

AN UMBRELLA REVIEW OF SYSTEMATIC REVIEWS OF THE IMPACT OF WRIST-WORN WEARABLES ON HEALTH OUTCOMES

Impact of wrist-worn wearables on health outcomes

Methods

Objective

We synthesized the evidence on the effectiveness of wrist-worn wearables on diverse health outcomes including health promotion (i.e., health behaviors and disease risk perception) morbidity, mortality, functioning, and other health-related metrics in humans.

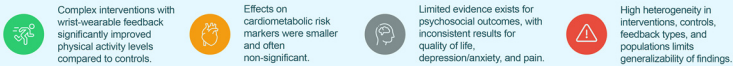
Inclusion Criteria

Systematic reviews of interventional or observational studies in humans, examining wrist-worn wearable device feedback (alone or within multicomponent interventions) compared to no intervention, usual care, waiting list, or similar interventions without wearable feedback, with reported health outcomes.

Outcome



Conclusion



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KEY WORDS

behavioral interventions; health outcomes; meta-analysis; umbrella review; wrist-worn wearables

CLINICAL HIGHLIGHTS

Wrist-worn wearables can help you move more. Studies show that receiving feedback information from wearables is effective at increasing daily physical activity across many groups, from adults in the general population to people living with conditions such as obesity, diabetes, heart disease, or cancer.

More steps, more movement. The strongest and most consistent benefit is seen in step counts and overall activity levels.

Other health benefits are still emerging. Evidence for improvements in heart-health markers, mood, pain, or quality of life is mixed and not yet definitive.

Most programs work best when wrist-worn wearables are combined with lifestyle changes such as coaching, goal-setting, or group support rather than used alone.

Keep in mind that not all studies are of high quality and results can vary depending on the population and device used.

AN UMBRELLA REVIEW OF SYSTEMATIC REVIEWS OF THE IMPACT OF WRIST-WORN WEARABLES ON HEALTH OUTCOMES

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Abstract

We conducted an umbrella review to synthesize the evidence on the effectiveness of interventions incorporating wrist-worn wearables' feedback on diverse health outcomes including health promotion (i.e., health behaviors and disease risk perception) morbidity, mortality, functioning, and other health-related metrics in humans. We searched in MEDLINE, Web of Science, Embase, and Cochrane Library until March 18, 2025, for eligible systematic reviews. After screening 9,487 citations, we identified 39 systematic reviews, which included 98 original studies (1 observational study, 95 randomized controlled trials, and 1 pre-post study). The reviews primarily focused on adult populations, individuals with cardiometabolic conditions, and cancer survivors. The original interventional studies mainly included Fitbit (40.2%), Polar (12.4%), and ActiGraph (10.3%) devices. Over 80% of the clinical trials involved complex behavioral interventions with wearable-based feedback, and the control groups varied. Most systematic reviews were rated as low confidence, with common flaws including inadequate consideration for risk-of-bias and heterogeneity. Interventions incorporating wrist-worn activity trackers increased physical activity in diverse populations. The effect of interventions incorporating wrist-wearables' feedback on cardiometabolic risk markers, quality of life, depression/anxiety, and pain was limited and remained inconsistent. Our findings rely on existing systematic reviews, which may vary in quality, review methodologies, and comprehensiveness. There is also potential for missing more recent evidence not yet captured in these reviews. These limitations should be considered when interpreting our results. Acknowledging these caveats, wrist-worn wearables seem to increase physical activity and may have additional benefits that require further study.

behavioral interventions; health outcomes; meta-analysis; umbrella review; wrist-worn wearables

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1. INTRODUCTION

Wearable health technology, more commonly known as “wearables,” refers to portable, noninvasive devices that

incorporate integrated sensors designed to gather diverse physiological data related to an individual's health status (1). These gadgets are engineered to be comfortably worn on the body, allowing for continuous monitoring without significantly interfering with daily activities (1). Popular consumer brands offer wearables that track or estimate basic fitness metrics including step count, energy expenditure, sleep quantity, and heart rate. More specialized devices extend these capabilities, measuring vital signs such as blood pressure, blood glucose, and blood oxygen saturation (2). Wearables offer a user-friendly method for continuous health data collection, storage, and sharing in real time. By providing immediate feedback, wearables aim to empower users to make informed adjustments to their

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CLINICAL HIGHLIGHTS

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More steps, more movement. The strongest and most consistent benefit is seen in step counts and overall activity levels.

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Keep in mind that not all studies are of high quality and results can vary depending on the population and device used.

daily habits and behaviors (3, 4). This ability to provide immediate feedback is exploited in point-of-care monitoring for identifying or tracking changes related to fatigue, inflammatory responses, metabolic states, atrial fibrillation, sleep apnea, hypertension, and cardiovascular disease risk (5–9). This capability may allow healthcare professionals to access patient data proactively and more rapidly, potentially leading to improved health outcomes and a reduction in the frequency of in-person medical visits and overall healthcare costs (10, 11). Thus, wearables offer a promising approach to promote desirable behavior or lifestyle modifications and improve individuals' adherence to a healthy lifestyle and improve their well-being (12).

Wearables have gained significant attention in recent years among both consumers and researchers, due to increased availability, utility, and accuracy in recent years (9, 13). In 2020, around 30% of adults in the United States reported regular use of wearables, and based on the market predictions, there is an expected annual growth of around 25% through 2026 (14, 15). In addition, a recent scoping review found that the number of published studies that included noninvasive, consumer-grade wearables increased by 400% between 2016 and 2020 (16). Thus, there are hundreds of studies investigating wearable devices in the context of health. Trying to harness this evidence, there is also a large number of systematic reviews and meta-analyses that either investigated wearables' validation and accuracy, comparing these to the gold standard measurements, or explored their effectiveness in healthy behavior promotion or in the diagnosis and treatment of specific health conditions (9, 17–23). Subsequently, the number of umbrella reviews is increasing to keep pace with the growing literature on wearables (24–30).

The evidence from prior published reviews and umbrella reviews remains highly heterogeneous and difficult to interpret and generalize for several reasons. First, they often focused on specific health conditions (23, 25) or on specific aspects of a healthy lifestyle, such as

physical activity (PA) promotion (26, 27). Second, they did not discriminate between studies that used wearables as data collection tools for patient-generated data of study outcomes that incorporated wearable-collected information in prediction models, those that used wearables as part of interventions alongside complex lifestyle/behavioral interventions, and those that used single-component interventions with wearables only to influence health outcomes. Third, earlier reviews did not disaggregate or distinguish between types of wearables used in research.

In this umbrella review, we focus on wrist-worn wearable devices. Our focus is intentional for several reasons. First, these devices are generally less intrusive and more comfortable for participants to wear consistently over time, which enhances user compliance and potentially reduces study dropout rates (31). Their familiar design, often resembling conventional wristwatches, minimizes disruption to daily life, making them well-suited for long-term monitoring. Indeed, acceptability measured through data availability (above 70%) and wearing time (above 85%) is high (31). Second, wrist-worn devices, particularly smartwatches and fitness trackers, frequently include integrated features such as real-time feedback, goal setting, and activity reminders (32). These interactive elements can enhance user engagement and potentially influence health-related behaviors, making them valuable tools not only for passive data collection but also for delivering behavior change interventions (17). Third, wrist-worn wearables are by far the most used form factor in both research and real-world applications. They account for more than 70% of wearables used in published studies, highlighting their methodological relevance and the availability of validation data (16). Additionally, they are among the most widely adopted smart devices globally, with nearly one in five adults in the United States using a smartwatch or fitness tracker (33). This widespread adoption increases the potential generalizability of research findings and facilitates translation of research into practice.

Thus, this umbrella review aims to comprehensively evaluate and summarize the evidence regarding the impact of wrist-worn wearable devices' feedback on various health outcomes in humans. These outcomes include health promotion (e.g., health behaviors and disease risk perception), morbidity, mortality, functioning, and other health-related metrics.

2. METHODS

2.1. Protocol and Registration

This umbrella review (a systematic review of systematic reviews and meta-analyses) was conducted following a

preregistered study protocol, which can be found in Open Science Framework (34). The findings were reported according to previously published guidelines on umbrella reviews (35, 36).

2.2. Eligibility Criteria

The study selection criteria were developed using the Population, Intervention/Exposure, Comparison, and Outcomes (PI/ECOS) framework, which considers population, intervention/exposure, comparison, outcome, and study type. For the population, all studies conducted in humans without any other restrictions were eligible. For intervention or exposures, wrist-worn wearable devices' feedback (i.e., smartwatches/fitness trackers, blood pressure monitors, glucose monitors, sleep trackers, activity and posture sensors, or any other wrist wearable sensor), either alone or as part of a multicomponent intervention, was considered. For comparison, either no intervention, usual care, waiting list control, or a similar intervention without a wearable component or feedback was accepted. Any health-related outcomes were eligible, including health promotion (encompassing health behaviors and disease risk perception), morbidity, mortality, functioning, etc. Systematic reviews of both interventional studies that explored the effectiveness of interventions involving wearables on health outcomes and observational studies that explored the associations of wearables with health outcomes were considered as the study design of choice.

Systematic reviews were excluded if they had the following characteristics: 1) incorrect study design (which lack systematic search and analysis of literature), expert reviews, commentaries, or abstracts/conference proceedings; 2) inclusion of studies focusing solely on validation outcomes (e.g., sensor accuracy) or studies in which wearable devices were used only for objective measurements of study outcomes (e.g., step count, total physical activity) rather than as part of an intervention strategy providing feedback to study participants; and 3) inclusion of wearable devices worn on body parts other than the wrist. Information on sensors placed in other body locations was informally collected, and a separate scientific publication focusing on other wearables will follow.

2.3. Search Strategy

Literature search was performed in collaboration with an experienced librarian in MEDLINE, Web of Science, Embase, and Cochrane Library (37). The search (for search strategy see APPENDIX A) was done from inception until March 18 2025. Searches were limited to human studies, and filters for systematic reviews and meta-analyses were applied in all databases. Database search results were exported into EndNote (EndNote x9;

Clarivate, Philadelphia, PA). To identify additional relevant articles, references cited in the included studies were screened.

2.4. Study Selection Process

Titles and abstracts of identified articles were screened by two reviewers independently. Subsequently, a full-text screening of potentially eligible articles was conducted by two reviewers in parallel. The discrepancies in the inclusion or exclusion of references were resolved through a discussion to reach a final decision, and if needed, a senior reviewer was consulted.

2.5. Data Extraction

Data extraction was conducted independently by two reviewers, with any discrepancies resolved through discussion and consensus. A preestablished data collection form was utilized to extract key information from the eligible systematic reviews, including authors and year of publication, date of last search, origin and types of studies considered (design), research question, study population, number of eligible studies, types of wearables examined, outcomes investigated, presence of meta-analysis, and results of both systematic reviews (descriptive conclusions) and meta-analyses (effect/association estimates). Additionally, we extracted basic characteristics from systematic reviews focusing on wearable devices placed on other body parts, which are provided as an overview in Supplemental Tables 1–3.

2.6. Risk of Bias Assessment for Systematic Reviews and for Primary Studies Included in Systematic Reviews

Two reviewers applied a measurement tool to assess systematic reviews (AMSTAR-2) (38) to evaluate the methodological rigor of systematic reviews included in the study. Any discrepancies between the reviewers were resolved with the assistance of a third reviewer. The AMSTAR-2 tool consists of a 16-item checklist, with 7 items typically deemed critical as they can affect the validity of a review. These critical items include protocol registration, adequacy of search strategy, justification for excluding individual studies, risk-of-bias assessment, appropriateness of meta-analytical methods, use of risk of bias during interpretation, and assessment of publication bias. The other nine items are considered noncritical, although these ratings can be altered depending on the context of the review. Reviews were rated as high confidence (0 critical weaknesses and <3 noncritical weaknesses), moderate confidence (1 critical weakness

and <3 noncritical weaknesses), low confidence (>1 critical weakness and <3 noncritical weaknesses), or critically low confidence (>1 critical weakness and ≥ 3 noncritical weaknesses). Additionally, we summarized the information on the risk of bias tool(s) used in the included systematic reviews.

2.7. Deviations from the Registered Protocol

For meta-analyses, we planned to extract effect/association estimates, 95% confidence intervals (95% CIs), heterogeneity estimates, meta-regression results, and any analyses indicating potential bias (e.g., small study effects, excess significance). As the published meta-analyses included both wrist-worn wearables and devices worn on other body parts, we could not directly use their estimates. Instead, we gathered relevant original study-level data from either the systematic review directly (main text or online supplement) or, when necessary, consulted the original publications. All health outcomes reported across meta-analyses were on a continuous scale. The original authors typically pooled either the mean difference in study outcomes from baseline to the end of the trial or performed end-of-study comparisons between intervention and control groups. We extracted information such as mean values and their standard deviations (SDs) pre- and postintervention or the mean difference and SD of the mean difference per clinical trial arm. This approach allowed us to conduct separate meta-analyses using standardized methods, focusing specifically on wrist-worn devices and ensuring consistency across our analyses.

2.8. Evidence Synthesis Methods

Basic computations were performed to visually present the characteristics of included systematic reviews (e.g., study populations, health conditions, health outcomes, or wearable devices used across studies). For systematic reviews using narrative synthesis, the most important findings have been illustrated in the article, and simple descriptive statistics have been provided (e.g., we computed the number of studies that found significantly favorable differences (defined as P values < 0.05) and expressed it as a percentage of the total number of studies available per outcome. We employed two methods to mitigate double reporting of studies in the summary effect/association estimates. First, we either reanalyzed the results from the most recently published review or, second, if the overlap was less than 10%, we considered all available information. We used random effects and unweighted least squares methods in all meta-analyses (12). We generated the summary effect estimate [i.e., standardized mean difference (SMD)], the 95% confidence

interval, the P value for the summary effect estimates, heterogeneity metrics (P value from Cochran's Q test and I^2 estimate), and performed tests for small study effects and for excess significance (PSTT-TESS) (13). The SMD was classified as follows: an SMD of around 0.2 was considered a small detectable difference; an SMD of ~ 0.5 was considered a moderate effect size; and an SMD of 0.8 or greater signified a large difference between groups. Data used for meta-analysis can be found in Supplemental Material S1. Statistical analysis was performed in R version 4.4.2.

3. RESULTS

The search identified 13,839 records. Following the removal of duplicates ($n = 4,303$), exclusions after title and abstract screening ($n = 9,536$), and exclusions after full-text evaluation ($n = 226$), 109 systematic reviews were retrieved on wearables worn in various locations. Of these, 39 reviews that included studies on wrist-worn wearables were included in the current umbrella review, while the remaining 70 focused on other types of wearables. Across the 39 included reviews, 98 unique studies were identified: 95 of the 98 studies were designed as randomized clinical trials (RCTs; among which 36 were either pilot or feasibility studies), 2 as pre-post studies, and one as a prospective study (FIGURE 1). Supplemental Material S2 provides a list of studies excluded based on full-text screening, along with the reasons for their exclusion.

Characteristics of systematic review articles included in the current umbrella review are provided in TABLE 1. FIGURE 2 summarizes the main characteristics of the included systematic reviews. The reviews were published between 2018 and 2025, with most being published after 2020 ($n = 25$; 64.1%). The majority applied time restrictions for the search strategy ($n = 27$; 69.2%) and searched three or more electronic databases ($n = 37$; 94.7%). Based on the information on the corresponding author, most of the reviews were led by researchers from Europe, North America, and Asia ($n = 33$; 84.6%). Among the included systematic reviews, 30 (76.9%) provided a quantitative synthesis; however, we were able to reanalyze the information from only 11 (28.2%). Information from the other 19 meta-analyses was used for narrative synthesis. The most common focus of the reviews was on adults without restricting based on health condition ($n = 10$; 25.6%) and on populations with cardiometabolic diseases ($n = 8$; 20.5%).

Supplemental Table S1 and FIGURE 3 summarize the main characteristics of the original interventional studies identified across 39 systematic reviews. In total, 98 original studies were included, of which 97 were interventional

(95 were RCTs) and 1 was observational. The characteristics of these 97 interventional studies are described in more detail in the following text. Most commonly studied devices were Fitbit ($n = 39$; 40.2%), Polar ($n = 12$; 12.4%), and ActiGraph ($n = 10$; 10.3%). Most of the original studies involved complex and heterogeneous behavioral/lifestyle interventions with wearable-based feedback to study participants ($n = 81$; 83.5%), whereas 17 involved simple (single-component) interventions with wearable-based feedback. The control group was also heterogeneous across original studies, with the majority applying behavioral/lifestyle interventions without wearable-based feedback to study participants ($n = 51$; 52.6%), followed by usual care ($n = 38$), waitlist ($n = 5$), and delayed intervention ($n = 4$).

3.1. Study Overlaps

Within the 39 systematic reviews, a total of 146 studies using wrist-wearable devices were identified, but there

were several overlaps, and eventually 98 were nonoverlapping original studies (97 being interventional studies). Although there were no identical research questions across the included systematic reviews, the original RCTs across studies overlapped either partially or completely. Thus, we prioritized the systematic reviews with the most complete data and the largest number of studies that would allow us to perform a meta-analysis. The remaining systematic reviews were included in a narrative synthesis (more details are provided in later sections).

3.2. Risk-of-Bias Results

Six systematic reviews (15.4%) were rated as having high confidence, while 16 (40.1%) were rated as critically low confidence, and the remaining 17 (43.6%) as low confidence (FIGURE 4). Common methodological flaws included a lack of consideration of risk of bias in the analysis and interpretation of findings ($n = 10$;

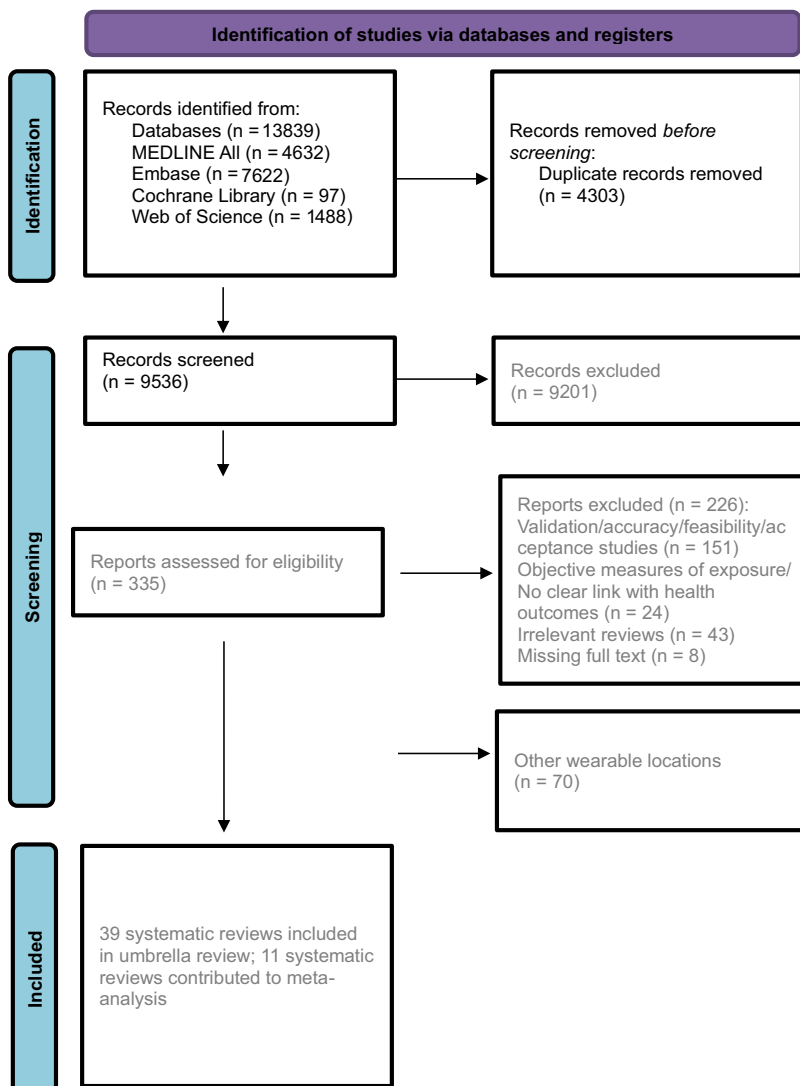


FIGURE 1. Flow chart of included studies. The study selection process is shown. Of 13,839 records identified, 4,303 duplicates were removed. After screening titles and abstracts, 9,201 were excluded, followed by 226 after full-text review. In total, 39 systematic reviews including wrist-worn wearables were included in the umbrella review, with 11 contributing to the meta-analysis. In addition, we identified 70 systematic reviews examining wearable devices worn on various body parts other than the wrist such as pedometers, or continuous glucose monitoring sensors, which were not included in the current umbrella review.

Table 1. Characteristics of included systematic reviews

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
AlSwayied et al. (39), 2022	UK	To evaluate the effectiveness, acceptability, and active behavior change techniques of mobile physical activity technologies among midlife menopausal women	Yes	RCTs, NRCTs, and pre-post	12	2015–2021	MEDLINE (Ovid), Embase, Scopus, CINAHL, Web of Science, SPORTDiscus, CENTRAL, PsycINFO, and the ProQuest Sports Medicine and Education Index	Midlife and menopausal women	Physical activity and frequency or severity of any common menopause-related symptoms	17% (2/12)	No
Antoniou et al. (40), 2022	Greece	To examine the effectiveness of wearable sensors-assisted cardiac rehabilitation in improving cardiorespiratory fitness	Yes	RCTs	14	2015–2021	PubMed, Scopus, Cinahl, Cochrane Library, and PsycINFO	Adults with a diagnosis of cardiovascular disease (e.g., heart failure, myocardial infarction, angina...)	Cardiorespiratory fitness, physical activity, quality of life (QoL), adherence to intervention, cardiovascular risk factors, and depression/anxiety levels	21% (3/14)	Yes
Ashur et al. (41), 2021	US	To study whether wearable activity trackers increase physical activity among cardiac rehabilitation participants	Yes	RCTs	19	2009–2020	Ovid MEDLINE, EMBASE, CINAHL, Scopus, IEEE Xplore, Web of Science Core Collection, Cochrane Central Register of Controlled Trials, and Clinical trials.gov	Adults in cardiac rehabilitation	Cardiorespiratory fitness and physical activity	15.8% (3/19)	No
Au et al. (42), 2024	China	To assess the effects of wearable activity trackers on physical activity in children and adolescents from both healthy and clinical populations	Yes	RCT	21	Inception to 2023	PubMed, Embase, SPORTDiscus, and Web of Science	Children or adolescents, or both, with a mean age of 19 years or younger of any health condition	Physical activity	14.3% (3/21)	No

Continued

Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Blount et al. (43), 2021	US	To synthesize interventional studies examining the effects of wearable health technology-based physiological activity interventions on cognitive, emotional, and emotional outcomes in breast cancer survivors	No	RCTs and NRCTs	14	2012–2019	NCBI, Academic Search Premier, EMBASE, Web of Science, PubMed, and Medline	Breast cancer survivors who were 6 mo posttreatment at the time of the study but not receiving treatment at the time of the study. Without any active form of cancer. At least 2 yr postdiagnosis	Physical activity, cognitive function, anxiety, depression, and fatigue	50% (7/14)	No
Brickwood et al. (44), 2019	Australia	To determine the effects of interventions utilizing consumer-based wearable activity trackers on physical activity participation and sedentary behavior when compared with interventions that do not utilize activity tracker feedback	Yes	RCTs	28	2007–2018	CENTRAL, MEDLINE, PubMed, Scopus, Web of Science, CINAHL, SPORTDiscus, and Health Technology Assessment	Adults	Physical activity participation and sedentary behavior	29% (8/28)	No
Chan et al. (45), 2021	UK	To evaluate the efficacy of wearable activity monitors as a feedback and monitoring tool in home-based exercise programs for patients with intermittent claudication	No	RCTs and observational	9	2010–2019	MEDLINE, EMBASE, and Web of Science	Adults with symptomatic intermittent claudication due to peripheral arterial disease	Walking ability, daily walking activity, cardiovascular metrics, and QoL	44% (4/9)	No

Continued

Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Chaudhry et al. (46), 2020	UK	To examine the effects of step-count monitoring devices (pedometers, body-worn trackers, and smartphone applications) on objectively measured step counts among the adult general population	Yes	RCTs	57	2000–2020	Ovid Medline, EMBASE, PsycINFO, Web of Science, Cochrane Library, CINAHL, and ASSIA	Adults ≥18 yr; mixed (community-based and primary care settings and workplace)	Physical activity	9% (5/57)	No
Cheatham et al. (47), 2018	US	To study the efficacy of wearable activity devices when used in a comprehensive weight loss program	No	Interventional studies	25	2005–2016	PubMed, CINAHL, SportDiscus, Proquest, and Google Scholar	Adults	Weight loss and adherence to weight loss program	24% (6/25)	Yes
Davergne et al. (48), 2018	France	To assess the adherence to and effectiveness of wearable activity trackers in patients with rheumatic and musculoskeletal diseases	Yes	RCTs and pre-post	17	2000–2018	Medline, Embase, PsycINFO, and Cochrane	Rheumatic and musculoskeletal diseases (lower extremity osteoarthritis, lower back pain), or chronic inflammatory rheumatic diseases (spondylarthritis, rheumatoid, psoriatic, or juvenile arthritis)	Physical activity	12% (2/17)	No

Continued

Table 1.—Continued

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Dehghan Ghahfarokhi et al. (49), 2022	Iran	To evaluate the efficacy of wearable and smartphone-based interventions to promote physical activity and improve quality of life and cardiovascular health outcomes among overweight/obese adults	Yes	RCTs and NRCTs	26	Inception to 2021	PubMed, the Cochrane Library, and Web of Science	Overweight/obese adults	Physical activity	12% (3/26)	Yes
Eboeime et al. (50), 2025	UK	To identify and appraise the evidence on the effectiveness of using wearable devices to promote physical activity and reduce pain in people with chronic musculoskeletal pain	No	RCTs and observational	13	Inception to 2023	PubMed, CINAHL, and Medline (Ovid)	Chronic musculoskeletal conditions	Physical activity and pain	61.5% (8/13)	No
Franssen et al. (51), 2020	Belgium	To evaluate the efficacy of consumer wearable activity tracker-based interventions to promote physical activity levels and cardiometabolic health in populations with chronic diseases	Yes	RCTs	35	Inception to 2019	PubMed, Embase, Web of Science, The Cochrane Central Register of Controlled Trials, and CINAHL	Adults ≥18 yr; chronic respiratory disease, type 2 diabetes, cardiovascular disease, overweight and obese, and Alzheimer's disease	Physical activity, cardiorespiratory fitness, and cardiovascular risk markers	6% (2/35)	No

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Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Gal et al. (52), 2018	The Netherlands	To evaluate the effectiveness of physical activity interventions using wearables and smartphone applications to promote physical activity in adult population	Yes	RCTs	18	2008–2017	PubMed, EMBASE, and the Cochrane Central Register of Controlled Trials	Adults	Physical activity	11% (2/18)	No
Gregory et al. (53), 2024	US	To determine the effectiveness of mHealth fitness/physical activity interventions on cardiorespiratory fitness outcomes among cancer patients and survivors	Yes	Interventional and observational studies	9	Inception to 2023	MEDLINE/PubMed, Scopus, and ClinicalTrials.gov	Cancer patients and/or cancer survivors	Cardiorespiratory fitness	33.3% (3/9)	No
Hannan et al. (54), 2019	Austria	To investigate the effect of Wearable PA monitoring devices in people with cardiovascular diseases	Yes	RCTs	5	Inception to 2019	NR	Myocardial infarction, acute coronary syndrome, percutaneous coronary intervention, coronary artery disease, history of cardiac surgery (coronary artery bypass graft, valvular repair or replacement)	Physical activity, cardiorespiratory fitness, QoL, depression, anxiety, and stress	40% (2/5)	No

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Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Lai et al. (55), 2023	Singapore	To evaluate the effectiveness of wearable-delivered sleep interventions on sleep outcomes among adults	Yes	RCTs	20	Inception to 2021	PubMed, EMBASE, Cochrane Library, Cumulative Index to Nursing and Allied Health Literature (EBSCO Publishing), PsycINFO (OvidSP), Scopus (Elsevier), Web of Science (Thomson Reuters), and ProQuest Dissertations and Theses Global	Individuals aged ≥ 18 yr old	Sleep duration, characteristics, and quality	35% (7/20)	No
Latif et al. (56), 2024	UK	To evaluate whether commercially available "off-the-shelf" wearable technology can improve patient rehabilitation outcomes	No	Interventional and observational studies	18	Inception to 2023	Embase, MEDLINE, Web of Science, and the Cochrane Library	Individuals undergoing rehabilitation after acute events (encompassing surgery, musculoskeletal injury, stroke, and undergoing cancer treatment)	Physical activity and upper limb movement	17% (3/18)	No
Liu et al. (57), 2020	Hong Kong	To evaluate the effectiveness of wearable activity tracker (WAT)-based interventions aimed at improving physical activity (PA) levels in sedentary older people	Yes	RCTs	11	2008–2018	Cochrane Library, MEDLINE, EMBASE, CINAHL, PsycINFO, Science Direct, Web of Science, and PubMed	Mixed older people (e.g., healthy, disease populations)	Physical activity and anthropometrics	9% (1/11)	No

Continued

Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Lynch et al. (58), 2020	Australia	To examine whether a fitness tracker (FT) intervention changes physical activity (PA) behavior compared to a control condition or compared to an alternative intervention	Yes	RCTs	21	2010–2019	PubMed, CINAHL, Cochrane CENTRAL, EMBASE, and PsycINFO	Community-based adults	Physical activity	10% (2/20)	No
Ocagli et al. (59), 2023	Italy	To evaluate how the use of wearable devices impacts physical activity in patients with non-inflammatory and inflammatory rheumatic diseases	Yes	RCTs and observational	51	2003–2021	MEDLINE via PubMed, Embase, CINAHL, and Scopus	Age ≥ 16 with non-inflammatory and inflammatory rheumatic diseases and connective tissue diseases	Physical activity	6% (3/51)	No
Oliveira et al. (60), 2018	Brazil	To investigate the effectiveness of physical activity-based interventions using electronic feedback in reducing pain and disability compared to minimal or no interventions in patients with chronic musculoskeletal pain	Yes	RCTs	4	1992–2015	EMBASE, MEDLINE, Cochrane Central Register of Controlled Trials, PsycINFO, Cumulative Index to Nursing and Allied Health Literature, SPORTDiscus, Web of Science, Physiotherapy Evidence Database, and main clinical trial registers	Adults (age ≥ 18) with chronic musculoskeletal pain lasting >3 mo. Patients were excluded if underwent surgery or had serious or inflammatory rheumatological conditions (e.g., tumor, fracture, infection, rheumatoid arthritis)	Pain, physical activity, GoL, and depression	75% (3/4)	No
Pan et al. (61), 2023	China	To study the effects of wearable devices on physical activity and health-related outcomes in breast cancer survivors	Yes	RCTs	16	2005–2021	PubMed, Embase, Web of Science, and Cochrane Library	Adults (age ≥ 18) who are survivors of breast cancer (any stage)	Physical activity, GoL, fatigue, and anxiety	38% (6/16)	No

Continued

Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Patel et al. (62), 2022	Canada	To examine the potential of wearable electronic devices to support heart failure self-care in ambulatory patients at home	No	RCTs and observational	6	2018–2021	MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review, and Other Nonindexed Citations and Daily, EMBASE, APA PsycINFO, and Cochrane Central Register of Controlled Trials, Ebsco databases included Cumulative Index to Nursing and Allied Health Literature Plus with Full Text.	Adults with heart failure	Level of physical activity, functional status, exercise capacity, adherence to exercise, intention to adhere to exercise, and self-efficacy in physical activity	33% (2/6)	No
Peng et al. (63), 2023	China	To evaluate the effects of the intervention using wearable activity monitors on blood glucose, blood pressure, blood lipid, weight, waist circumference, and body mass index in individuals with type 2 diabetes	Yes	RCTs	25	2004–2022	PubMed, Cochrane Library, Web of Science, and Embase	Adults (age ≥18) diagnosed with T2DM	Glucose homeostasis, physical activity (steps per day), and cardiovascular risk markers	20% (5/25)	Yes

Continued

Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Ringeval et al. (64), 2020	Canada	To assess the effectiveness of interventions that incorporate a Fitbit device for healthy lifestyle outcomes and to identify which additional intervention components or study characteristics are the most effective at improving healthy lifestyle outcomes	Yes	RCTs	37	2007–2019	MEDLINE, EMBASE, CINAHL, and CENTRAL (Cochrane)	Mixed (e.g., healthy, disease populations)	Physical activity and body weight	30% (11/37)	No
Sharp et al. (65), 2022	UK	To summarize the evidence from RCTs about the effectiveness of interventions to increase participation in physical activity (device-measured) and manage gestational weight gain in pregnant women	Yes	RCTs or quasi-RCTs	18	2013–2022	Cochrane Central Register of Controlled Trials (CENTRAL), Medline (EBSCO), SportDiscus (EBSCO), APA PsycINFO (EBSCO), Embase, and Web of Science	Pregnant women (≥ 18 yr), including those with or without high-risk pregnancy	Physical activity and body weight	28% (5/18)	No
Singh et al. (66), 2022	Australia	To evaluate the effect of wearable devices for improving physical activity and health-related outcomes in cancer survivors	Yes	RCTs	35 trials	2011–2019	CINAHL, Cochrane, Ebscohost, MEDLINE, Pubmed, ProQuest Health and Medical Complete, ProQuest Nursing and Allied Health Source, ScienceDirect, and SPORTDiscus	Any age with a diagnosis of cancer at any stage of treatment or multiple cancer types	Physical activity QoL, fatigue, aerobic fitness, and physical function, safety, and feasibility	26% (9/35)	Yes

Continued

Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Sypes et al. (67), 2019	US	Use of an electronic activity monitor system as a component of physical activity and weight-loss interventions in non-clinical populations	No	RCTs	22	Inception to 2017	MEDLINE (via Ovid), Medscape, PsycINFO, and Cochrane databases	Overweight or obese individuals	Physical activity and body weight	18% (4/22)	Yes
Szeto et al. (68), 2023	Australia	To evaluate the association of interventions that use wearable activity trackers during hospitalization with patient physical activity, sedentary behavior, clinical outcomes, and hospital efficiency outcomes	Yes	RCTs and NRCTs	15	Inception to 2022	OID MEDLINE, CINAHL, Embase, EmCare, PEDro, SportDiscuss, and Scopus	Adults who are hospitalized (i.e., aged 18 yr or older) with medical illnesses, undergoing rehabilitation or surgery	Physical activity, sedentary behavior, and hospital efficiency outcomes (e.g., LOS, readmission)	20% (3/15)	No
Tang et al. (69), 2020	Australia	To review the effectiveness of wearable trackers for improving physical activity and weight reduction among healthy adults	Yes	RCTs	12	2000–2017	MEDLINE, CINAHL, Cochrane Library, Web of Science, PubMed, and Scopus	Healthy and overweight	Physical activity and body weight	33% (4/12)	No
Teo et al. (70), 2023	Singapore	To evaluate the effect of wearable technology-assisted interventions on the physical activity and weight of breast cancer survivors	Yes	RCTs	17 RCTs in 19 articles	2005–2021	CINAHL, Cochrane Library, Embase, ERIC, IEEE Xplore, Pro-Quest Dissertations and Theses Global, PsycINFO, PubMed, Scopus, and Web of Science	Adults (≥18 yr) who survived breast cancer	Physical activity, sedentary behavior, and body anthropometric metrics	29.4% (5/17)	Yes

Continued

Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Thomas Craig et al. (71), 2021	US	To identify context-aware digital behavior change interventions (DBCIs) that provide individualized interventions to improve health	No	RCTs and observational studies	33 articles based on 30 studies	2013–2020	MEDLINE, the Cochrane Library, and Embase	Adults	Physical activity, sedentary behavior, and dietary behavior	3% (1/30)	No
Treadwell et al. (72), 2022	US	To summarize consumer blood pressure monitors that collect patient-generated health data for managing hypertension to summarize their clinical impact on health and surrogate outcomes	No	RCTs or single-arm studies	49	1999–2017	MEDLINE and Embase, in-process MEDLINE and PubMed unique content, and the Cochrane Database of Systematic Reviews	Included individuals who have (or may potentially develop) hypertension Excluded individuals with other health conditions, pregnant and postpartum women	QoL and blood pressure	2% (1/49)	No
Wang et al. (73), 2022	China	To evaluate the effectiveness of wearable devices as physical activity interventions on obesity-related anthropometric outcomes in children and adolescents	Yes	RCTs	12	Inception to 2021	PubMed, EMBASE, Cochrane Library, Scopus, and EBSCO	Children and adolescents aged 6–18 yr	Body composition	42% (5/12)	Yes

Continued

Table 1.—Continued

Author (Reference), Publication Year	Corresponding Author Country	Objective	Meta-Analysis (Yes/No)	Type of Included Studies (Observational, Interventional, Mixed)	Number of Included Studies	Literature Search Time Span	Databases Searched	Population	Health Outcomes	Percentage of Studies Using Wrist Wearables	Contributed to Our Meta-Analysis (Yes/no)
Wong et al. (74), 2022	Singapore	To assess the effectiveness of lifestyle interventions delivered by wearable technology in improving weight loss and physical activity among obese adults and to explore the effects of covariates on intervention outcomes	Yes	RCTs	30 RCTs in 31 articles	2006–2020	Cumulative Index to Nursing and Allied Health Literature, Cochrane Library, PubMed, PsycINFO, Excerpta Medica Database, ProQuest	Adults aged between 18 and 64 who were obese (body mass index ≥ 30 kg/m ²) or overweight (body mass index = 23–29.9 kg/m ²)	Body composition and cardiovascular risk markers	10% (3/30)	Yes
Wu et al. (75), 2023	China	To summarize the effectiveness of wearable activity trackers on PA and sedentary time in older adults	Yes	RCTs	45	2003–2022	PubMed, Web of Science, Google Scholar, Embase, Cochrane Library, and Scopus	Adults over 60 yr included. Participants were excluded if they suffered from severe cognitive impairment or mental illness or had any physical disability	Physical activity and sedentary time	16% (7/45)	Yes
Yen and Chiu (76), 2019	Taiwan	To investigate the effects of wearable technologies as physical activity interventions on weight control	Yes	RCTs	19	Inception to 2019	EBSCO, ScienceDirect, and PubMed	Adults	Body composition	37% (7/19)	Yes
Yien et al. (77), 2021	Taiwan	To explore the effectiveness of mobile health technology in reducing the body mass index of obese children	Yes	RCTs and review articles	9	2012–2019	Embase, Medline, Cochrane Library, Web of Science, and ScienceDirect	Children and adolescents (<18 yr) with obesity risks	Body anthropometrics	22% (2/9)	No

LOS, length of stay; NCBI, National Center for Biotechnology Information; NR, not reported; NRCT, nonrandomized clinical trial; QoL, quality of life; RCT, randomized clinical trial; UK, United Kingdom; US, United States.

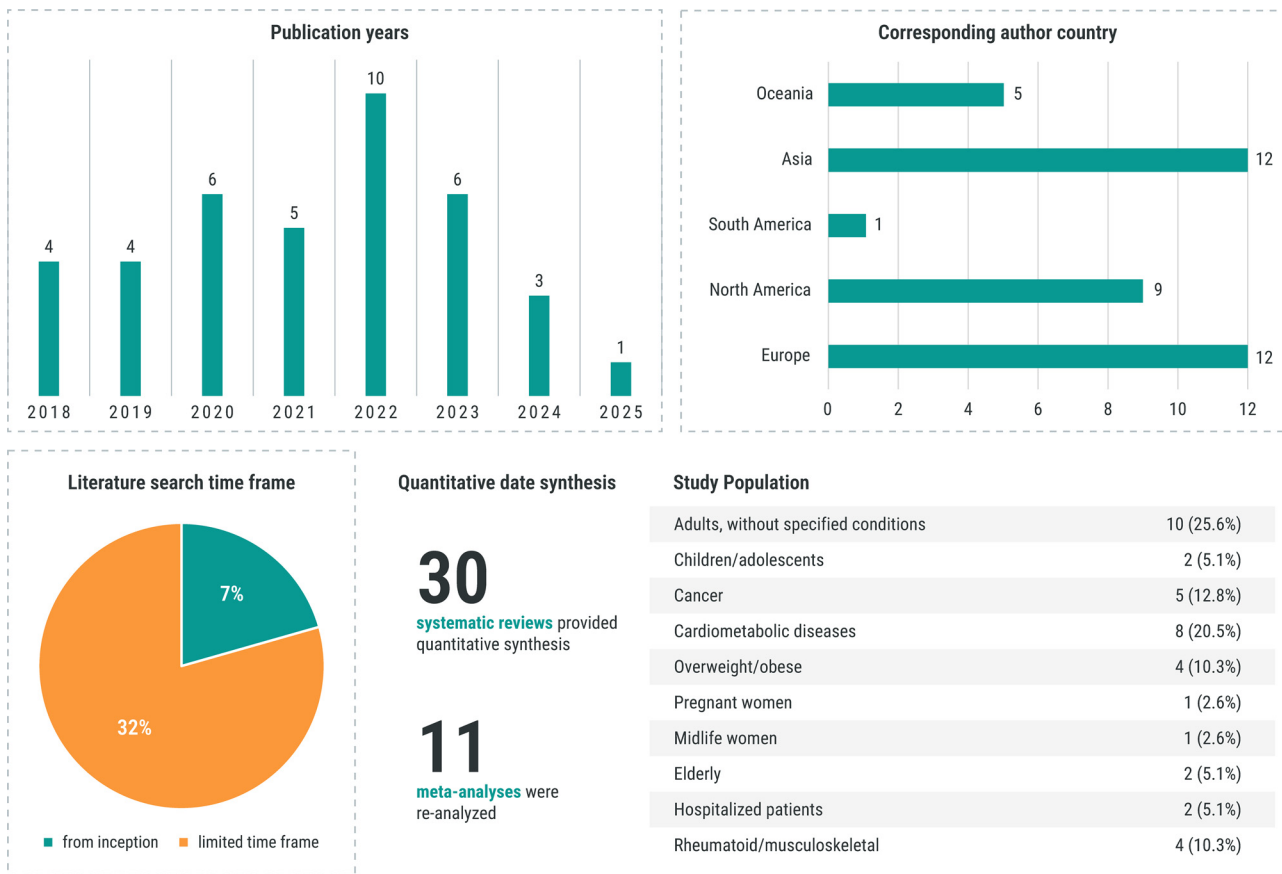


FIGURE 2. Summary of characteristics included systematic reviews. An overview of the year of publication, country of corresponding author, characteristics of the search strategies used, and the variety in study populations included across the 39 included systematic reviews is provided. The figure was created using Adobe Illustrator, and the icons used were obtained from Flaticon.com (Premium license).

25.6%), as well as insufficient exploration of heterogeneity across meta-analyses ($n = 9$; 23.4%). Moreover, most systematic reviews ($n = 33$; 84.6%) did not provide an exclusion list, which influenced their overall

confidence ratings since this was considered as a critical flaw; if this criterion is removed, then 22 (56.4%) systematic reviews would be rated as having high confidence. Additionally, 17.9% of the reviews ($n = 8$)

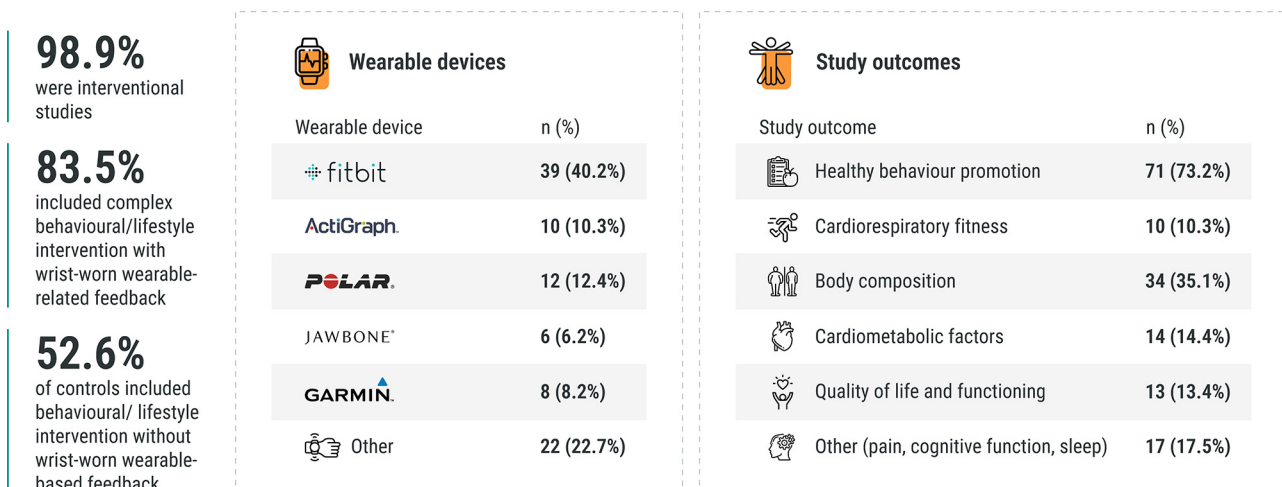


FIGURE 3. Summary of original interventional studies identified across included systematic reviews. Ninety-seven original interventional studies identified across 39 systematic reviews included in the current umbrella review are summarized. Provided is an overview of study designs, interventions, and controls used, as well as types of wearable devices and study outcomes considered. The figure was created using Adobe Illustrator, and the icons used in the figure were obtained from Flaticon.com (Premium license).

	Research question included PICO																Overall assessment
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	
AlSwayied et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↗
Antoniou et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Ashur et al., 2021	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Au et al., 2024	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↗
Blount et al., 2021	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Brickwood et al., 2019	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Chan et al., 2021	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Chaudhry et al., 2020	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Cheatham et al., 2018	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Davergne et al., 2019	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Dehghan Ghahfarokhi et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Eboreime et al., 2025	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Franssen et al., 2020	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Gal et al., 2018	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Gregory et al., 2024	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Hannan et al., 2019	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Lai et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Lattif et al., 2024	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Liu et al., 2020	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Lynch et al., 2020	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Ocagli et al., 2023	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↗
Oliveira et al., 2018	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↗
Pan et al., 2023	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Patel et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Peng et al., 2023	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Ringeval et al., 2020	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Sharp et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Singh et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Sypes et al., 2019	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Szeto et al., 2023	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↗
Tang et al., 2020	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Teo et al., 2023	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↗
Thomas Craig et al., 2021	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Treadwell et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Wang et al., 2022	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Wong et al., 2021	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Wu et al., 2023	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Yen et al., 2019	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘
Yen et al., 2021	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	↘

● Yes ● Probably yes ● No ● Not applicable ↗ High ↘ Low ↓ Critically low

did not register a study protocol. Most reviews assessed the risk of bias in original studies using the risk of bias (RoB) tool ($n = 26$; 66.7%), followed by the Physiotherapy Evidence Database (PEDro) scale ($n = 4$) and the Joanna Briggs Institute (JBI) checklist ($n = 2$). The remaining reviews employed other tools ($n = 7$), as detailed in Supplemental Table S2.

3.3. Healthy Behavior Promotion

Most identified systematic reviews reported on the effectiveness of wearable devices in healthy behavior promotion ($n = 28$; 71.8%) (39, 42–46, 48–52, 54–61, 64–71, 75). Physical activity (PA) was the most common health behavior targeted either solely or with sedentary behavior across the included reviews. Additionally, reviews considered changes in eating behavior (47, 49, 66, 71, 74), sleep quality (55), anxiety, and distress (54). When considering the overlapping systematic reviews (43, 44, 46, 51, 52, 54, 57, 58, 60, 61, 64, 66, 67, 69, 70), we were able to reanalyze the information from four systematic reviews (40, 49, 66, 75). Notably, exercise capacity improved in adults with cardiovascular diseases in interventions comprising feedback on physical activity engagement versus control group (SMD in $\dot{V}O_{2\max} = 0.3$; 95% CI: 0.2–0.59; $I^2 = 0\%$; TABLE 2). Wrist wearable activity trackers increased daily step count with the effect size of SMD = 0.62 (95% CI: 0.19–1.02; $I^2 = 0\%$) in overweight/obese population and in older adults (SMD = 0.97 (95% CI: 0.2–1.74; $I^2 = 87.19\%$). Total physical activity (SMD = 0.64; 95% CI: 0.18–1.1; $I^2 = 64\%$), moderate physical activity (SMD = 0.6; 95% CI: 0.28–0.93; $I^2 = 23.58\%$), and moderate-to-vigorous activity (SMD = 0.67; 95% CI: 0.34–1.0; $I^2 = 82.45\%$) increased and sedentary time decreased (SMD = -0.72 ; 95% CI: -1.3 to -0.14 ; $I^2 = 75.5\%$) in wearable-activity tracker assisted intervention in cancer survivors. There was no strong evidence of an excess of significant results, nor publication bias. Among older adults, moderate-to-vigorous activity increased (SMD = 0.95; 95% CI: 0.2–1.72; $I^2 = 93.25\%$) in a wearable-activity tracker-assisted intervention as compared to

control, and there was an indication of potential publication bias. No changes in light PA or in step counts were observed between the intervention and control group (TABLE 2).

Findings from our meta-analyses, although based on limited number of RCTs (ranging between 2 and 9 RCTs depending on the study outcome), are in line with findings across the other systematic reviews (TABLE 3), in which most of the included original RCTs (65.5%) reported a significant increase in physical activity after complex behavioral/lifestyle interventions incorporating wearable activity monitors and feedback to study participants. Twelve original RCTs focused on simple, single-component interventions designed to promote PA. These studies incorporated wearable device-based feedback for participants. Notably, 91.7% of trials demonstrated significant improvements in physical activity levels among the intervention groups compared to their respective control groups (TABLE 3). We provide a brief overview of the findings from reviews that were not included in our meta-analyses below.

Szeto et al. (68) summarized the evidence on the effectiveness of wearable activity monitor use in inpatient settings to estimate physical activity pre- and postsurgery. Women undergoing gynecologic surgery monitored their step counts and were encouraged to achieve individualized daily step-count goals demonstrated increased physical activity compared to the control group. However, no significant differences in pain levels, fatigue, or length of hospital stay were observed between the two groups (78). The group of patients undergoing knee and hip arthroplasty wearing an activity tracker and receiving feedback were 1.7 times more likely to achieve a mean of 7,000 steps per day than the subjects without feedback at 6 wk after surgery versus the group that received no feedback (79). Similarly, patients undergoing laparoscopic surgery who received feedback of their step counts using an activity tracker wristband increased the average step count during the first 5 postoperative days (80). The group of patients undergoing knee and hip arthroplasty wearing

FIGURE 4. Risk-of-bias (RoB) assessment using a measurement tool to assess systematic reviews (AMSTAR-2) is depicted for the following studies: AISwayied et al. (39), Antoniou et al. (40), Ashur et al. (41), Au et al. (42), Blount et al. (43), Brickwood et al. (44) Chan et al. (45), Chaudhry et al. (46), Cheatham et al. (47), Davergne et al. (48), Dehghan Ghahfarokhi et al. (49), Eboreime et al. (50), Franssen et al. (51), Gal et al. (52), Gregory et al. (53), Hannan et al. (54), Lai et al. (55), Latif et al. (56), Liu et al. (57), Lynch et al. (58), Ocagli et al. (59), Oliveira et al. (60), Pan et al. (61), Patel et al. (62), Peng et al. (63), Sharp et al. (65), Singh et al. (66), Sypes et al. (67), Szeto et al. (68), Tang et al. (69), Teo et al. (70), Thomas Craig et al. (71), Treadwell et al. (72), Wang et al. (73), Wong et al. (74), Wu et al. (75), and Yen and Chiu (76). This tool is a 16-item checklist designed to assess the quality of systematic reviews, with 7 items considered critical due to their impact on the validity of a review. These critical items include protocol registration, adequacy of search strategy, justification for excluding studies, risk-of-bias assessment, appropriateness of meta-analytical methods, use of risk of bias in interpretation, and assessment of publication bias. The remaining 9 items are classified as noncritical. Reviews are categorized into 4 confidence levels: high confidence (0 critical weaknesses and fewer than 3 noncritical weaknesses), moderate confidence (1 critical weakness and fewer than 3 noncritical weaknesses), low confidence (more than 1 critical weakness and fewer than 3 noncritical weaknesses), and critically low confidence (more than 1 critical weakness and or more noncritical weaknesses). NRSI, nonrandomized study of interventions; PICO, population/problem, intervention, comparison, and outcome; RCT, randomized clinical trial. The figure was created using Adobe Illustrator.

Table 2. Meta-analysis summary

Study Outcome/Systematic Review	Study Population	Number of Studies	Total Sample Size (Number of People in Intervention and Control Arms)	SMD (95% CI)	I ²	Evidence for Excess Significance	Evidence for Publication Bias
Total physical activity							
Singh et al. (66), 2022	Cancer	5	239 (121; 118)	0.64 (0.18; 1.1)	64.05%	No	No
Light physical activity							
Singh et al. (66), 2022	Cancer	4	132 (69; 63)	0.16 (−0.19; 0.52)	0%	NA	NA
Moderate physical activity							
Singh et al. (66), 2022	Cancer	4	207 (104; 103)	0.6 (0.28; 0.93)	23.58%	NA	NA
Vigorous physical activity							
Singh et al. (66), 2022	Cancer	3	148 (70; 78)	0.67 (0.34; 1)	0%	NA	NA
Moderate to vigorous physical activity							
Singh et al. (66), 2022	Cancer	9	471 (239; 232)	0.53 (0.07; 1)	82.49%	NA	NA
Wu et al. (75), 2023	Older adults	6	530 (269; 261)	0.95 (0.2; 1.72)	93.25%	No	Yes
Steps count							
Singh et al. (66), 2022	Cancer	3	158 (80; 78)	−1.25 (−4.44; 1.93)	98.47%	NA	NA
Dehghan Ghahfarokh et al. (49), 2022	Overweight/obese adults	2	90 (44; 46)	0.62 (0.2; 1.05)	0%	NA	NA
Wu et al. (75), 2023	Older adults	5	255 (126; 129)	0.97 (0.2; 1.74)	87.19%	No	No
Sedentary time							
Singh et al. (66), 2022	Cancer	5	333 (151; 182)	−0.72 (−1.3; −0.14)	75.47%	No	No
Exercise capacity ($\dot{V}O_{2max}$)							
Antoniou et al. (40), 2022	Cardiovascular diseases	3	199 (98; 101)	0.3 (0.2; 0.59)	0%	No	NA
Body weight							
Wong et al. (74), 2022	Overweight/obese adults	2	460 (240; 220)	−0.16 (−0.61; 0.29)	0%	NA	NA
Yen and Chiu (76), 2019	Adults	7	959 (492; 467)	−0.28 (−0.57; 0.01)	65.93%	NA	No
Cheatham et al. (47), 2018	Adults	2	222 (114; 108)	−1.04 (−2.44; 0.36)	95.07%	NA	NA
Teo et al. (70), 2023	Breast cancer survivors	2	51 (29; 22)	0.02 (−0.55; 0.59)	0%	NA	NA
Body mass index							
Yen and Chiu (76), 2019	Adults	3	755 (378; 377)	−0.45 (−0.98; 0.08)	89.32%	NA	NA
Sypes et al. (67), 2019	Overweight/obese	2	97 (56; 41)	−0.28 (−0.77; 0.22)	0%	NA	NA

Continued

Table 2.—Continued

Study Outcome/Systematic Review	Study Population	Number of Studies	Total Sample Size (Number of People in Intervention and Control Arms)	SMD (95% CI)	I^2	Evidence for Excess Significance	Evidence for Publication Bias
Wang et al. (73), 2022	Children and adolescents	2	369 (202; 167)	−0.01 (−0.29; 0.27)	39.53%	NA	NA
Peng et al. (63), 2023	Type 2 diabetes	3	102 (58; 44)	−0.72 (−1.69; 0.24)	0%	NA	NA
Waist circumference							
Wang et al., 2022 (73)	Children and adolescents	2	231 (112; 119)	−0.28 (−0.86; 0.29)	39.53%	NA	NA
Cheatham et al. (47), 2018	Adults	2	94 (50; 44)	−1.69 (−4.03; 0.65)	94.44%	NA	NA
Body fat percentage							
Wang et al. (73), 2022	Children and adolescents	3	307 (169; 138)	0.1 (−0.2; 0.39)	0%	NA	NA
Sypes et al. (67), 2019	Overweight/obese	2	97 (56; 41)	−0.2 (−0.73; 0.32)	11.43%	NA	NA
Fasting glucose							
Peng et al. (63), 2023	Type 2 diabetes	3	90 (46; 44)	−1.63 (−3.22; −0.03)	89.93%	NA	NA
Hemoglobin A1C							
Peng et al. (63), 2023	Type 2 diabetes	5	266 (138; 128)	−0.63 (−1.4; 0.14)	87.63%	No	No
Total cholesterol							
Peng et al. (63), 2023	Type 2 diabetes	2	50 (26; 24)	−0.71 (−2.43; 1.01)	86.83%	NA	NA
HDL cholesterol							
Peng et al. (63), 2023	Type 2 diabetes	2	48 (26; 24)	0.33 (−0.31; 0.97)	18.79%	NA	NA
LDL cholesterol							
Peng et al. (63), 2023	Type 2 diabetes	2	50 (26; 24)	−0.74 (−1.59; 0.1)	49.53%	NA	NA
Triglycerides							
Peng et al. (63), 2023	Type 2 diabetes	2	50 (26; 24)	−0.32 (−0.95; 0.31)	15.39%	NA	NA
Systolic blood pressure							
Peng et al. (63), 2023	Type 2 diabetes	4	120 (60; 60)	0.31 (−0.3; 0.94)	63.39%	NA	NA
Diastolic blood pressure							
Peng et al. (63), 2023	Type 2 diabetes	2	40 (20; 20)	−1.18 (−2.02; −0.34)	48.13%	No	NA

The standardized mean difference (SMD) is a unitless measure of effect size that allows comparisons across variables measured on different scales. It represents the difference between groups in standard deviation units. According to conventional thresholds, an SMD of approximately 0.2 is considered a small effect, around 0.5 a medium effect, 0.8 a large effect, and values greater than 1.2 indicate a very large effect. CI, confidence interval; NA, not applicable. Statistically significant results are in boldface ($P < .05$).

an activity tracker and receiving feedback were 1.7 times more likely to achieve a mean of 7,000 steps per day than those without feedback at 6 weeks after surgery (79). Chan et al. (45) summarized the efficacy of wearable

activity monitors as a feedback and monitoring tool in home-based exercise programs for patients with intermittent claudication and identified four RCTs using wrist wearables (81–84). Maximum walking distance, peak

Table 3. Summary of overall findings based on meta-analysis and narrative synthesis of evidence

Health Outcomes	Complex Interventions		Simple, Single-Component Intervention
	Findings from our Meta-Analysis	Narrative Synthesis	Narrative Synthesis
Physical activity (total, LPA, MVP, MVPA, steps count, and exercise capacity)	<p>A meta-analysis based on Singh et al. (66) systematic review reanalysis showed medium positive effect for improvement in total PA, MVPA, MPA, and VPA and decreased sedentary time in individuals with cancer.</p> <p>A meta-analysis based on Dehghan Ghahfarokhi et al. (49) systematic review reanalysis showed medium effect size in increased step count in overweight/obese individuals.</p> <p>A meta-analysis based on Wu et al. (75) systematic review showed large effect size in increased steps count in older adults.</p> <p>A meta-analysis based on Antoniou et al. (40) systematic review reanalysis in adults with cardiovascular diseases showed small effect size in $\dot{V}O_{2max}$ increase in adults with cardiovascular diseases.</p>	65.6% (21/32) of original RCTs identified across 15 systematic reviews showed improvement in intervention vs. controls; others showed no differences.	91.7% (11/12) of original studies identified across 11 systematic reviews showed improvements in intervention vs. control group.
Eating attitude		100% (4/4) of original RCTs identified across 2 systematic reviews showed improvement in different aspects of eating attitudes after complex interventions incorporating wearables-based feedback.	
Sleep		50% (3/6) original RCTs identified across a single systematic review showed improvements in some aspects of sleep (e.g., quantity or quality).	None (0/1) of RCTs identified across 1 systematic review showed improvements in sleep quality in comparison to control group.
Body composition	Based on 5 meta-analyses based on Wong et al. (74), Yen and Chiu (76), Teo et al. (70), Peng et al. (63), and Wang et al. (73), systematic review reanalysis in adults with cardiovascular diseases showed no significant differences in body composition parameters between intervention and control groups.	57% (4/7) of original RCTs identified across 3 systematic reviews showed improvement in intervention vs. controls; others showed no differences.	
CVD markers (blood lipids, glucose, and blood pressure)	A meta-analysis based on Peng et al. (63) systematic review reanalysis showed large positive effect of intervention on diastolic blood pressure and glucose decrease in comparison to control group. No differences were seen in gbA1C and systolic blood pressure and blood lipids.		<p>A single pilot RCT, which did not contribute to the meta-analysis, did not demonstrate significant difference between continuous blood pressure monitoring using wrist-blood pressure cuff vs. standard care.</p> <p>Blood pressure and anthropometrics were similar between the intervention group (physical activity regime with weekly feedback to study participants) and usual care at baseline and remained stable during the follow-up period.</p>

Continued

Table 3.—Continued

Health Outcomes	Complex Interventions		Simple, Single-Component Intervention
	Findings from our Meta-Analysis	Narrative Synthesis	Narrative Synthesis
Quality of life		50% (2/4) RCTs identified across 2 systematic reviews showed improvement in QoL after complex interventions incorporating wearables-based feedback.	
Anxiety, depression, and stress		50% (1/2) of RCTs identified across 2 systematic reviews showed improvement in depressive symptoms after interventions incorporating wearables-based feedback.	
Pain		80% (4/5) RCTs identified across 4 systematic reviews showed improvement in pain after complex interventions incorporating wearables-based feedback (all in people with musculoskeletal problems).	0% (0/2) of RCTs identified across 2 systematic reviews showed differences between intervention vs. control group in pain among women undergoing a gynecologic surgery.
Length of hospital stay			0% (0/2) of RCTs identified across a single systematic review showed differences between intervention vs. control group in length of hospital stay among people undergoing major visceral surgery.

CVD, cardiovascular disease; LPA, low physical activity; MVPA, moderate-to-vigorous physical activity; MPA, moderate physical activity; MPV, moderate to vigorous; PA, physical activity; QoL, quality of life; RCTs, randomized clinical trial; VPA, vigorous physical activity.

walking time, and claudication distance significantly increased in the wearable activity monitor intervention but not in control group (usual care and supervised exercise therapy) (81–84). Lai et al. (55) reviewed the evidence on the effectiveness of wearable-delivered sleep interventions in improving sleep outcomes among adults. While their meta-analysis included 20 RCTs, only seven focused specifically on wrist-worn devices that provided personalized feedback to participants. Among the complex interventions that combined wearable-based feedback with lifestyle or educational components targeting sleep, 50% of the RCTs reported improvements in certain aspects of sleep, such as quantity or quality (55).

3.4. Cardiometabolic Health Outcomes

Nineteen systematic reviews focused on the use of wearable devices in the context of improving cardiometabolic health outcomes (e.g., cardiorespiratory fitness, body composition, blood lipids, blood glucose, blood pressure). Most of the systematic reviews ($n = 10$; 55.6%) considered the body composition and weight control-related study outcome (47, 65, 67, 69–71, 73, 74, 76, 77). Other systematic reviews explored the effectiveness of complex lifestyle/behavior interventions combined with personalized

feedback from wearable devices on cardiometabolic biomarkers among populations with type 2 diabetes (63), hypertension (72), cardiovascular diseases (40, 41, 45, 54, 62), and chronic diseases (51, 53). After considering the overlapping studies (40, 41, 67, 69, 73, 77) and focusing only on RCTs that used the wrist wearable device-assisted interventions, we were able to meta-analyze information from eight systematic reviews. Among individuals with type 2 diabetes, interventions incorporating wrist-wearable feedback yield a large positive effect on diastolic blood pressure (SMD = -1.18 ; 95% CI: -2.02 to -0.34 ; $I^2 = 48.13\%$) and fasting glucose (SMD = -1.63 ; 95% CI: -3.22 to -0.03 ; $I^2 = 89.93\%$) decrease in comparison to control group with no evidence of excess significant results. No differences were seen in body weight, glycated hemoglobin, systolic blood pressure, and blood lipids, TABLE 2. Based on five meta-analyses including a limited number of RCTs, the feedback from wrist-worn wearables did not yield significant differences in body composition parameters among individuals with cardiovascular disease in comparison to control intervention (TABLE 2). On the original study level, four RCTs (57%) identified across three systematic reviews showed improvement in anthropometrics in intervention versus controls; others showed no differences. Further below,

we provide a brief overview of the findings from reviews that were not included in our meta-analyses.

A systematic review by Ashur et al. (41) explored the effectiveness of wrist-worn wearable activity monitors in individuals undergoing cardiac rehabilitation, and only a single RCT met our inclusion criteria. Blood pressure and anthropometrics were similar between the intervention group (physical activity regime with weekly feedback to study participants) and usual care at baseline and remained stable during the follow-up period (85). A systematic review by Treadwell et al. (72) studied the effectiveness of continuous blood pressure monitoring on several health outcomes in people with hypertension. Only a single pilot RCT met our inclusion criteria. In both, intervention group (incorporating blood pressure monitoring using the wrist-cuff blood pressure monitor) and the control group (with no blood pressure monitoring), modest linear reductions in systolic and diastolic blood pressure were observed after 6 mo, and there was no statistically significant difference between the two groups (86). A systematic review by Sharp et al. (65) summarized the evidence about the effectiveness of interventions to manage gestational weight gain in pregnant women. Among the three eligible RCTs, none showed differences in gestational weight gain between intervention and control groups (87–89).

3.5. Other Health Outcomes

Among the included systematic reviews, 13 explored the role of wearables on quality of life (QoL), physiological distress, pain management, and functioning across various populations and predominantly involving individuals with cardiometabolic diseases (40, 43, 45, 49, 50, 54, 59, 60, 62, 66, 68, 72, 90). Since the number of original studies identified across systematic reviews was limited, here we summarize the evidence from original trials identified across the above-mentioned systematic reviews. Two RCTs comparing home-based telerehabilitation with wearable-based feedback to regular outpatient training for cardiac rehabilitation patients showed significant improvements in exercise capacity and QoL (91, 92). However, a separate 3-mo study found that while a home-based intervention with wearable feedback improved exercise capacity, it did not significantly impact QoL (85). For heart failure patients, the HeartMan intervention, which incorporated sporadic blood pressure monitoring with patient feedback, demonstrated improved self-care behavior compared to standard care (93). Similarly, a 6-mo mobile health intervention for hypertension self-monitoring led to improvements in systolic blood pressure and medication adherence self-efficacy (86). A pilot RCT comparing smartwatch-based exercise interventions with and without activity trackers showed no changes in QoL among

cancer survivors (94). Another study found significant improvements in cognitive function and physical activity among breast cancer survivors who monitored their activity levels as compared to the usual care group (95). For individuals with knee osteoarthritis, a multifaceted wearable-based program did not yield changes in depressive symptoms (96). In the surgical realm, activity trackers showed promise in enhancing perioperative mobilization after laparoscopic and gynecologic surgeries. These interventions were associated with increased physical activity and, in some cases, lower morbidity and but there was no link with shorter hospital stay (78–80).

Further, Eboime et al. (50), Oliveira et al. (60), Ocagli et al. (59), and Davergne et al. (90) summarized the evidence on wearable activity monitors on mobility in patients with musculoskeletal, rheumatoid, and inflammatory diseases. Eighty percent ($n = 4$) of RCTs identified across those systematic reviews showed improvement in pain after complex interventions incorporating wearable-based feedback, while no benefits of simple (single-component interventions) were reported (TABLE 3). In particular, wearable-activity monitor-assisted intervention led to improvement in pain and perceived walking habits in patients with rheumatoid arthritis and systemic lupus erythematosus, and improved physical activity in those with knee osteoarthritis (96, 97). Further, the use of a novel smartphone app in conjunction with a wearable activity monitor provided additional improvement on mobility parameters and pain with walking in the 6-min walk test in patients with knee osteoarthritis who were treated with hylan G-F 20 (injection into the knee joint meant to lubricate and cushion the joint) (98). Wearables-based walking intervention in addition to the usual physiotherapy care in individuals with low back pain with medium or high risk of chronicity improved pain symptoms in comparison to usual physiotherapy care (99).

3.6. Other Wearable Devices

In addition to the main focus of our umbrella review, we identified 70 potentially relevant systematic reviews examining wearable devices worn on various body parts other than the wrist such as pedometers or continuous glucose monitoring sensors. About half of these systematic reviews focused on glucose monitoring and outcomes ($n = 33$; 47.1%). Other topics considered were physical activity or cardiorespiratory fitness ($n = 14$; 20.0%), weight management ($n = 6$; 8.5%), functioning and quality of life ($n = 8$; 11.4%), blood pressure regulation ($n = 3$; 4.3%), and other outcomes ($n = 6$; 8.5%). Since those sensors are worn on locations like the hip or upper arm, they were not included in the current umbrella review due to our specific focus on wrist-worn devices. For a descriptive summary of these articles,

please consult Supplemental Table S3. This summary outlines the research questions addressed, the types of wearable devices used, and the primary outcomes investigated in each study.

4. DISCUSSION

This umbrella review summarizes the effectiveness of interventions incorporating feedback from wrist-worn wearable devices. This study analyzed 39 systematic reviews with evidence from 97 interventional studies. Most of the systematic reviews addressed physical activity outcomes and found that complex lifestyle/behavioral interventions incorporating feedback from wrist-wearable activity trackers consistently outperformed controls for physical activity outcomes with moderate to large effect sizes. Fewer systematic reviews addressed cardiometabolic risk markers, and the effect sizes were smaller, and often nonsignificant. Only a few systematic reviews addressed psychosocial outcomes, and the evidence on the effect of wrist-wearables feedback on quality of life, depression/anxiety, and pain was limited and often inconstant. There is a high heterogeneity across studied interventions, control groups, type of personalized feedback, and underlying populations, which limits the generalizability of those findings.

4.1. Strengths and Limitations of Current Umbrella Review

To our knowledge, this is the first umbrella review regarding the effectiveness of wrist wearable devices-based interventions to improve very diverse types of health outcomes ranging from health promotion to disease risk, recovery or prognosis. When interpreting our findings, it is important to consider the inherent limitations of umbrella reviews. These include reliance on the quality of the included systematic reviews and the potential omission of relevant new studies or reviews that had not yet been published at the time of our search. Additionally, variations in study populations, interventions, outcomes, and methodologies across the included reviews can hinder the ability to draw clear and generalizable conclusions.

To enhance the reliability of our findings, we employed a highly sensitive search strategy to identify as many relevant studies as possible. Where feasible, we conducted meta-analyses using standardized research methods and cross-checked the original studies included in the systematic reviews. To focus on the role of wearable feedback as an active intervention component, we restricted inclusion to studies in which wearables were used to deliver feedback. In contrast, we excluded studies where wearables were only used to measure exposure or

outcomes in both intervention and control groups. However, we acknowledge a key methodological challenge: it remains unclear whether the use of wearables solely for measurement may influence the effectiveness of a behavioral intervention. In theory, wearable feedback could enhance a well-designed intervention, while having little to no impact in a control condition with poor engagement or support. Disentangling such potential augmentation effects is difficult, especially when both groups use the same devices, and it is often not possible to determine whether wearable data were used equally by participants in both arms.

In our narrative synthesis, we distinguished between studies employing complex behavioral interventions with personalized wearable feedback and those using simpler, single-component interventions (e.g., physical activity prescriptions) paired with wearable feedback. Notably, no study evaluated the isolated effectiveness of wearable devices alone. In most cases, wearables were embedded within broader behavioral strategies that also included educational, motivational, or lifestyle components. For wearable feedback to be effective, users must understand and act upon the information, often requiring additional support or interaction. As such, isolating the independent effect of wearables remains methodologically challenging and most likely not feasible with the current evidence base.

4.2. Behavioral, Physiological, and Clinical Relevance

Wearables align closely with the Oinas-Kukkonen concept of behavior change support systems (100). These devices serve as digital companions in the journey toward better well-being, providing tools that cater to various stages of behavioral modification. For instance, wearables excel in reinforcing positive behaviors by gamifying exercise through detailed workout histories and performance metrics, making fitness routines more appealing and sustainable. This multifaceted approach allows users to actively engage in their health improvement, whether they are initiating new healthy habits, modifying existing ones, or maintaining positive behaviors already in place (100). Wearable devices are increasingly equipped with integrated behavior change strategies designed to actively motivate users toward healthier habits. Common features include goal setting, which allows users to establish personalized targets; prompts and cues that provide timely reminders to stay on track; rewards that recognize achievements and make the journey enjoyable; and social support mechanisms that foster community (101). This is evident in the existing literature. The interventions that were involved in the eligible studies were rather complex and heterogeneity stemmed from various factors

intrinsic to the intervention, such as the number of components, the diversity of behaviors addressed, the expertise and skills demanded from both the deliverers and recipients of the intervention, or the allowable level of flexibility in the intervention or its components and wearable feedback delivery elements (i.e., characteristics of the feedback message, variations in feedback frequency, its content or user-interface complexity).

The use of wearable devices not only supports behavior change but also has significant physiological implications. The continuous monitoring provided by wearables enables real-time insights into fundamental physiological systems such as cardiovascular regulation, metabolic homeostasis, and circadian biology (102, 103). For example, wearables that track heart rate variability offer insights into autonomic nervous system regulation, which can reveal how the body adapts to stress and recovery (104). Similarly, devices that monitor physical activity and sleep patterns contribute to a better understanding of metabolic processes, including energy expenditure and glucose regulation, as well as diurnal patterns, which are critical for overall health and well-being (105). Wearables further provide valuable data on the dynamic interplay between physiological systems, allowing researchers to identify patterns of variability that may signal early signs of disease or health deterioration (106). For instance, the integration of activity tracking with heart rate data may reveal how exercise impacts cardiovascular health, while sleep-monitoring wearables could inform our understanding of circadian misalignment and its effects on metabolic function (107, 108).

The results of our meta-analysis on the effectiveness of wearable activity monitor feedback to improve physical activity and decrease sedentary time appear robust and are supported by findings from another umbrella review (27). Based on a narrative synthesis of 11 RCTs (78–80, 86, 95, 109–114) that did not contribute to our meta-analysis, results remained consistent. It appears that wearable activity monitor feedback either alone or integrated within complex lifestyle/behavioral interventions improves engagement in physical activity.

In contrast to the clear benefits in behavioral change, the current evidence does not demonstrate clear, significant benefits of interventions incorporating wearable feedback on cardiometabolic disease markers, quality of life, and other health-related outcomes. This discrepancy could be due to multiple reasons. First, a significant number of studies were categorized as either pilot or feasibility studies ($n = 36$; 37.1%). Such trials may be underpowered to achieve statistical significance at the commonly used 5% level. However, pilot studies also tend to be affected more by selective reporting and by generalizability biases (115, 116). Thus, the published

literature may present, on average, exaggerated effect sizes, if anything. Second, the control group consisted of waiting list/usual care/usual activity patterns/active control (depending on the context), and the heterogeneity in underlying control groups can at least partially be responsible for the lack of intervention effectiveness observed in some of the trials. Due to the limited number of RCTs using wrist-worn wearables, we were not able to perform a subgroup analysis or meaningfully use meta-regression approaches to explore the sources of high heterogeneity, which was observed in 35% of the meta-analyses. Third, nearly all identified studies were complex, multicomponent interventions, making it difficult to distinguish the specific influence of the wearable device itself from that of additional exercise prescriptions and/or educational/motivational strategies on cardiometabolic disease markers and other outcomes beyond the increase in physical activity. To address this literature gap, researchers may consider applying a multifactorial study design that allows for the assessment of individual intervention components' effects, unlike traditional RCTs that evaluate interventions as a whole. The multiphase optimization strategy (MOST) framework can be utilized to develop and optimize multicomponent interventions (117). Fourth, the duration of follow-up may have been too limited to demonstrate benefits in hard outcomes that may take many years to emerge. However, the same argument (lack of long-term follow-up) may be raised to question whether the demonstrated benefits of physical activity would be sustainable in the long term. Many people use wearables only sporadically (118). Long-term use of wearables has been shown to be associated with using a wider variety of functions, wearing the wearable every day, being female, exercising more frequently, having higher education, not engaging in step count competition, and not having chronic conditions (119). Most of these factors suggest that high-risk populations (e.g., men, sedentary, lower socioeconomic status, with multiple comorbidities) may engage less with wearables and thus may be less likely to reap long-term benefits, even though they might have benefited the most.

4.3. Extending to Other Wearable Sensors and Evolving Technologies

Our focus was on wrist-worn wearable devices that provided feedback on simple metrics such as number of steps, active time, sedentary time, heart rate, and blood pressure. There is an increasing number of complex wearable sensors (worn on other body parts) that measure physical parameters and biochemical markers simultaneously. Without doubt, these sensors may play a significant role in advancing precision medicine by

enabling measurement of clinically relevant parameters. However, their use beyond exploratory research purposes, particularly in the context of personalized feedback to users, remains challenging, as they often provide sophisticated data that may be difficult for users to interpret (120). While wearable technology has greatly enhanced our ability to collect a diverse array of physiological data, our capacity to interpret this data through algorithms remains significantly behind (1). Researchers are actively developing advanced methods for continuous time series data analysis and sensor fusion, which aim to integrate multiple sensor types for a more comprehensive understanding of health. These efforts are crucial for translating raw data into actionable health insights, addressing the current limitations in algorithmic interpretation. In Supplemental Table S3, we have provided a summary of an additional 70 potentially eligible systematic reviews focusing on other wearable technologies (beyond wrist-worn sensors). The existing umbrella reviews fail to differentiate between interventions that integrate wearable feedback and those that use wearables solely for intervention or outcome monitoring (25, 26, 121–123). Thus, it would be beneficial to incorporate this literature into a comprehensive umbrella review once the field becomes more mature.

4.4. Conclusions

Lifestyle and behavioral interventions that incorporate feedback from wrist-worn wearable activity trackers are effective in increasing physical activity across diverse populations, including individuals of older age, with cancer, and with obesity. Consequently, programs aimed at stimulating physical activity may benefit from integrating these devices. However, the impact of such interventions on health-related clinical outcomes and quality of life remains unclear. Future studies with sufficient statistical power and long-term follow-up are needed to address current methodological limitations and to clarify the extent to which wearable-guided interventions translate into sustained health benefits. In addition, further research should examine how tailored applications or feedback mechanisms may optimize user motivation and interpretation of the data. Finally, considerations of data privacy and security are essential, as these devices often connect to third-party applications and cloud-based services, the risk of unauthorized access or misuse of health-related information exists. While this study focused on the health-promoting potential of wearable devices, future research and policy discussions should also consider the development of robust data protection standards and transparent governance frameworks to ensure the safe use of wearable-derived data.

APPENDIX A: SEARCH STRATEGY USED IN CURRENT UMBRELLA REVIEW

The date of the last run search was March 18th, 2025.

Information sources and content coverage dates were as follows:

- 1) MEDLINE (R) ALL (Ovid), Coverage 1946 to Present;
- 2) Embase (Ovid), Coverage 1974 to Present;
- 3) Cochrane Library (Wiley), Coverage, 1996 to Present; and
- 4) Web of Science, Coverage, 1900 to Present.

The search strategy and deduplication process were as follows.

The literature search was performed by combining controlled vocabulary terms (e.g., MeSH, Emtree) and free text terms for the following concepts: wearable electronic devices, wireless technology, monitoring, telemetry, accelerometry, fitness trackers, blood pressure monitoring, and glucose monitoring. No language or date limits were applied. Filters for systematic review and meta-analysis were implemented in all databases. Search strategies were translated accordingly for each information source. Duplicates were removed with Deduplick, a fully automated deduplication software, and complemented with the duplicate function of EndNote. A new total of 7,710 records were prepared for screening (124).

A1. MEDLINE (R) ALL (Ovid)

Ovid MEDLINE(R) ALL <1946 to October 13rd, 2023>
n=3866

- 1) Wearable Electronic Devices/ 7974
- 2) Wireless Technology/ 4705
- 3) Monitoring, Physiologic/ 58822
- 4) (health monitor* or health watch or mobile health technolog* or (wireless adj3 technology) or mobile electrochemical or (patch* adj1 (skin or epidermal)) or (smart adj1 (band or device? or patch* or watch)) or smartband or smartpatch or smartwatch or wearable* or (wireless adj1 sensor?) or (wrist adj2 (band or watch or strap or worn or bracelets)) or wristband or wristwatch or arm band or armband or arm-band or (monitor* adj2 (nutrition or intake or physiologic*))).tw. 45457
- 5) exp telemetry/ 15236
- 6) (telemetr* or (remote adj2 sensing)).tw. 21757
- 7) Accelerometry/ 7618
- 8) (acceleromet* or (step? adj1 count*) or step-based or telesensing or workout tracking or gyroscopes or magnetometers or (activit* adj1 (monitor* or tracker* or device-derived or device-measured))).tw. 31908
- 9) Actigraphy/ 4772

- 10) (actigraph? or polysomnogra* or (sleep* adj3 (track* or self-monitor* or self monitor*)))tw. 31753
 - 1) Fitness Trackers/ 1141
- 12) ((fitness adj2 (monitor* or tracker?)) or (activity* adj2 tracker?) or pedomet*).tw. 4546
- 13) blood glucose self-monitoring/ 10006
- 14) ((glucose or sugar) adj3 (self-monitor* or self monitor* or sensing)).tw. 6156
- 15) Blood Pressure Monitors/or Blood Pressure Monitoring, Ambulatory/ 13917
- 16) (blood pressure adj2 (watch-type or wrist-type or self-monitor* or self monitor* or monitor*)).tw. 12852
- 17) (amazfit or athos or apple watch or biostrap or emfit or fitbit or garmin or huawei or hexoskin or nike fuel-band or myontec or omron heartguide or samsung or suunto or xiaomi or withings).tw. 3494
 - 18) or/1-17226288
 - 19) Systematic Review/or Systematic Reviews as Topic/or Meta-Analysis/or Meta-Analysis as Topic/ 352099
- 20) ((systematic* adj3 review*) or meta-analy* or meta-analy*).ab,ti. 457134
 - 21) or/19-20 494125
 - 22) and/18,21 3886
 - 23) (exp animals/or animal experimentation/or models, animal/or exp plants/or exp fungi/) not humans/ 5592042
 - 24) 22 not 23 3866

A2. Embase (Ovid)

Embase <1974 to October 13rd, 2023> n=6291

- 1) exp wearable computer/ 9026
- 2) wireless communication/ 7714
- 3) physiologic monitoring/ 6863
- 4) (health monitor* or health watch or mobile health technology* or (wireless adj3 technology) or mobile electrochemical or (patch* adj1 (skin or epidermal)) or (smart adj1 (band or device? or patch* or watch)) or smartband or smartpatch or smartwatch or wearable* or (wireless adj1 sensor?) or (wrist adj2 (band or watch or strap or worn or bracelets)) or wristband or wristwatch or arm band or armband or arm-band or (monitor* adj2 (nutrition or intake or physiologic*))).ti,ab. 52143
 - 5) telemetry/or remote sensing/ 36255
 - 6) (telemetr* or (remote adj2 sensing)).ti,ab. 26549
 - 7) accelerometry/ 10126
 - 8) (acceleromet* or (step? adj1 count*) or step-based or telesensing or workout tracking or gyroscopes or magnetometers or (activit* adj1 (monitor* or tracker* or device-derived or device-measured))).ti,ab. 40365
 - 9) actimetry/ 12260
 - 10) (actigraph? or polysomnogra* or (sleep* adj3 (track* or self-monitor* or self monitor*))).ti,ab. 55691
 - 1) exp activity tracker/ 5076
 - 12) ((fitness adj2 (monitor* or tracker?)) or (activity* adj2 tracker?) or pedomet*).ti,ab. 6217
 - 13) blood glucose monitoring/ 36721

- 14) ((glucose or sugar) adj3 (self-monitor* or self monitor* or sensing)).ti,ab. 8448
- 15) blood pressure monitor/ 3863
- 16) (blood pressure adj2 (watch-type or wrist-type or self-monitor* or self monitor* or monitor*)).ti,ab. 20921
- 17) (amazfit or athos or apple watch or biostrap or emfit or fitbit or garmin or huawei or hexoskin or nike fuel-band or myontec or omron heartguide or samsung or suunto or xiaomi or withings).ti,ab. 6286
 - 18) or/1-17265856
 - 19) Systematic Review/or Meta-Analysis/ 561784
- 20) ((systematic* adj3 review*) or meta-analy* or meta-analy*).ab,ti. 572086
 - 21) or/19-20711284
 - 22) and/18,21 6346
 - 23) (exp animal/or exp animal experiment/or exp animal model/or exp plant/or exp fungus/or (rat or rats or animal? or mouse or mice or "in vivo" or rabbit? or murine? or pig or pigs or dog or dogs or bovine? or fish* or fishes or vertebrate? or cat or cats or rodent? or mammal? or chicken? or monkey? or sheep or canine? or porcine? or cattle or bird? or hamster? or primate? or salmon).ti,ab,kw.) not exp human/ 7036068
 - 24) 22 not 23 6291

A3. Cochrane Library (Wiley)

Advanced Search Mode

Cochrane reviews 1996 to October 13rd, 2023> n=97

- #1) MeSH descriptor: [Wearable Electronic Devices] explode all trees 841
- #2) MeSH descriptor: [Wireless Technology] this term only 62
- #3) (digital NEAR/3 monitor*):ti,ab,kw 399
- #4) ((health or digital) NEAR/4 watch):ti,ab,kw 86
- #5) (wireless NEAR/6 (technology or sensor*)):ti,ab,kw 261
- #6) ((smart NEAR/1 (band or device? or patch* or watch)) or smartband or smartwatch or wearable*):ti,ab,kw 2700
- #7) ((wrist NEAR/2 (band or watch or strap or worn or bracelets)) or wristband or wristwatch or arm band or armband or arm-band or (monitor* NEAR/2 (nutrition or intake or physiologic*))).ti,ab,kw 4921
- #8) MeSH descriptor: [Telemetry] explode all trees 378
- #9) (telemetr* or (remote NEAR/2 sensing)):ti,ab,kw 1384
- #10) MeSH descriptor: [Accelerometry] explode all trees 1326
- #11) (acceleromet* or (step? NEAR/1 count*) or step-based or telesensing or workout tracking or gyroscopes or magnetometers or (activit* NEAR/1 (monitor* or tracker* or device-derived or device-measured))).ti,ab, kw 8488
- #12) MeSH descriptor: [Actigraphy] explode all trees 630

- #13) (actigraph? or polysomnogra* or (sleep* NEAR/3 (track* or self-monitor* or self monitor*))) :ti,ab,kw 11418
- #14) MeSH descriptor: [Fitness Trackers] explode all trees 197
- #15) ((fitness NEAR/2 (monitor* or tracker?)) or (activity* NEAR/2 tracker?) or pedomet*):ti,ab,kw 3022
- #16) MeSH descriptor: [Blood Glucose Self-Monitoring] explode all trees 1273
- #17) ((glucose or sugar) NEAR/3 (self-monitor* or self monitor* or sensing)):ti,ab,kw 7958
- #18) MeSH descriptor: [Blood Pressure Monitoring, Ambulatory] explode all trees 1793
- #19) (blood pressure NEAR/2 (watch-type or wrist-type or self-monitor* or self monitor* or monitor*)):ti,ab,kw 11532
- #20) (amazfit or athos or apple watch or biostrap or emfit or fitbit or garmin or huawei or hexoskin or nike fuelband or myontec or omron heartguide or samsung or suunto or xiaomi or withings):ti,ab,kw 1558
- #21) {OR #1-#20} 46792
In Cochrane Reviews 97

A4. Web of Science

Advanced Search Mode

Web of Science 1900 to October 13rd, 2023 > n=1108

- 1) TS=(wearable NEAR/2 device*) 26369
- 2) TI=(((smart or wrist) NEAR/1 (band or device* or watch or strap or worn or bracelets)) or wristband or wrist-watch) 3967
- 3) AB=(((smart or wrist) NEAR/1 (band or device* or watch or strap or worn or bracelets)) or wristband or wristwatch) 21277
- 4) TS=(telemetr*) 31507
- 5) TI=((remote NEAR/2 sensing) or telemetr*) 55060
- 6) AB=((remote NEAR/2 sensing) or telemetr*) 139645
- 7) TS=(accelometr*) 8820
- 8) TI=((step? NEAR/1 count*) or ((fitness or activit* NEAR/1 (monitor* or tracker* or device-derived or device-measured))) 4333
- 9) AB=((step? NEAR/1 count*) or ((fitness or activit* NEAR/1 (monitor* or tracker* or device-derived or device-measured))) 22542
- 10) TS=(((blood pressure) NEAR/2 (self monitoring)) OR ((glucose) NEAR/2 (self monitoring))) 3414
- 11) TI=(((blood pressure) NEAR/2 (self monitoring)) OR ((glucose) NEAR/2 (self monitoring))) 1254
- 12) AB=(((blood pressure) NEAR/2 (self monitoring)) OR ((glucose) NEAR/2 (self monitoring))) 2433
- 13) #12 OR #11 OR #10 OR #9 OR #8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1 248067
- 14) TI=(((systematic* NEAR/2 review*) OR meta-analy* OR metaanaly*) 400530
- 15) #14 AND #13 1108

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SUPPLEMENTAL MATERIAL

Supplemental Tables S1–S3: <https://doi.org/10.6084/m9.figshare.31100629>.

Supplemental Material S1: <https://doi.org/10.6084/m9.figshare.30931928>.

Supplemental Material S2: <https://doi.org/10.6084/m9.figshare.30932180>.

DISCLOSURES

M. P. Turakhia is an employee of iRhythm Technologies, Inc. T. Muka serves as a cofounder and CEO at Epistudia, GmbH. No conflicts of interest, financial or otherwise, are declared by the other authors.

John Ioannidis is an editor of *Physiological Reviews* and was not involved and did not have access to information regarding the peer-review process or final disposition of this article. An alternate editor oversaw the peer-review and decision-making process for this article.

AUTHOR CONTRIBUTIONS

S.S. prepared figures; M.G., A.L., T.M., and J.P.A.I. drafted manuscript; M.G., A.L., S.S., E.L., Z.M.R.-D., P.F.R., L.K., L.W., M.P.T., E.A., and T.M. edited and revised manuscript; M.G., A.L., S.S., E.L., Z.M.R.-D., P.F.R., L.K., L.W., M.P.T., E.A., T.M., and J.P.A.I. approved final version of manuscript.

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