraction, meta-analysis, mobile health intervention, nursing, pain, parents, pediatric, systematic review
INTRODUCTION

According to the World Health Organization (WHO), a day surgery refers to a patient being admitted to hospital and discharged within hours after the surgery, typically in the span of one day. A patient is carefully selected and well-prepared for treatment and the surgical procedure is nonemergency in nature (WHO, 2007). In the USA, 57.8% of invasive, therapeutic surgeries occur in a hospital-owned day surgery setting (Steiner, Karaca, Moore, Imshaug, & Pickens, 2017). In Finland, 84% of all surgeries are day surgeries (Mattila & Hynynen, 2009). The European Association for Children in Hospital (EACH) stated, “Children shall be admitted to hospital only if the care they require cannot be equally well provided at home or on a day basis; children and their families are entitled to know what is going to happen to them before undergoing a treatment; and information must be based on the child’s age and understanding” (EACH, 2016, Articles 1 and 4). It is important to help children cope with any upcoming surgery because the more anxious they are, the more pain they experience after the day surgery (Kain, Mayes, Caldwell-Andrews, Karas, & McClain, 2006; Rabbits, Groenewald, Tai, & Palermo, 2015). In addition, postoperative delirium in children is strongly affected by postoperative pain severity (González-Cardenas et al., 2018).

Background

According to earlier studies, the more anxious a child is before surgery, the more likely they will be to experience delirium and the development of negative postoperative behavioral changes (Kain et al., 2004; Rabbits et al., 2015). In addition, children may have sleeping problems (Rabbits et al., 2015), fears and eating problems after surgery (Kain et al., 1996). The parents of hospitalized children also perceive high levels of stress and anxiety (Commodari, 2010; Scrimin, Haynes, Altoè, Bornstein, & Axia, 2009), meaning that often, children are affected by parental distress (McCann & Kain, 2001; Rodriguez, Clough, Gowda, & Tucker 2012; Rabbits et al., 2015). It might affect both the negative and positive feelings for parents if they could be present when their children are going to surgical treatment (Waseem et al., 2018). A child’s pain treatment at home after day surgery is also important because most children are rated as experiencing significant pain on the second day following treatment (Fortier, MacLaren, Martin, Perret-Karimi, & Kain, 2009; Rabbits et al., 2015). One way to reduce a child’s anxiety or pain in treatment is to use distraction tools, which can shift their attention to something else besides the anxiety or pain (Koller & Goldman, 2012). Distraction is a commonly used nonpharmacologic pain management technique used by both health professionals and parents. Distractors can be divided into...
active or passive. For children, active distractors include the use of virtual reality, interactive toys, controlled breathing, guided imagery and relaxation. Passive distractors include listening to music or watching television or videos (Koller & Goldman, 2012; Wohlheiter & Dahlquist, 2013). Humor or therapeutic play is a good active distraction tool for children because this can reduce their anxiety before treatment (Berger, Wilson, Potts, & Polivka, 2014; He et al., 2015). One further example of such tools is clown therapy or medical clowns (Meiri, Ankri, Hamad-Saied, Konopnicki, & Pillar, 2016; Messina et al., 2014; Zhang, Yang, Lau, Garg, & Lao, 2016). However, clown therapy is not always possible to use or may not be cost-effective. Therefore, it is important to find cost-effective methods, such as web-based mobile health interventions.

Mobile health (mHealth) is a new area of healthcare that can be used for the empowerment of patients and their relatives in self-care (Nacinovich, 2011; WHO, 2011; Danaher et al., 2015). Mobile phones have become prolific in developed countries. For example, in the USA, 82.1% of the population had a smartphone in 2018 (Statista, 2019). In Finland, 94% of all people under the age of 55 have a smartphone (Statistic Finland, 2019).

Multimedia apps or games can be used as active or passive distractors and can help to reduce anxiety and pain in children and their parents in surgery situations. Web-based mobile health interventions are defined as any tool or treatment that assists a patient through their day surgery journey; these interventions are typically behaviorally based, operationalized and transformed for delivery via the Internet or mobile platforms (e.g., web services, smartphone applications, mobile platform, the use of telemetry; Eysenbach & CONSORT-EHEALTH Group, 2011; Ritterband andersson, Christensen, Carlbring, & Cuijpers 2006; Danaher, Brendryen, Seeley, Tyler, & Woolley, 2015).

With technological innovations rapidly developing, we have an increasing amount of mobile apps and games that children can potentially use as distractors while waiting for an operation. In one study, children played an interactive video game while receiving anesthesia by the facemask. This was considered a better distractor than the parental presence or oral midazolam (Patel et al., 2006). Moreover, previous literature has shown that multimedia applications, which were shown to be easy to use, reduce children’s perioperative anxiety (Lee et al., 2013; Liguori et al., 2016). In one study, it was found that an interactive distractor like playing video games benefits more children in managing their acute pain than a passive distractor like watching videos while children had a cold-pressor trial. (Wohlheiter & Dahlquist, 2013). In addition, a randomized controlled study tested an educational application
for reducing anxiety in children and parents before anesthesia. In the study, the application reduced parental anxiety and improved satisfaction, but the authors did not find a difference regarding a reduction in the children’s anxiety between the intervention and control groups (Ji et al., 2016).

Some reviews have focused on audiovisual interventions for reducing children’s (Chow, Van Lieshout, Schmidt, Dobson, & Buckley, 2015) and parent’s (Chow et al., 2018) anxiety, along with children’s postoperative pain when going into elective surgery; however, these studies have not provided answers to the question of whether there are interventions that can cover the whole outpatient pathway for pediatric patients. One of these studies did not find Internet-based interventions to be effective (Chow et al., 2015). However, a mixed-method systematic review was conducted on the effectiveness of different preoperative psychological preparation programs for children, finding web-based preparation programs may be effective in reducing pediatric preoperative anxiety; however, this study only used two web-based programs in its review (Dai & Livesley, 2018). A systematic review and meta-analysis of the effectiveness of clown therapy on psychological distress on children and parents (Zhang et al., 2017) was performed, but no conclusions were drawn on the efficacy of web-based health interventions on reducing children’s anxiety and pain or parental anxiety and satisfaction in the context of a day surgery.

THE REVIEW

Aims

The current systematic review and meta-analysis aimed to evaluate the effectiveness of web-based mobile health interventions on pediatric patients and their parents in the context of day surgeries. The following review questions were addressed:

1. What kind of web-based mobile health interventions are used in pediatric patients?
2. What is the effectiveness of web-based mobile health interventions on reducing pediatric patients’ anxiety and pain during a day surgery?
3. What is the effectiveness of web-based mobile health interventions on reducing parental anxiety and increasing their levels of satisfaction?

Design
A systematic review and meta-analysis of randomized controlled trials were conducted based on the Cochrane Collaboration Handbook (Higgins et al., 2019). The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement was applied for reporting the selection process of the articles (Liberati et al., 2009). The investigation was registered in PROSPERO, the International Prospective Register of Systematic Reviews (CRD42019139375).

**Search methods**

A search method was devised to identify studies that met our inclusion criteria (Table 1) (Whittemore, 2005). The search was conducted with no discriminating starting point to December 2018; the goal was to identify the available evidence examining the use of web-based mobile health interventions for anxiety and pain in children and anxiety and satisfaction in parents in pediatric day surgery. Five electronic databases were systematically searched to identify the relevant studies: CINAHL, Scopus, Ovid MEDLINE, Web of Science and CENTRAL (Cochrane Central Register of Controlled Trials). We included studies in both English and Finnish. The search strategy involved a comparison of advanced and basic searches with appropriate permutations, along with an information specialist. A Google Scholar search was also performed. The following key terms were used: ambulatory surgery or outpatient or day surgery and children or adolescence or infant or pediatric and tablet or mobile application or mhealth or medical technology or telemedicine or smartphone or cell phone or mobile phone or mobile device or mobile communication or mobile technology or ehealth or connected health or information system or game or gamification and randomized controlled trial. The key Medical Subject Headings (MESH) terms were explored wherever possible in the databases. Manual searches were also undertaken for the references in the selected studies; this was done based on the reference title and when the article met the inclusion criteria, the full article was retrieved. Titles and abstracts were screened and potentially relevant citations with full texts were assessed independently by two reviewers (AR and TP). A full electronic search strategy for the CINAHL database is illustrated (Table S1).

**Search outcome**

In the first stage, five database searches produced a total of 352 records. After removing duplicates, in the second stage, 281 records were screened by title and abstract and 268 were excluded. In the third stage, the full texts (N=12) of studies that met the inclusion criteria
were analyzed. A study by Goedeke, Ertl, Zoller, Rohleder and Muensterer (2018) did not meet the inclusion criteria because the intervention differed from others, lacking any preparation for children in the preoperative section. A study by Kim, Jung, Yu and Park (2015) was excluded because of a lack of web-based interventions and a study by Ko, Whiting, Nguyen, Liu and Gilmore (2016) was excluded because of a lack of day surgery: in their study, the patients received cast or pin removals, for instance, without any surgery. Eight RCTs met the inclusion criteria (Figure 1). There was complete agreement among the reviewers’ final selections. The study selection was documented using the RefWorks web-based research management tool and Microsoft Excel to ensure the current study’s repeatability.

Quality appraisal

The studies were assessed for quality and the risk of bias by using the risk of bias tool, as suggested by the Cochrane Effective Practice and Organisation of Care (EPOC, 2017a). Relevant studies (N=8) were assessed for their quality by two reviewers (AR & TP) independently. Studies were rated as having a high, low, or unclear risk of bias in nine domains by RevMan 5.3 (Supplemental online file 2).

All studies reported using random assignment to the intervention and control groups. Six of the eight studies reported having conducted a power analysis calculation to determine the sample size. Only one study reported an intention-to-treat analysis (Marechal et al. 2017). The measures in Chow, Van Lieshout, Schmidt and Buckley (2017) and Fernandes, Arriaga and Esteves (2015) were self-reported measures and had certain biases (e.g., some children may not have been able to provide an accurate response in a stressful environment on the day of surgery). Due to the intervention delivery, children wearing video glasses or had an application before treatment or had an iPad or smartphone while entering the induction room in most of the studies, made blinding of participants and researchers impossible (Table 2).

Data abstraction

The data were extracted using a modified data extraction template (EPOC, 2017b; Centre for Reviews & Dissemination, 2009). Both reviewers (AR & TP) independently extracted details about the population, intervention, comparisons, outcomes and study designs (PICOS) and compared the results (Table 1).

Synthesis
Six RCTs out of the eight found were included in the meta-analysis and analyzed only for children’s preoperative anxiety. A meta-analysis was not carried out on the other outcomes based on the heterogeneity of the measurements used in the research. Studies that were pooled in the meta-analysis were chosen based on their homogeneity, including the availability of meaningful data on anxiety, which was measured at the same point (at induction) in all studies using the same measurement (mYPAS, Modified Yale Preoperative Anxiety Scale). mYPAS is validated and it is the “gold standard” assessment tool to measure pediatric anxiety in the perioperative period (Kain et al., 1997). For the meta-analysis component, mean and standard deviation values of mYPAS measuring children’s anxiety from the intervention and control groups at induction were extracted from the studies that presented these data. For the meta-analysis, we included two groups from multiarm design studies, excluding a third group from a meta-analysis because those third groups had both interventions and premedication. In addition, the sample size of both groups was required to calculate the effect size. The studies included in the meta-analysis had the same primary outcomes (Higgins et al., 2019; Greco, Zangrillo, Biondi-Zoccai, & Landoni, 2013; Centre Reviews & Dissemination, 2009; Polit & Beck, 2011). A random effect meta-analysis was used to pool the standardized mean differences (SMD; Cohen’s d) and its 95% confidence interval (CI) between the groups. The effect values of Cohen’s d can be interpreted as 0.2–0.5 small, 0.5–0.8 moderate and over 0.8 large (Cohen, 1992). Heterogeneity of the results was estimated with I^2 values, ranging from 0% to 100% (Higgins, Thompson, Deeks, & Altman, 2003). Outcomes unable to be pooled in the meta-analysis because of different measurement tools were presented with a synthesis without a meta-analysis SWiM (Campbell et al., 2020; EPOC, 2017b); those studies measured children’s anxiety with other measures, such as the CPMAS (Children’s Perioperative Multidimensional Anxiety Scale) and CSWQ (Child Surgery Worries Questionnaire; Chow et al., 2017; Fernandes et al., 2015). Studies that demonstrated a statistically significant difference in their outcome (at the p <0.05) for reducing children’s anxiety before treatment, pain after treatment, reducing parental anxiety, or increasing parental satisfaction were deemed “Positive,” while those with no significant improvement in the outcome were deemed “No difference” (Table 2).

RESULTS

Study characteristics

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The current review included RCTs with the following designs: six parallel and two multiarm designs. Four of the studies were conducted in the United States, two in Canada and two in Europe (one in France and one in Portugal). The sample sizes varied (range 40–115).

Pediatric patients, heterogeneity with different types of surgery (e.g., circumcisions, excisions, tonsillectomy, herniorrhaphy, adenoidectomy, general surgery, ENT, urology, general surgery, gastrointestinal, dentistry, orthopedics, etc.) at baseline were recruited.

**Characteristics of the intervention**

Different types of web-based mobile health interventions were identified. Here, interactive distractors were those that the role of the children was active and passive distractors were those that their role was passive (Table 2). All the studies tested their interventions in the preoperative period when the pediatric patients were waiting for their day surgery treatment. Three of the studies included elements of the hospital and were designed as educational preparation for the children and their families and developed for the research in question (Chow et al., 2017; Fernandes et al., 2015; Fortier et al., 2015). The rest of the studies (N=4) used accessible mobile apps or games or streamed videos from mobile phones or from iPads. One study developed its intervention to cover the entire day surgery but was not powerful enough to test its effectiveness during the postoperative period (Fortier et al., 2015).

Interactive distractors included tablet-based interventions using story-telling medicine (Chow et al., 2017), the educational multimedia application “An Adventure at the Hospital” (Fernandes et al., 2015) and a web-based, tailored intervention and website comprising education (Fortier et al., 2015) developed in the hospital environment and including gaming elements. Other interactive distractors included playing games on iPads (Marechal et al., 2017; Seiden et al., 2014; Stewart, Cazzell, & Pearcy, 2018). Passive distractors included watching television programs using portable media players by video glasses (Kerimoglu, Neuman, Paul, Stefanov, & Twersky, 2013) or on an iPad (Mifflin, Hackmann, & Chorney, 2012). All the listed interventions compared the intervention with standard care before anesthesia induction. Premedication was common in most of the studies. In four studies, the intervention groups did not receive premedication (Kerimoglu et al., 2013; Marechal et al., 2017; Mifflin et al., 2012; Seiden et al., 2014; Stewart et al., 2018) and in one study (Fortier et al., 2015), both groups received premedication, while two did not report premedication as the usual care (Fernandes et al., 2015; Chow et al., 2017; Table 2).

**Outcome measures**
Children’s perioperative anxiety was measured using several observational and self-reported anxiety levels: the CPMAS (Chow et al., 2017) and CSWQ (Fernandes et al., 2015) measure children’s anxiety and are patient-related self-reported outcomes, while the mYPAS (Fortier et al., 2015; Kerimoglu et al., 2013; Marechal et al., 2017; Mifflin et al., 2012; Seiden et al., 2014; Stewart et al., 2018) is a set of observational anxiety scales rated by a researcher, staff, or family members.

Children’s pain was measured as a nurse-rated outcome in one study, here using the observational Pediatric Anesthesia Emergence Delirium (PAED) scale, which assesses specific behavioral components that are distinct from pain and anxiety (Fortier et al., 2015). Heart rate was measured by SPO\(^2\) and electrocardiogram monitors (Kerimoglu et al., 2013; Seiden et al., 2014) to estimate the correlations between anxiety and heart rate. Parental preoperative anxiety was measured using STAI-Y (State-Trait Anxiety Inventory Form Y), which measures trait and state anxiety, in three studies (Fernandes et al., 2015; Fortier et al., 2015; Marechal et al., 2017). Parental satisfaction was measured in three studies using Likert scales (Marechal et al., 2017; Seiden et al., 2014; Stewart et al., 2018). Children’s posthospitalization behavior was measured in three studies (Seiden et al., 2014; Stewart et al., 2018; Marechal et al., 2017) and children’s postoperative anxiety (CPMAS) was measured after the day surgery in one study (Chow et al., 2017).

**Effectiveness of interventions**

**Pooled analysis of children’s perioperative anxiety**

A meta-analysis of six of the studies found a significant (z test=3.61, p<0.001) difference between the groups in terms of children’s preoperative anxiety (Cohen’s d=0.58, 95% CI 0.89, 0.26), indicating that web-based mobile health interventions reduced pediatric patients’ preoperative anxiety. However, heterogeneity was statistically significant (\(I^2=70.0\%, p=0.005\)). The forest plot of the effect sizes of the original studies and the overall effect sizes are presented in Figure 2. As a sensitivity analysis, we calculated the pooled effect size by excluding a study with a differing effect (influence analysis). When we omitted the one study (Marechel et al., 2017) with the most different effect, the pooled effect size increased to 0.72 (95% CI 0.53, 0.91; Figure 3).

Two studies were not included in the meta-analysis because of the differences in the measurements or different measurement points (Chow et al., 2017; Fernandes et al., 2015). Both studies measured children’s preoperative anxiety or worries. Chow et al. (2017)
reported that story-telling medicine with the usual care demonstrated greater reductions in anxiety when compared with the usual care group, as measured by the CPMAS (p=0.015). Fernandes et al. (2015) reported a significant effect from the group condition on the overall level of preoperative worries about surgery; the main effect of the phase was found for both valence, \( p < 0.001 \) and arousal, \( p < 0.001 \) (Fernandes et al., 2015).

**Postoperative pain and parental anxiety and satisfaction**

The secondary outcomes considered in the current systematic review were children’s postoperative pain, parental anxiety and parental satisfaction. In one study, the pain was measured by the PAED, which is distinct from pain and nurse-rated pain severity (0–10 numerical rating scale; Fortier et al., 2015). Children in the Web-Based Tailored Intervention for Preparation of Parents and Children for Outpatient Surgery (WebTIPS) group may have experienced significantly lower emergence delirium compared with children in the control group on the PAED test (\( p=0.04 \)) at the postanesthesia care unit. However, nurse-rated pain severity was not experienced as significantly different between the groups: WebTIPS (mean=0; SD 0.67) and control (mean=0.38; SD 1.76; \( p=0.30 \)). In that study, no differences were detected among the groups regarding the postoperative recovery variables (Fortier et al., 2015.)

Fernandes et al. (2015) measured parental anxiety using a 4-point Likert scale (from 1=not at all to 4=very much anxiety) and reported that parental anxiety was lower in the educational multimedia group (mean=1.89; SD 0.54) compared with the control group (mean=2.19; SD 0.60; \( p=0.033 \)). However, the differences between the educational multimedia and the entertainment video game (mean=1.85; SD 0.50) groups on parental anxiety were not significant (\( p=0.805 \)). Fortier et al. (2015) reported that parents in the WebTIPS group experienced less anxiety in the preoperative holding area compared with parents in the standard care group (\( p=0.004 \)), but there were no significant differences in parental anxiety between the groups at separation when going into the operation room (\( p=0.26 \)). Mifflin et al. (2012) reported parental anxiety only by baseline measurements but did not measure the differences between groups after allocation nor by the intervention. Marechal et al. (2017) found no differences in parental anxiety (STAI) between the TAB (age-appropriate tablet game apps) and control groups. The mean level of STAI was not different between the TAB and control groups. STAI 1 (at arrival at the surgical ward) for parental anxiety did not differed statistically in TAB group (mean=40.1; SD 8.67) compared with MDZ (mean=39.7;SD 8.4) (\( p=0.79 \)) and STAI 3 (at mask induction) was in TAB group (mean=35.3; SD 9.3) compared with MDZ group (mean=36.5; SD 9.7) (\( p=0.48 \)). However, the findings in the Marechal et al.’s (2017)
study suggest the parents in the TAB group found the procedure of anesthesia more satisfying (mean=9.1 SD 1.5; Likert 0=not satisfied 10=high satisfied) when compared with the MDZ (effects of midazolam 0.3mg/kg) group (mean 9.6; SD 0.7, p=0.04). However, Stewart et al. (2018) found no statistical difference in terms of satisfaction at separation from their children between groups (Likert 0–6): oral midazolam (mean=5.7; SD 0.7) versus tablet-based interactive distraction (TBID; mean=5.8; SD 0.6; p=0.40). In Seiden et al.’s study (2014), 43 out of the 53 (80%) parents in the TBID group were very satisfied with the child separation process compared with 22 out of 37 (59%) in the midazolam group (p=0.02).

DISCUSSION

The studies included in the current review presented an overview of the effect of web-based mobile health interventions on pediatric patients and their parents in the pathway of day surgery. The interventions included active and passive distractors, such as videos and/or gaming mobile apps, including games that are easy to find on the Internet and that are age-appropriate (Kerimoglu et al., 2013; Marechal et al., 2017; Mifflin et al., 2012; Seiden et al., 2014; Stewart et al., 2018). Three of the games or apps were not publicly available but were designed for the respective studies (Chow et al., 2017; Fernandez et al., 2014; Fortier et al., 2015); these interventions tested the effectiveness of tailored, prepared, or educational web-based materials for reducing children’s preoperative anxiety and in two of the studies, they tested parents’ preoperative anxiety based on patient use of tailored web-based interventions (Fernandez et al., 2014; Fortier et al., 2015). Most of the studies tested commonly used multimedia applications, here considered a distraction tool, in their studies. Children could watch videos on an iPad, play web-based games, or have the opportunity to educate themselves about the hospital environment by playing games online at home before going to treatment. Web-based health interventions tailored and that are educational for children will be needed in the future because of the digitalization of hospital care and this would mean that children would not be dependent on their parents’ ability to prepare them for their day surgery in the future. One thing that was common to all of the reviewed studies was that all the interventions required Internet access. The challenge here is the availability of such interventions for all pediatric patients because a smartphone or an iPad is required to take advantage of these interventions. Most people have smartphones, but there are patient groups whose socio-economic status may influence their participation in the intervention. One study, a meta-analysis, differed from the others in its results. In this study, the authors reported a robust method of data collection: the anxiety levels were collected by reliable psychologists

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(Marechal et al., 2017). In other studies, children’s anxiety was measured by healthcare personnel, which might have affected heterogeneity. Kerimoglu et al. (2013) reported there was a weak correlation between heart rate and mYPAS, finding that heart rate was probably not an accurate secondary measure of anxiety in the preoperative setting. A pooled analysis answered the question regarding whether web-based mobile health interventions are good distraction tools for pediatric patients when it comes to reducing preoperative anxiety; the results are in line with previous studies (Lee et al., 2013; Liguori et al., 2016). Studies of previous web-based mobile health interventions differed in their studied intervention types regarding the web-based interventions and outcome measures (Lee et al., 2013; Liguori et al., 2016; Ji et al., 2016). A systematic review of audiovisual interventions recommended future research to cover all children and surgeries (Chow et al., 2015). In Chow et al.’s systematic review (2015), even though they did not solely investigate the effectiveness of web-based interventions, they found audiovisual interventions reduced children’s anxiety and the current review confirms their review results.

There is little evidence that web-based mobile health interventions reduce pediatric patients’ pain in a postoperative setting. However, in all studies, the types of surgeries were heterogeneous. This might have contributed to the fact that postoperative pain has not been studied in these interventions. Children’s pain levels were measured in one study; in the study of Fortier et al. (2015), it was mentioned that it would also be important to examine postoperative data, namely postoperative pain and the administration of analgesic in the home setting. In a systematic review of audiovisual interventions by Chow et al. (2015), postoperative pain was measured in two studies, which increases the need for further research on children’s postoperative pain in web-based mobile health interventions. Indeed, children feel pain after treatment (Fortier et al., 2009; Rabbits et al., 2015). However, our systematic review found that this was not measured or powered enough to measure the effectiveness of reducing pain after day surgery.

The current review shows that web-based multimedia apps may reduce parental anxiety in a preoperative setting, but there is not enough evidence to make conclusions about this. Parents in the intervention group showed less anxiety compared with the parents in the control group (Fernandes et al., 2015). This review also showed that parents whose children received a web-based mobile intervention were more satisfied with the separation from their children in the operation room than those parents whose children did not receive an intervention (Seiden et al., 2014; Stewart et al., 2018). Even with these possible limitations, web-based mobile
health interventions are a distraction tool that do not require premedication and are a safe and positive alternative nonpharmacological tool for use in hospitals.

**Strengths and limitations**

The quality of the studies included in the systematic review varied. We followed the Cochrane tools guidance in conducting the systematic review and PICOS questions were used to clarify the study search. A search strategy was created with the help of an information specialist.

There were some methodological limitations in the included studies. Although, we used the CENTRAL as one of the databases, which includes records from bibliographic databases and records from other published and unpublished sources including Clinical Trials.gov and the WHO’s International Clinical Trials Registry Platform, the publication bias might have been reduced by using other grey literature. Thus, the grey literature including such as academic or conference papers, research and committee reports and ongoing research could have made important contribution to our systematic review (Paz 2017). In addition, the sample sizes were small for most of the studies. The children in the studies varied in age and types of surgeries. When it comes to age, their level of development may also have influenced the results of many studies. However, our meta-analysis pooled the anxiety levels of 560 children and found that web-based mobile health interventions reduced children’s anxiety in preoperative settings and the heterogeneity was statistically significant ($I^2=70.0\%$, $p=0.005$; Higgins et al., 2003). To reduce subjective selection bias, the inclusion process and the quality of the articles were carefully assessed by two independent researchers. There is a risk of language bias because we only included studies written in English or Finnish. The strength of the current study is that it synthesizes evidence of different interventions using SWiM (Campbell et al., 2020).

**CONCLUSIONS**

The results of the current systematic review, which included a meta-analysis of six studies, indicate that web-based mobile interventions are an effective nonpharmacological distraction tool for reducing children’s preoperative anxiety in the context of day surgery. These tools can also increase parental satisfaction regarding separation from their children in the preoperative setting and anesthesia procedure. We recommend that these kinds of interventions should be used as safe and easy nonpharmacological distraction tools that can help children deal with reducing their anxiety. However, there is little evidence of the
effectiveness of reducing children’s postoperative pain and parental anxiety using similar interventions. There is still a need for further interventions that cover the whole pediatric patient surgical pathway, including pre-, intra- and postoperative settings. There is also a need for more tailored, educational web-based mobile health interventions in the hospital environment.
Conflict of Interest statement

No conflicts of interest are declared by the author(s).
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Wohlheiter, K. A., & Dahlquist, L. M. (2013). Interactive versus passive distraction for acute pain management in young children: The role of selective attention and develop-
Table 1 Inclusion criteria based on PICOS format.

<table>
<thead>
<tr>
<th>Review questions</th>
<th>Inclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Pediatric (&lt;18 years) patients in outpatient surgery</td>
</tr>
<tr>
<td>Intervention</td>
<td>Web-based Mobile Health Interventions delivered via the Internet or mobile platforms</td>
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<tr>
<td>Comparisons</td>
<td>Standard care</td>
</tr>
<tr>
<td>Outcomes</td>
<td>Anxiety, pain, parental anxiety, and satisfaction</td>
</tr>
<tr>
<td>Study design</td>
<td>RCT</td>
</tr>
</tbody>
</table>
## Table 2. Summary of the studies reviewed

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study design</th>
<th>Participants</th>
<th>Setting</th>
<th>Measures</th>
<th>Intervention(s)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chow et al. (2017)</td>
<td>RCT Pilot study</td>
<td>Children (N=40) between 7 and 13 years old. The experimental (n=20) and (n=20) control groups with tonsillectomy and herniorrhaphy.</td>
<td>McMaster Children’s Hospital in Southwestern Ontario Canada. October 2013 to March 2015</td>
<td>CPMAS (Children’s Perioperative Multidimensional Anxiety Scale)</td>
<td>Active distractor A novel tablet-based, an educational application designed to prepare children for hospital</td>
<td>Anxiety: Positive Pain: NM** Parental satisfaction: NM** Parental anxiety: NM**</td>
</tr>
<tr>
<td>Fernandez et al. (2014)</td>
<td>RCT Room availability</td>
<td>Children (N=90) between 8 and 12 years old. The experimental (n=30) comparison (n=30) control (n=30) groups with circumcisions, excisions, and herniorrhaphies.</td>
<td>In three hospitals in Lisbon January 2012 to February 2013</td>
<td>CSWQ (Child Surgery Worries Questionnaire) Parental anxiety (STAI-Y)</td>
<td>Active distractor Multimedia application “An Adventure to Hospital” to prepare children for hospital and video games in the experimental group</td>
<td>Anxiety: Positive Pain: NM** Parental satisfaction: NM** Parental anxiety: Positive Parental anxiety between VG and exp groups: No difference</td>
</tr>
<tr>
<td>Fortier et al. (2015)</td>
<td>RCT Blank envelope</td>
<td>Children (N=82) between 2 and 7 years old. Experimental (n=38) and control (n=44) groups with tonsillectomy adenoidectomy, the most frequent surgery types.</td>
<td>Two medical centers in California USA August 2011 to August 2012</td>
<td>mYPAS Parental anxiety (STAI-Y) Nurse-rated pain severity PAED****</td>
<td>Passive distractor Tablet computer game (TAB) appropriate for according to age and to their preferences</td>
<td>Anxiety: Positive Pain: No difference Parental satisfaction: NM** Parental anxiety: Positive Parental anxiety in the holding area before surgery, no difference in separation to OR</td>
</tr>
<tr>
<td>Kerimoglu et al. (2013)</td>
<td>RCT Sealed envelopes</td>
<td>Children (N=96) between 4 and 9 years old. Three groups MDZ ***(n=32), VG (n=32), or both (n=32) with ambulatory surgery using general anesthesia.</td>
<td>IRBs at SUNY Downstate Medical Center and its affiliate Long Island College Hospital. New York USA July 2009 - August 2011</td>
<td>mYPAS Parental anxiety Heart rate marking anxiety</td>
<td>Passive distractor Video glasses connected to a portable media player for viewing television programmers</td>
<td>Anxiety: Positive Pain: NM** Parental satisfaction: NM** Parental anxiety: NM**</td>
</tr>
<tr>
<td>Marechal et al. (2017)</td>
<td>RCT Sealed envelopes</td>
<td>Children (n=115) between 4 and 10 years old. The TAB group (n=60) or MDZ ***group (n=55) with gut and urologic, ENT, eyes, and orthopedic. 110 parents</td>
<td>Children’s Hospital of the Lyon, France May 2013 to March 2014</td>
<td>mYPAS and STAI Parental Anxiety STAI</td>
<td>Active distractor Tablet computer game (TAB) appropriate for according to age and to their preferences</td>
<td>Anxiety: No difference Pain: NM** Parental satisfaction: Positive Parental anxiety: No difference</td>
</tr>
<tr>
<td>Mifflin et al. (2012)</td>
<td>RCT Sealed envelopes</td>
<td>Children (N=89) between 2 and 10 years old. Intervention (n=42) and control (n=47) groups with ear, nose throat, urology, general surgery, dentistry, and other.</td>
<td>Canada</td>
<td>mYPAS Parental anxiety STAI</td>
<td>Passive distractor: Streamed video clips from YouTube™ Control group received traditional distraction methods during induction</td>
<td>Anxiety: Positive Pain: NM** Parental satisfaction: NM** Parental anxiety: Only baseline measures</td>
</tr>
<tr>
<td>Seiden et al. (2014)</td>
<td>RCT Sealed envelopes</td>
<td>Children (N=108) between 1 and 11 years old. Tablet distraction (n=57) and MDZ***(n=51) with ENT, urology, general surgery, gastrointestinal, dental, or orthopedic.</td>
<td>At the Children’s Hospital of Chicago, USA February 2013 to June 2013</td>
<td>mYPAS Heart rate Parental satisfaction</td>
<td>Active distractor Age-appropriate video games</td>
<td>Anxiety: Positive Pain: NM** Parental satisfaction: Positive Parental anxiety: NM**</td>
</tr>
<tr>
<td>Stewart et al. (2018)</td>
<td>RCT card from a whimsical hat</td>
<td>102 children between 4 and 12 years old. TBID experimental group (n=51) and MDZ*** (n=51) with general surgery, urology, otolaryngology, and other.</td>
<td>Texas, USA February 2016 to September 2016</td>
<td>mYPAS-SF (short form) Caregivers’ satisfaction</td>
<td>Active distractor TBID were given an iPad mini with an age-appropriate gaming app for 1 minute</td>
<td>Anxiety: Positive Pain: NM** Parental satisfaction: Positive Parental anxiety: NM**</td>
</tr>
</tbody>
</table>

*Results are presented in meta-analyses ** Not measured ***Midazolam ****Pediatric Anesthesia Emergence Delirium
Figure 1 PRISMA flow diagram. Adapted from: Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine, 6*(7), e1000097. (Color figure can be viewed at wileyonlinelibrary.com).
Figure 2 The forest plots indicate the difference between the control group and web-based mobile health intervention group for measuring anxiety at induction, as measured by mYPAS.
### Study Results

The forest plots indicate the difference between the control group and web-based mobile health intervention group for measuring anxiety at induction, as measured by mYPAS (after sensitivity analyses).

#### Table: Study Results

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean</th>
<th>SD</th>
<th>Total</th>
<th>Mean</th>
<th>SD</th>
<th>Total</th>
<th>SMD (95% CI)</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stewart et al 2018</td>
<td>28.6</td>
<td>11.6</td>
<td>51</td>
<td>35.7</td>
<td>16.4</td>
<td>51</td>
<td>0.50 (0.11, 0.89)</td>
<td>23.81</td>
</tr>
<tr>
<td>Fortier et al 2015</td>
<td>43.5</td>
<td>21.7</td>
<td>38</td>
<td>57</td>
<td>21.2</td>
<td>44</td>
<td>0.63 (0.18, 1.07)</td>
<td>18.70</td>
</tr>
<tr>
<td>Kerimogly et al 2013</td>
<td>33.3</td>
<td>15.4</td>
<td>32</td>
<td>45</td>
<td>17.9</td>
<td>32</td>
<td>0.70 (0.20, 1.21)</td>
<td>14.50</td>
</tr>
<tr>
<td>Mifflin et al 2012</td>
<td>39.4</td>
<td>25</td>
<td>42</td>
<td>60.5</td>
<td>26.8</td>
<td>47</td>
<td>0.81 (0.38, 1.25)</td>
<td>19.71</td>
</tr>
<tr>
<td>Seiden et al 2014</td>
<td>22</td>
<td>25.3</td>
<td>57</td>
<td>46</td>
<td>25.3</td>
<td>51</td>
<td>0.95 (0.55, 1.35)</td>
<td>23.28</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>220</td>
<td></td>
<td>225</td>
<td></td>
<td></td>
<td></td>
<td><strong>0.72 (0.53, 0.91)</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

**Overall (I-squared = 0.0%, p = 0.592)**

- Heterogeneity chi-squared = 2.80 (d.f. = 4) p = 0.592
- Test of SMD=0 : z= 7.33 p < 0.001

**NOTE:** Weights are from random effects analysis

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**Figure 3.** The forest plots indicate the difference between the control group and web-based mobile health intervention group for measuring anxiety at induction, as measured by mYPAS (after sensitivity analyses).