



Wearable devices for patient monitoring in the early postoperative period: a literature review

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Abstract: The early postoperative period is a crucial stage in a patient's recovery as they are susceptible to a range of complications, with detection and management the key to avoiding long term consequences. Wearable devices are an innovative way of monitoring patient's post-intervention and may translate into improved patient outcomes, and reduced strain on healthcare resources, as they may facilitate safer and earlier discharge from the hospital setting. Several recent studies have investigated the use of wearable devices in postoperative monitoring. This review outlines the current literature including the range of wearable devices used for postoperative monitoring, the variety of surgeries investigated, and the outcomes assessed. A search of five electronic databases was performed. Data on the range of wearable devices, outcomes and surgeries investigated were extracted and synoptically analysed. Twenty-four articles were retrieved. Data on several different types of surgery were available and discussed. Most studies used wrist-mounted wearable devices and accelerometers or pedometers to assess physical activity metrics, including step counts and physical activity intensity (PAI), as markers of recovery. Wearable devices can provide objective data capture in the early postoperative phase to remotely monitor patients using various metrics including temperature, cardiac monitoring and physical activity. The majority of current research is focussed on wrist-mounted accelerometers and pedometers used to assess physical activity as a marker of postoperative function. Further research is required to demonstrate improved safety and cost-effectiveness of this technology.

Keywords: Wearable devices; early postoperative monitoring; physical activity monitoring; accelerometer; surface sensor technologies

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Background

Postoperative monitoring is a vital aspect of modern surgical practice, with the aim to facilitate a fast and safe recovery. This is especially important in the early

postoperative period, where multiple serious complications are prevalent (1,2). Surgical insult presents a significant physiological stressor, resulting in a potent stress hormone response involving the release of catecholamines, cortisol

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Table 1 Chronology of common complications of the early postoperative period (1,10-15)

Postoperative day(s)	System	Common complications
0-1	Cardiovascular	Myocardial infarction
		Hypotension
	Respiratory	Respiratory depression
1-3	Cardiovascular	Basal atelectasis
		Falls and secondary complications (fractures, head injuries, lacerations, immobility)
	Respiratory	Respiratory depression
4-7	Cardiovascular	Myocardial infarction
		Congestive heart failure
	Respiratory	Pneumonia
	Genito-urinary	Urinary tract infection
1-3	Cardiovascular	Arrhythmia
		Deep vein thrombosis/pulmonary embolism
	Respiratory	Pneumonia
	Mobility	Falls and secondary complications (fractures, head injuries, lacerations, immobility)
4-7	Cardiovascular	Arrhythmia
		Superficial and deep surgical site infection
	Genito-urinary	Urinary tract infection
	Mobility	Falls and secondary complications (fractures, head injuries, lacerations, immobility)

and glucagon. The subsequent systemic changes can have serious consequences (3), particularly in at-risk groups including the elderly, overweight or co-morbid (4-7). There are several common complications which may occur in the early postoperative period and can result in significant morbidity and mortality, as well as increased length of hospital stay, re-operation, readmission to hospital and significant costs (1,8,9). These complications and their general chronology, in terms of peak incidence, are outlined in *Table 1* (1,10-15).

Early postoperative monitoring involves the health care team regularly assessing vital signs, pain, mood, wound healing, mobility, diet, fluid balance and bowel motions. Postoperative monitoring continues post-discharge via patient education and follow up consultations with surgeons, nurses and primary care physicians (1,2,16,17). There has been a recent push for early discharge and minimisation of length of hospital stay, with numerous studies reporting improvements to patient outcomes and reduced strain on hospital resources (18-23). This has included the rise of minimally invasive surgery (24-27), Enhanced Recovery After Surgery protocols (28-30) and

telemedicine (31-34). The recent COVID-19 pandemic strained healthcare institutions in an unprecedented manner and further highlighted the need for innovative solutions such as telemedicine (35-38). The rise of mobile health technology has facilitated the development of medical grade wearable devices. This technology allows for a vast range of personal data to be measured by multiple potential devices and has seen widespread popularity, multiple applications and increasing sophistication (39-43). There is growing interest in the healthcare applications of wearable devices given the possibility of increasing efficiency, cost-effectiveness and objectivity of collecting health-related data (39). A number of studies have investigated their use in a range of disease processes and clinical settings (44-47). One area of recent development and great promise is the application of wearable technology to early postoperative monitoring (48). As wearable devices can allow for discrete, continuous and remote collection of a range of health metrics, including cardiac monitoring, body temperature and physical activity (39), they can potentially improve the detection of complications in the early postoperative period, thereby improving patient outcomes and reducing health

Search	Actions	Details	Query	Results
#12	...	>	Search: (((((wearable devices) OR (wearable)) AND ((postoperative) OR (intervention)))) AND (monitoring)) AND (early)) AND ((complications) OR (recovery))	47
#11	...	>	Search: (complications) OR (recovery)	3,765,968
#10	...	>	Search: (postoperative) OR (intervention)	8,830,133
#9	...	>	Search: (wearable devices) OR (wearable)	22,958
#8	...	>	Search: recovery	517,087
#7	...	>	Search: complications	3,336,664
#6	...	>	Search: early	1,582,452
#5	...	>	Search: intervention	8,470,145
#4	...	>	Search: postoperative	893,997
#3	...	>	Search: monitoring	1,017,018
#2	...	>	Search: wearable	13,894
#1	...	>	Search: wearable devices	16,170

Figure 1 Structure of search and search terms for PubMed.

care costs. To our knowledge, there is no existing review of wearable devices used for early postoperative monitoring. This review of the literature looks to outline and assess the use of wearable devices for patient monitoring in the early postoperative period, with particular focus on the range of wearable devices used, the variety of surgeries investigated, and the outcomes assessed. We present the following article in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) reporting checklist (available at <http://dx.doi.org/10.21037/mhealth-20-131>) (49).

Methods

Electronic searches were performed using Ovid Medline, PubMed, Cochrane Central Register of Controlled Trials (CCRCT), Cochrane Database of Systematic Reviews (CDSR) and Ovid Embase from their dates of inception to June 2020. To achieve the maximum sensitivity of the search strategy, we used the terms “wearable devices”, “wearable”, “monitoring”, “postoperative”, “intervention”, “early”, “complications” and “recovery” as either keywords or MeSH terms. The search terms were combined using Boolean operators “AND” and “OR” functions. Truncation was not used for these terms. *Figure 1* outlines one of these searches. The reference lists of all full-text articles assessed for eligibility were examined to identify relevant studies as determined by the inclusion and exclusion criteria.

Two investigators independently reviewed each retrieved article (TA, NM). Discrepancies between reviewers were resolved through discussion and consensus.

Inclusion criteria

Studies eligible for this review included those in which surgical patients were monitored in the early postoperative period using wearable device technology. We defined the early postoperative period as within 7 days after surgery. All publications were limited to those involving human subjects.

Exclusion criteria

Studies including non-surgical patients were excluded. Case reports, abstracts, conference presentations, editorials, expert opinions, study protocols, patents and letters to the editor were excluded.

Data collection

All data were extracted from article texts, tables, and figures. Data of interest included the range of wearable devices investigated, the types of surgery performed, the outcomes assessed and the results produced. Two investigators independently extracted data from each retrieved article (TA, NM). Discrepancies between reviewers were resolved through discussion and consensus.

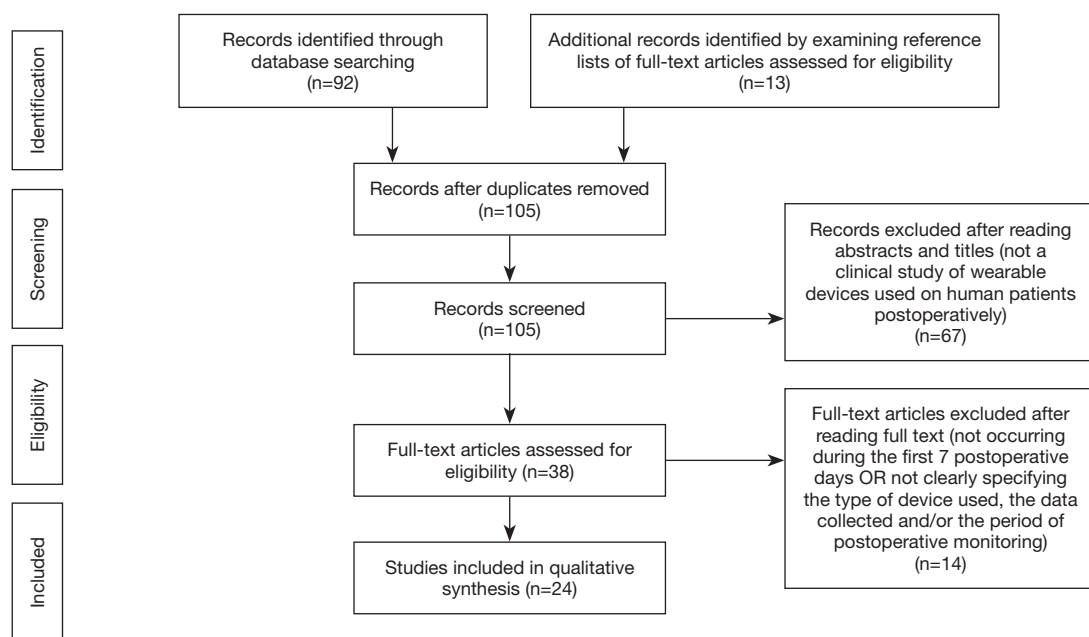


Figure 2 PRISMA search strategy for the present literature review.

Results

A search of five electronic databases yielded 92 records. The inclusion and exclusion criteria were used to screen the titles and abstracts of these records, allowing for 67 articles to be excluded. The full texts of the surviving 38 articles were then assessed using the inclusion and exclusion criteria. There were 13 additional records identified in the reference lists of these articles. These were screened and surviving records also subjected to a full text analysis, in the same aforementioned manner. Ultimately 24 articles were deemed eligible and included in this review. There were six general surgery studies, five neurosurgery studies, four surgical oncology studies, two cardiac surgery studies, two orthopaedic surgery studies, two studies investigating more than one surgical specialty, one urological surgery study, one paediatric surgical study and one obstetric surgery study. The sample sizes of retrieved articles ranged from 5 to 200 subjects. A summary of the search strategy and these results can be seen in *Figure 2* and *Table 2*, respectively.

Study metrics and results

The majority of studies identified in this review (23/24; 95.8%) used either accelerometry or pedometer to track measures of physical activity, which served as a marker of

postoperative function and recovery. Berthelot *et al.* (53) developed and investigated a novel wearable device which used spectroscopy to assess tissue oxygen saturation (StO₂), as a marker of free tissue transfer perfusion and survival. The most prevalent device-collected data included step counts (17/24; 70.8%) and various measures of physical activity intensity (PAI) (5/24; 20.8%). Other mobility-related data included distance ambulated (3/24; 12.5%) measures of speed or acceleration (4/24; 16.7%) and step length (1/24; 4.2%). Estimates of caloric expenditure were provided by 2/24 (8.3%) studies. Agarwal *et al.* (50) reported sleep-related data including minutes slept and night time awakenings. Most of the retrieved articles used wrist-mounted wearable devices (13/24; 54.2%). Other devices were ankle-mounted (4/24; 16.7%) and waist-mounted (3/24; 12.5%). Two studies (2/24; 8.3%) used a clip-on wearable device, with one (51) specifying where they were attached. Aziz *et al.* (52) used an ear-mounted device. Berthelot *et al.* (53) used a skin-patch type device. Fitbit, Inc. (San Francisco, CA, USA) products were investigated in 10/24 (41.7%) studies and were the most researched devices. Several wearable devices required accessory devices (52,55), an application on a mobile phone (50,64,67,73), an online account, personal computer or a tablet device (51,65,66,68,71) to allow for data collection and transmission. The majority of studies identified in our

Table 2 Summary of the retrieved articles

Author(s)	Surgery	Wearable device(s)	Device type	Device-collected data	N
Agarwal <i>et al.</i> (50)	Radical prostatectomy	Fitbit Charge HR (Boston, MA, USA)	Wrist-mounted	TDS, minutes slept and night-time awakenings	46
Appelboom <i>et al.</i> (51)	Cranial and spinal neurosurgery	FitBit Zip (San Francisco, CA, USA)	Clip-on; waist-mounted and ankle-mounted	Total steps ambulated, total distance walked, gait velocity, step length	37
Aziz <i>et al.</i> (52)	Abdominal surgery	e-AR	Ear-mounted	PAI	5
Berthelot <i>et al.</i> (53)	Free tissue transfer for breast reconstruction post-mastectomy	StO ₂ device	Skin-patch	StO ₂	14
Carmichael <i>et al.</i> (54)	Thoracic, inguinal hernia and open and minimally invasive abdominal surgery	Garmin Vivofit 3 (Schaffhausen, Switzerland)	Wrist-mounted	TDS	143
Cook <i>et al.</i> (55)	Cardiac surgery	Fitbit (San Francisco, CA, USA)	Ankle-mounted	TDS	149
Daskivich <i>et al.</i> (56)	Lung lobectomy, gastric bypass, hip replacement, robotic cystectomy, open colectomy, abdominal hysterectomy, sleeve gastrectomy and laparoscopic colectomy	Fitbit Charge (San Francisco, CA, USA)	Wrist-mounted	TDS	100
Ghomrawi <i>et al.</i> (57)	Paediatric surgery	Actigraph GT3X or wGT3X-BT (Pensacola, FL, USA)	Wrist-mounted	PAI	25
Gorzeltz <i>et al.</i> (58)	Endometrial and ovarian surgical oncology	MiniMitter Phillips Actiwatch 64 (Bend, OR, USA)	Wrist-mounted	PAI	96
Inoue <i>et al.</i> (59)	Laparoscopic and open colorectal surgery	Active Tracer AC-301 (Tokyo, Japan)	Ankle-mounted	CA	62
Inoue <i>et al.</i> (60)	Laparoscopic partial, open distal or open total gastrectomy	Active Tracer AC-301 (Tokyo, Japan)	Ankle-mounted	CA	20
Keppler <i>et al.</i> (61)	Hip arthroplasty, intramedullary nailing and osteosynthesis	Trium actibelt (Munich, Germany)	Waist-mounted	TDS, gait speed	31
Kim <i>et al.</i> (62)	Laminectomy	Fitbit Charge (San Francisco, CA, USA)	Wrist-mounted	TDS, TDDT, DCE	22
Low <i>et al.</i> (63)	Cytoreductive surgery for peritoneal carcinomatosis	Fitbit Flex or Charge (San Francisco, CA, USA)	Wrist-mounted	TDS	71
Massouh <i>et al.</i> (64)	Caesarean delivery	Jawbone UP (San Francisco, CA, USA)	Wrist-mounted	TDS	200
Mobbs <i>et al.</i> (65)	Lumbar spine surgery	Fitbit Zip (San Francisco, CA, USA)	Clip-on	TDS, TDDT, DCE	30
Scheer <i>et al.</i> (66)	Spinal surgery	Fitbit Flex (San Francisco, CA, USA)	Wrist-mounted	TDS, total hourly steps, PAI	32

Table 2 (continued)

Table 2 (continued)

Author(s)	Surgery	Wearable device(s)	Device type	Device-collected data	N
Stienen <i>et al.</i> (67)	Spinal surgery	Mi Band (Mountain View, CA, USA)	Wrist-mounted	TDS	30
Sun <i>et al.</i> (68)	Curative resection for major abdominal cancer	Garmin Vivofit 2 (Olathe, KS, USA)	Wrist-mounted	TDS	20
Symer <i>et al.</i> (69)	Major abdominal surgery	Fitbit Charge (San Francisco, CA, USA)	Wrist-mounted	TDS	31
Takahashi <i>et al.</i> (70)	Cardiac surgery	Active Style Pro HJA-350IT (Kyoto, Japan)	Waist-mounted	TDS	133
Toogood <i>et al.</i> (71)	Total hip arthroplasty	Fitbit (San Francisco, CA, USA)	Ankle-mounted	TDS	33
Wasowicz-Kemp <i>et al.</i> (72)	Laparoscopic cholecystectomy	PAM Model AM101 (Doorwerth, The Netherlands)	Waist-mounted	PAM score	64
Wu <i>et al.</i> (73)	Laparoscopic or open gastrectomy for gastric cancer	Apple Watch (Cupertino, CA, USA) or Samsung Gear S2 (Seoul, South Korea)	Wrist-mounted	TDS	43

Data on surgery types, wearable devices and device-collected data is reported as presented in the retrieved articles. TDS, total daily steps; e-AR, ear-worn activity recognition; PAI, physical activity intensity (studies varied on their definitions of different intensity levels); StO₂, tissue oxygen saturation; CA, cumulative acceleration; TDDT, total daily distance travelled; DCE, daily caloric expenditure; PAM, personal activity monitor.

review provide evidence to support the notion that wearable devices are useful, cost-effective and objective tools to reliably, remotely and regularly monitor postoperative function and recovery (50,53–56,59–61,63–68,71). A number of studies also reported high levels of patient compliance and satisfaction (50,61,65,67,68,71,73).

Discussion

The development of wearable devices and their recent healthcare applications have led to great interest in their use in postoperative monitoring. This review of the current literature demonstrates that wearable device technology has been investigated for postoperative monitoring after a range of surgeries, with the evidence suggesting that they are a useful and objective method of continuously and remotely monitoring patients postoperatively, thereby potentially improving patient safety and reducing health care costs. The popularity of wrist-mounted devices among the retrieved articles was likely due to the pervasiveness, relatively low cost and discrete nature of watch-based sensors, such as the Fitbit products and wrist-mounted wearable devices in general. Most studies used accelerometry or pedometry to track measures of physical activity, which served as a marker

of postoperative function and recovery. This was likely due to the associations between early mobilisation and improved survival and functional outcomes (51,74–77). While our inclusion and exclusion criteria ensured all retrieved studies monitored patients in the early postoperative period, many studies also monitored patients preoperatively to produce a baseline to compare postoperative scores against.

The potential impact of wearable devices in postoperative monitoring

The great potential of applying wearable device technology to postoperative monitoring lies in the possibility of continuous and objective monitoring in both the hospital and the home (51), thereby improving patient safety and enhancing continuity of care. Through the continuous monitoring of multiple health metrics, potentially replacing inpatient monitoring for suitable, low-risk patients, wearable devices may facilitate earlier discharge and so reduce the length of hospital stay (52), therefore providing time and financial savings (55). These health metrics may also be quantitatively combined, potentially enhancing accuracy and allowing for more objective inter- and intra-patient comparisons. The Gait Posture index (GPi) is one

such promising tool which demonstrates this concept by synthesising a number of physical activity metrics, ideally collected via a wearable device, into a simple index (78,79). Wearable devices may also improve the implementation of prophylactic measures (62) such as tracking the body positions of patients and providing alarms after a pre-determined period of inactivity to ensure that patients are rolled to prevent pressure sores. These devices may allow for the immediate detection of accidents, as well as the earlier detection of complications (57,62) and patients with slow recovery trajectories, thus allowing for earlier interventions in these patient groups (54,55,63,68,71). This is highlighted by Ghomrawi *et al.*, who reported a link between a drop in mobility scores measured using wearable devices and the onset of postoperative complications, with detection occurring prior to medical attention being sought (57). Further, Mobbs *et al.* (80) reported a case demonstrating the utility of wearable device data, in conjunction with clinical and radiologic assessment, in detecting a postoperative complication and so allowing for timely intervention.

Specific at-risk populations identified in our review which may especially benefit from postoperative wearable device monitoring include obese patients (50), disabled patients (51) and orthogeriatric patients (61). Patient groups which may be particularly suited to wearable device monitoring include those who are difficult to adequately monitor using traditional methods. This includes patients who are elderly, young (57), intellectually impaired (68), speech impaired or who have psychiatric or substance related issues (62). However, these patients may also present unique challenges regarding informed consent, patient education and compliance, thereby necessitating a well-planned and multi-disciplinary approach to ensure adequate implementation. The data provided by wearable devices may also aid the recovery process (50,51,54,64). Patients may find quantitative and graphical evidence of their improvements motivating, thereby potentially creating a positive feedback loop. This can also be extended and potentially integrated into physiotherapy and rehabilitation efforts. For example, these devices may be pre-programmed to emit alarms after pre-determined periods of inactivity to ensure that newly ambulating patients mobilise frequently and progressively overload, possibly by increasing parameters such as duration, intensity or distance.

Postoperative monitoring via wearable devices may also be extended preoperatively to provide baselines for comparison, as well as form part of a prehabilitation strategy (50),

thereby holistically enhancing peri-operative care. This preoperative monitoring may motivate patients to improve or maintain their function and so maximise their physiological reserve and postoperative level of function. Preoperative monitoring can also allow for the identification of lower mobility patients groups. These patients may be given more intensive prophylactic therapies to prevent immobility related complications (52). Mobbs *et al.* and Sun *et al.* both noted the discordance in scores between traditional subjective and recent objective measures, such as wearable device data, of function and recovery (65,68). As such, the objective data collected by wearable devices may replace or serve as an important adjunct to static and subjective traditional monitoring tools, such as clinical assessments or patient reported questionnaires (61,62,65-68,71).

Limitations

A significant issue is the lack of quality short-term and long-term data to demonstrate improved patient safety and reduced health care costs. Guidelines must also be developed to ensure responsible and ethical use of this technology. Careful assessment is required to distinguish between patients requiring in-patient monitoring and low-risk patients suitable for safe early discharge with wearable monitoring. A desire to reduce departmental costs or to improve healthcare key performance indicators must not be allowed to sway clinical decision making. While wearable devices will likely enhance postoperative monitoring of patients, the data must still be analysed within each patient's unique clinical context. Some ultimately successful procedures may eliminate pain or serve a palliative function, yet produce minimal functional improvement, while others may provide functional improvement, but leave patients with debilitating side effects. Further, the data data themselves require careful interpretation. Some wearable device systems may not be able to distinguish pathological movements, such as seizures, from normal ambulation, thus inappropriately over-estimating movement and possibly failing to detect a serious health event (52).

Important patient factors include the reliance of wearable devices on patient compliance, as highlighted by Ghomrawi *et al.* (57). Patient monitoring via wearable devices will also likely incur similar confidentiality and data safety concerns experienced by other mobile health technologies (81). These issues are particularly significant if standardisation, of outcomes, devices, data analytics or databases, is prioritised, such as for research purposes. Further, raw data, such as

acceleration, may still violate patient privacy given that unknown diseases or personal habits may be detected. Robust protections, such as data encryption, password protection and access restrictions, must be employed to provide safety and patients must also be educated in order to alleviate their concerns (50,55). Some patients may also find quantitative and graphical evidence of slow recovery, plateauing or regression demotivating, thereby potentially creating a negative feedback loop. To ensure efficacy, promote compliance and improve the lifespan of wearable devices patients must also be educated on how to use and maintain their devices.

Wearable device factors include the set-up, maintenance, repair and education costs associated with these devices. These may be substantial and are a significant institutional barrier to uptake and will likely ultimately be borne by patients, governments or both. Preoperative monitoring further increases the cost of the system and may be deemed wasteful in the event of cancelled or delayed procedures. Crucially, some studies have questioned the accuracy of the data provided by wearable devices. Appelboom *et al.* reported that wearable devices tended to be more accurate for healthier and more mobile patients, whereas patients with slow and minimised movements as well as those using aids such as walkers had their movements underestimated (51). Some studies have indicated that accelerometers may fail to register very fast movements (71) and that wearable devices may consistently inaccurately assess step counts and PAI (64,82). Also, there is a paucity of research into inter-device reliability for many of the commercially available wearable device brands, as well as into intra-device reliability (82). Some devices may require frequent charging and syncing of data, which may impair compliance and data capture (50,73). Additional problems include device malfunction, damage or loss (56,57,66). Protocols must be developed to rapidly assess and respond to device failure, significant patient non-compliance or faulty readings. These issues raise the potential time and financial costs associated with the technology. Also, most devices identified in this review were wrist-mounted, likely due to the pervasiveness and discretion of existing wrist-mounted wearable devices. Ankle-mounted or ear-mounted devices may therefore experience issues due to their size, anatomical location and lack of public familiarity.

Limitations of the research

Research into the healthcare applications of wearable

devices is a nascent area. In the niche of postoperative monitoring, there is an abundance of pilot studies, validation studies and studies with small sample sizes. It is difficult to compare the studies in this review meaningfully and directly due to significant inter-study variation, including in devices, study time periods, frequency of monitoring, outcomes, and samples examined by different studies. Some studies did not fully report the exact device model used, their methodology or their results. Several studies did not report the actual data recorded by their wearable device or how data were manipulated, only a study-specific outcome. This may reflect protections placed on commercially available wearable devices to safeguard intellectual property, such as the methodology of computing input data in order to produce output data. One study incentivised participation by providing gift cards to subjects, thereby impairing the external validity of their results (57). Further, patients undergoing surgery due to cancer may have also received chemotherapy and/or radiotherapy, and as such are no longer solely surgical patients.

Further research

There is an urgent need for further research to substantiate the potential of this technology, most importantly to demonstrate improved patient and institutional outcomes. Ideally large, multi-centre prospective trials should be run, using validated tools to assess outcomes and therefore demonstrate the safety and cost-effectiveness of this technology. The financial analysis may involve comparisons of costs associated with beginning and maintaining wearable device monitoring programs against savings made due to reduced staffing needs, complication rates and hospital lengths of stay. The value of longer-term postoperative monitoring may also be assessed, possibly through discrete devices or by using wearable devices already used by consumers, which may additionally enhance patient compliance. This is particularly important given the findings of Gorzelitz *et al.* (58) and Carmichael *et al.* (54) who reported impaired activity levels at 4 months and at 28 days postoperatively, respectively. However, the specificity of their relatively well-educated, wealthy female cohort with gynaecologic cancer limits their external validity. Also, a lack of a preoperative baseline renders a comparison with postoperative values impossible.

While wearable devices may be useful tools for postoperative monitoring for any surgery or procedure, some devices and data may be more useful for certain

surgeries. For example, a wearable device with sensors on either side of a joint may be a useful tool to monitor changes in joint range of motion following orthopaedic surgery. This is highlighted by Appelboom *et al.* demonstrating that hip-mounted sensors were more accurate in detecting movement than ankle-mounted sensors (51). Research is needed to thus optimise devices, their application and the outcomes assessed for different surgical specialties and surgeries. Ideally, cost-benefit analyses should also be performed to balance increased number or sophistication of sensors and the value of resultant information against costs and patient comfort. Research is also needed to validate the length of preoperative monitoring needed for a significant baseline to be developed. This may vary depending on patient factors such as American Society of Anaesthesiologists (ASA) Classifications (83) and surgical factors such as the type of surgery. Research into the value of postoperative monitoring data alone is still needed, as this may be useful in monitoring emergency or preoperatively non-compliant patients.

While data trends are generally thought to be useful, researchers may also determine whether demographic-matched absolute data values, for example by age, gender and ASA Classifications, are useful as well. Research is also needed to define significant drops in collected data in order to warrant patient contact or emergency intervention (57), as well as to define thresholds or guidelines for objective input into discharge planning (55). While much of the research identified in this review is focussed on physical activity, the feasibility of collecting other types of data, such as vital signs, and their usefulness should be explored. These data types may ultimately be synthesised into an index capable of quantitatively representing overall patient function, thereby making greater use of currently available health data and extending existing tools, such as the GPi (78,79), to more accurately assess and monitor patient recovery.

Conclusions

In summation, wearable devices are a promising innovative approach to postoperative patient monitoring, with the potential to remotely assess a range of health metrics and so provide objective outcomes assessment, monitor and detect early complications, improve patient safety and potentially reduce healthcare costs. The current literature is focussed on wrist-mounted accelerometers and pedometers used to assess physical activity as a marker of postoperative function

and recovery, however a range of wearable options will likely evolve with more detailed data streams to improve every aspect of postoperative care. These studies suggest that wearable devices are feasible and cost-effective tools capable of remotely and regularly monitoring patients postoperatively. Further research is required to validate these findings and develop this nascent field.

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