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FULL RESEARCH PAPER
Telehealth

Educational methods to improve digital health literacy: a systematic review and meta-analysis for the EAPC Opti(MI)se initiative

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Aims

Digital health literacy (DHL) is essential for managing chronic diseases and promoting healthy aging. Despite its importance, evidence on how to improve DHL remains limited. This systematic review and meta-analysis assessed the impact of educational interventions on DHL among adults with chronic diseases and healthy older adults, with implications for both primary and secondary prevention.

Methods and results

This review followed PRISMA guidelines and was registered in PROSPERO (CRD42024592890). Studies from 2000–24 targeting adults (≥18 years) with chronic diseases or healthy individuals (≥65 years) and evaluating educational interventions to improve DHL were included. Nine databases were searched. Outcomes were assessed using validated tools (e.g. eHEALS). Follow-up was categorized as short-term (T1) and long-term (T2), with durations ranging from 3 to 12 months, depending on the study. Risk of bias was evaluated with ROB 2 and ROBINS-I. Twenty-one studies ($n = 4195$) were included: 14 randomized controlled trials and 7 pre–post studies. Most interventions ($n = 17$) were in-person programmes. Meta-analysis revealed significant eHEALS score improvements at short-term {T1: [mean difference (MD) 3.30, 95% confidence interval (CI): 1.21–5.40, $I^2 = 0\%$, $P = 0.03$]} and long-term (T2: MD 2.18, 95% CI: 1.42–2.95, $I^2 = 1\%$, $P = 0.007$). In-person and interactive interventions were most effective; app-based and online-only approaches showed limited benefit. Learning-by-doing interventions had limited impact on DHL but reduced clinical events.

Conclusion

Educational interventions, especially in-person, improve DHL among older adults and individuals with chronic disease. Given the high heterogeneity among studies, standardized methodologies and tailored educational strategies are needed to maximize effectiveness and ensure equitable access. Addressing foundational digital skills and bridging the digital health divide remain crucial priorities in secondary prevention care.

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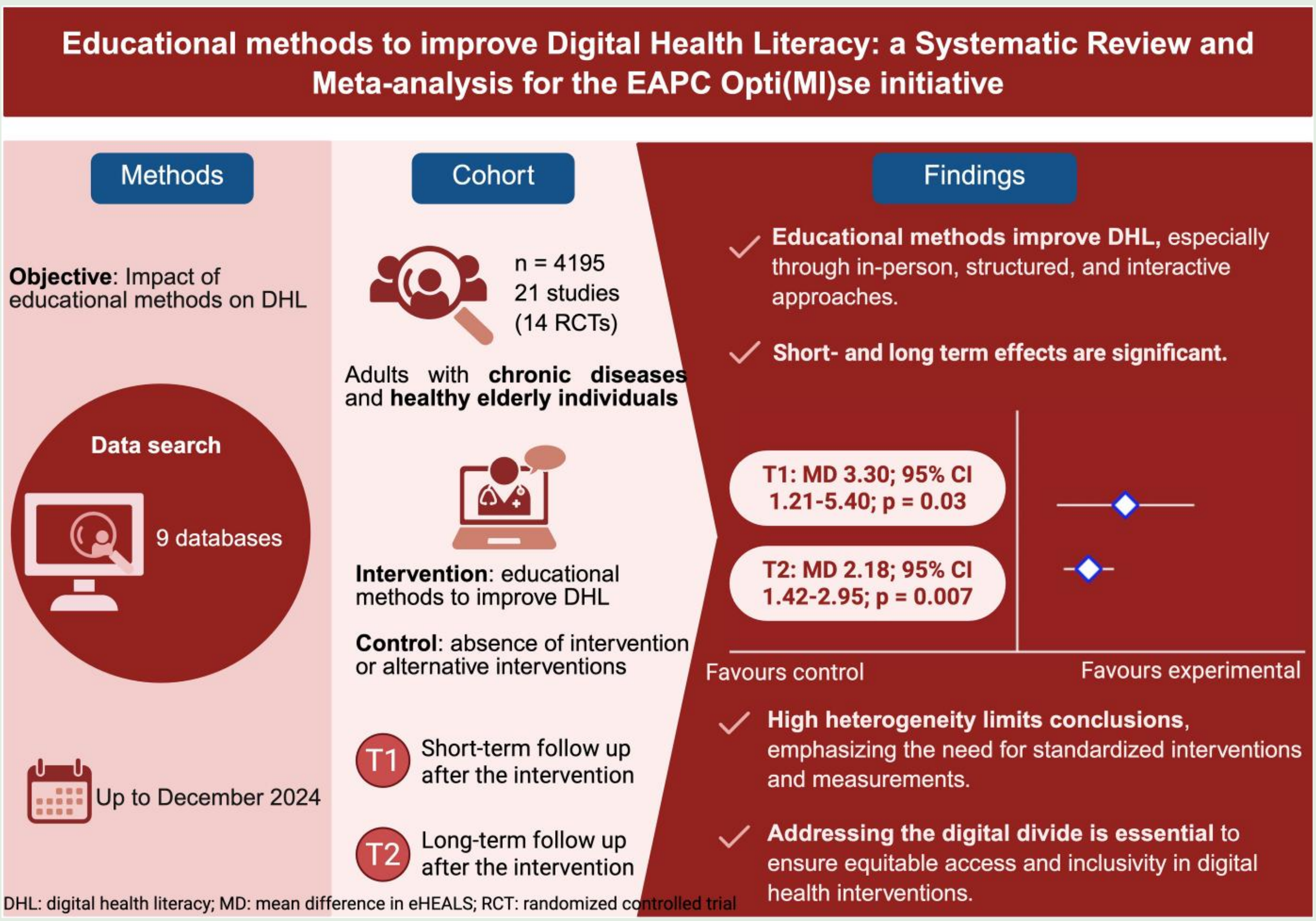
Lay summary

Older adults and people with chronic conditions learn to use digital health tools most effectively through structured, face-to-face training, rather than by trying to use apps or websites on their own.

- In-person, interactive training led to big improvements in people's ability to use digital health tools both immediately and months later, whereas app-only or online lessons had only a small effect.
- Programmes that left people to 'learn by doing' with little guidance did not improve their digital skills much (although some health improvements were seen), underscoring that structured, personalized training is crucial to help patients manage their conditions and avoid complications, and to ensure everyone can benefit equally from digital health tools.

Graphical Abstract



Keywords Digital health literacy • eHealth literacy • Educational methods • Digital health literacy interventions • Secondary prevention

Introduction

Digital health care concerns the use of information and communications technology in support of health,[1] which stimulates patients to actively engage in personal health.[2] As the health system faces challenges due to aging population, workforce constraints, availability, and affordability, it is important to take advantage of digital healthcare to address these challenges.[3] Digital interventions such as text messages, apps, and wearable devices are recommended to improve adherence to healthy lifestyle and medical therapy among patients with coronary artery disease.[2] Furthermore, the EAPC clinical consensus statement on adherence to treatment in secondary prevention of cardiovascular disease, identified that digital health also can improve health literacy.[4] Unfortunately, due to limitations in the healthcare system and patients-related barriers, ideal conditions for implementing digital health care are often not met.[3] An important issue that requires more attention is patients' digital health literacy (DHL) and readiness to benefit from digital tools.[5] A previous systematic review reported that DHL can mediate changes in health-related behaviour.[6] As such, educational methods supporting DHL may improve secondary prevention care.

Digital health literacy represents the ability and motivation to access, understand, appraise, and use digital information to solve health problems.[7] Without adequate DHL, individuals may struggle to manage their health, leading to poorer health outcomes and higher costs. Moreover, it encompasses the ability to confidently communicate and interact about health, both synchronously and asynchronously, using digital tools and services.[8] Various instruments have been developed to measure DHL, including the eHealth Literacy Scale (eHEALS)[7] and the eHealth literacy questionnaire (eHLQ).[9] Data from these instruments can guide educational methods to improve DHL and promote health and equity outcomes.[10] This includes ensuring that every patient, despite age and socioeconomic factors, can access digital health services.[11]

Digital health literacy is a dynamic skill that evolves over time as digital health is introduced. In this way, DHL is as much a process as an outcome. A process that requires constant attention and education.[12] Digital health literacy interventions have shown positive effects among older adults[13] and patients with chronic diseases,[14] and across different population groups.[15] Given these results, it is crucial that healthcare services invest in educational methods designed to bolster DHL.[16]

This systematic review and meta-analysis was conducted to identify optimal educational methods to improve DHL. Given its role in supporting adherence to lifestyle and pharmacological recommendations after myocardial infarction, strengthening DHL is a key strategy in secondary prevention. This review was carried out within the Optimal Therapy after Myocardial Infarction (Opti(MI)se) Programme of the European Association of Preventive Cardiology (EAPC) of the ESC; a series of scientific documents developed to address the optimal treatment of patients to prevent further cardiovascular events after myocardial infarction.

Aim

The aim is to identify and evaluate the impact of educational methods on DHL among adults with chronic diseases and healthy elderly individuals, and to summarize the implications for healthcare practice in enhancing patient DHL in secondary prevention contexts.

Methods

This systematic review and meta-analysis was conducted in accordance with the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[17] A protocol detailing the research methodology was registered in the international prospective register of systematic reviews (PROSPERO CRD42024592890) prior to the commencement of the review.

Eligibility criteria

The study eligibility criteria were based on the Population, Intervention, Comparison, Outcomes and Study Design (PICOS) framework.[18]

Studies were eligible if the *population* included adults (≥18 years) with a chronic disease or healthy elderly individuals (≥65 years). This differentiation addressed the unique challenges of these groups, and thus to capture interventions targeting those most likely to benefit from improved DHL. Adults with chronic diseases may benefit from digital health tools supporting chronic condition management. Healthy elderly individuals are more vulnerable to lower DHL.

The *interventions* had to include educational methods explicitly designed to improve DHL or consist of learning-by-doing approaches that, though not primarily intended to improve DHL, included it as a secondary outcome. These interventions promoted healthy behaviours through digital tools such as smartphone apps, online platforms, or wearables. Although their primary focus was not on DHL, they met eligibility by incorporating educational elements like feedback, interactive learning, and digital skill-building, emphasizing experiential learning through the use of these tools. Educational elements within learning-by-doing interventions were defined as having at least one instructional feature, such as structured user guidance, digital skill-building exercises, feedback mechanisms, or interactive learning activities. Their presence was assessed based on the original intervention descriptions. Two reviewers independently evaluated each study resolving discrepancies with a third reviewer. No formal threshold or checklist was applied, allowing flexibility in identifying diverse educational components.

The *comparison* included all interventions types and no-intervention groups. Although causality cannot be established, such studies provide valuable insights into the potential effects on DHL.

The *outcome* of interest was improvements in DHL, primarily measured through validated tools like the eight-item eHeals[7] or equivalent metrics. Studies using qualitative methods to assess DHL were also eligible for inclusion to ensure a comprehensive understanding of outcomes. This approach promoted consistency while accommodating diverse methodologies to capture DHL improvements.

Eligible *study designs* included randomized controlled trials (RCTs), non-randomized controlled trials (NRCTs), and pre–post studies. Randomized controlled trials were prioritized for their high-quality evidence on intervention efficacy. Other designs were included to capture broader range of evidence in this emerging area. No minimum follow-up duration was required. Studies with varying follow-up periods and intervention durations were included to explore both short- and long-term impacts.

Only peer-reviewed articles published from 1 January 2000 to 31 December 2024 were included to ensure relevance to the context of contemporary digital health technologies. There were no language restrictions. Non-peer-reviewed literature, reviews, editorials, abstracts, commentaries, and letters were excluded to maintain methodological rigour and focus on primary research.

Information sources

A comprehensive search strategy was developed in consultation with an experienced librarian. The following databases were searched for articles published between 1 January 2000 and 31 December 2024: PubMed/Medline, Embase, Web of Science, Scopus, Cochrane Library, CINAHL, IEEE, ERIC (ProQuest), and APA PsycNet. Additionally, reference lists of relevant studies and grey literature sources were screened. The search strategy was initially designed for PubMed/Medline and subsequently modified for application in other databases (see Supplementary material online, *Table S1*).

Search strategy

The search strategy combined keywords and Medical Subject Headings (MeSH) related to DHL, and educational methods. The search terms and MeSH headings are listed in Supplementary material online, *Table S1*. Search terms for all databases are available on PROSPERO (CRD42024592890).

Selection process

All search results were imported into Endnote (Clarivate, Philadelphia, PA, USA, version 21) to remove duplicates. Two independent reviewers (S.E.K. and L.X.) screened the titles and abstracts for eligibility based on the predefined inclusion and exclusion criteria. Full-text articles of potentially eligible studies were subsequently retrieved and assessed. Disagreements were resolved through discussion or by consultation with a third reviewer (M.F.).

Data collection process

Data extraction used a standardized form designed for this review. Extracted data included study characteristics (e.g. title, first author, year, country, and trial), population characteristics (e.g. sex, age, recruitment, race/ethnicity, income, and education), sample size, inclusion and exclusion criteria (see Supplementary material online, *Table S2*), disease description (if patients), study objectives, intervention characteristics (e.g. intervention procedure, session frequency and duration, follow-up, technology used for the intervention, training/instruction on technology, health information source, performer, location, theory, delivery, and adherence), comparison details (if applicable), and outcomes (e.g. primary and secondary outcomes, time points, and summary of findings).

Two reviewers (S.E.K. and L.X.) independently extracted data; discrepancies were resolved by consensus. If needed, a third reviewer (M.F.) resolved disagreements.

For data were missing, controversial, or unclear, authors were contacted for clarification.

Study risk of bias assessment

The methodological quality was assessed using the Cochrane Risk of Bias tool for RCTs (ROB 2)[19] and ROBINS-I[20] for NRCTs and pre–post studies. Each domain was rated as low, high, or unclear risk of bias, and an overall risk of bias score was assigned to each study. Two reviewers (B.A. and O.B.) independently performed quality assessment; disagreements were resolved by consensus, or if needed, by consulting a third reviewer (S.E.K.).

Funnel plot asymmetry was not assessed due to the small number of studies, as such methods are unreliable with fewer than 10 studies.

Effect measures

Effect measures for the DHL outcome were calculated as mean differences (MDs) with 95% confidence intervals (CIs). For between-group analyses, MDs reflect the difference in change in eHEALS score between intervention and control groups, calculated as (T1 or T2) minus T0: T1 for short-term and T2 for long-term. A positive MD indicates an improvement in DHL.

For studies without control groups, pre–post differences were reported. The MDs account for variability across studies by standardizing the effect sizes, enabling comparisons between studies with different measurement scales.

All calculations were performed using Review Manager Version 5.4, ensuring consistent and robust evaluation.

Synthesis methods

Narrative synthesis was used to summarize findings. Where appropriate, meta-analyses were performed using statistical software (Review Manager Version 5.4) to pool estimates from RCTs using eHEALS with mean and standard deviation (SD) data. A random-effects model with inverse-variance weighting, restricted maximum likelihood estimation, and Knapp–Hartung adjustment was used. Heterogeneity was assessed using the I^2 statistic. Heterogeneity was assessed using the I^2 statistic: ≤25% low, 26–50% moderate, and >50% substantial. Missing summary statistics and data conversions were documented. If data were missing and not reported, the lead author (S.E.K.) contacted study authors.

Certainty assessment

The certainty of evidence was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) framework.[21] This included an assessment of risk of bias, inconsistency, indirectness, imprecision, and publication bias. Study-level influence was evaluated via studentized residuals, Cook's distance, leverage, and changes in heterogeneity statistics (τ^2, Q).

Sensitivity analysis

The sensitivity analysis was conducted using the leave-one-out method used to assess the influence of individual studies on the overall results. It involved systematically removing one study at a time from the meta-analysis and recalculating the pooled effect estimate.

Results

Literature search and study selection

The initial search of nine electronic databases yielded 6017 records. After removing 885 duplicate records, 5132 records were screened for eligibility. Following the title and abstract screening, 5108 records were excluded, and 24 reports were sought for full-text retrieval. All 24 reports were successfully retrieved and assessed for eligibility (*Figure 1*).

Of the 24 reports assessed, three were excluded for the following reasons: one study population focused on young, healthy individuals, one study targeted caregivers rather than patients, and DHL was not reported as an outcome in one study. Ultimately, 21 studies met the eligibility criteria and were included in the final synthesis.[22–42] No additional studies were identified from manual searches of reference lists. The PRISMA checklist can be found in Supplementary material online, *Table S3*.

Study characteristics

Study characteristics are reported in *Table 1*. All 21 studies were published between 2011 and 2024. Of these, 11 studies focused on healthy elderly individuals ≥ 65 years, while 10 studies investigated patients with chronic diseases. The chronic diseases studies included diabetes, cardiovascular disease (CVD), heart failure, human immunodeficiency virus, high cardiovascular risk, and multiple comorbidities such as arthritis, cancer, and osteoporosis. The study design included 14 RCTs and 7 pre–post studies. Studies were conducted across multiple countries, with the majority originating from the USA ($n = 12$, 60%), followed by Taiwan ($n = 3$), South Korea ($n = 2$), and one study each from Italy, Spain, Australia, and Denmark. A total of 4195 participants enrolled across all the studies, with sample sizes ranging from small pilot studies ($n = 11$) to larger RCTs with up to 934 participants. Mean ages over the studies are spanning from 42 to 75 years. Sex distributions were reported in most studies, with some showing balanced male-to-female ratios and others reporting predominance of one gender, depending on the condition studied. Dropout rates varied, ranging from 0% in smaller studies to as high as 39.2% in larger trials. Of all studies, 86% reported on level of education, 62% reported on ethnicity/race, and 52% income (see Supplementary material online, *Table S4*).

Intervention characteristics

Intervention characteristics are reported in *Table 2* and Supplementary material online, *Table S5*. The *interventions* reported in the included studies primarily consisted of educational programmes ($n = 17$)[22–33,36,37,39,40,42] and learning-by-doing interventions ($n = 4$).[34,35,38,41]

Studies with *educational programmes* as interventions ($n = 17$) were predominantly delivered in-person ($n = 14$), with one study delivered online,[33] another using a combination of in-person and online methods,[42] and one study not providing information on the delivery method.[41]

All the studies with *learning-by-doing intervention* as intervention were delivered online. Two of these four studies used specifically a smartphone application[31–32] as intervention.

The *comparison groups* of the 14 RCTs varied across studies, with nine studies with an absence of intervention as comparison group,[26,33–36,38,41,42] and in six studies employing educational programmes as comparison group,[23,25,29,32,39,40] albeit implemented differently from the intervention group, which included following approaching: four studies that compared collaborative training with individualistic training group,[23,25,39–41] one study that compared computer-based training with paper-based training,[29] and one study

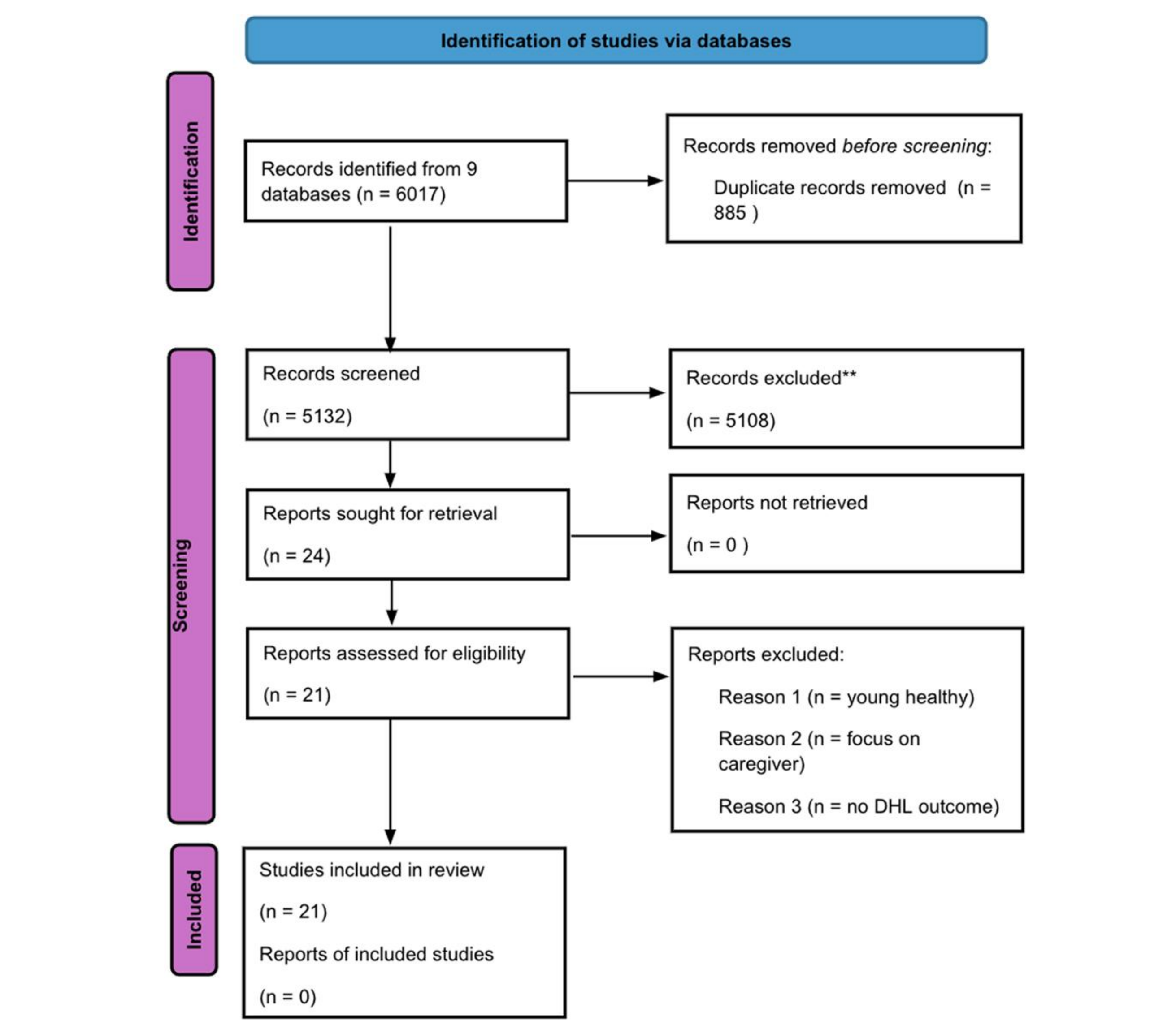


Figure 1 The PRISMA flow diagram[17] describing selection procedure of reviewed articles.

that compared in-person training with online training.[32] Six other studies employed pre–post analyses without formal control groups.[22,24,27,28,30,31,37]

Intervention frequencies ranged from one-time sessions[25,30] ($n = 2$) to weekly programmes[22–24,26,27,29,33,36,37,39,40,42] ($n = 12$) and daily use in learning-by-doing interventions.[34,35,38,41] Some studies did not provide the intervention frequency[28,31,32] ($n = 3$). The *duration of intervention* also varied widely, ranging from 2 to 52 weeks.

Technology played a central role in delivering the interventions, with computers being the most frequently used tool ($n = 11$), followed by tablets and smartphones ($n = 7$). Customized platforms, such as electronic personal health records (ePHR) and patient portals, were used in several studies to facilitate learning.[23,30,31]

Education characteristics

To analyse educational characteristics, it is essential to understand the teaching methods, categorized teaching methods into five domains (teaching strategies, learning environment, structure, mechanisms of engagement, and feedback and evaluation); see Supplementary material online, *Tables S6–S8*.

Teaching strategy

Reviewed studies described teaching strategies to improve DHL in older adults. Common methods included blended learning with hands-on exercises, competition, collaborative peer-based approaches, and personalized, age-specific designs using tailored modules and tech-assisted training. Theoretical frameworks like COM-B,[26] Intervention Mapping,[24] and Self-Determination Theory[35] ensured behavioural change and engagement.

Engagement mechanisms

Engagement mechanisms often included collaborative approaches ($n = 12$),[22–25,27,29,31,36,37,39,40,42] where participants engaged in small group discussions, peer collaborations, or interactive exercises. Some

Table 1 Study characteristics ($n = 21$)

	Author, year	Country	Population	Trial design	N	Experimental groups				Control group			
						n	Dropout (%)	Age (years)	Sex (m/f)	n	Dropout (%)	Age (years)	Sex (m/f)
1	Bevilacqua, 2021[22]	Italy	Healthy elderly individuals	Pre–post	58	58	N/A	58	34/24	N/A	N/A	N/A	N/A
2	Bo Xie, 2011[23]	USA	Healthy elderly individuals	RCT	140	140	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Bo Xie, 2011[24]	USA	Healthy elderly individuals	Pre–post	172	172	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	Bo Xie, 2011[25]	USA	Healthy elderly individuals	RCT	118	118	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	Caroll, 2019[26]	USA	HIV	RCT	360	180	0	52	112/68	180	0.6	51	101/78
6	Chang, 2021[27]	South Korea	Healthy elderly individuals	Pre–post	11	11	0	N/A	N/A	N/A	N/A	N/A	N/A
7	Chiu, 2016[28]	Taiwan	Healthy elderly individuals	Pre–post	39	39	48	70	N/A	N/A	N/A	N/A	N/A
8	De Main, 2022[29]	USA	Healthy elderly individuals	RCT	99	49	N/A	72	18/31	50	N/A	74	17/33
9	Guo, 2023[30]	Taiwan	Diabetes	Pre–post	132	96	N/A	42	72/24	36	N/A	41	21/15
10	Lee, 2019[31]	USA	Healthy elderly individuals	Pre–post	59	59	6.8	74	20/35	N/A	N/A	N/A	N/A
11	Lyles, 2019[32]	USA	Chronic disease	RCT	93	44	4.5	56	29/23	49	6.1	53	26/25
12	Nahm, 2019[33]	USA	High blood pressure, arthritis, depression, cancer, heart problems, osteoporosis, diabetes, moderate to high CV risk or an established CVD diagnosis	RCT	272	138	18.1	70	45/93	134	5.2	70	36/98
13	Parker, 2022[34]	Australia	Overweight and obese patients attending primary care	RCT	215	120	39.2	59	60/60	95	30.5	56	63/32
14	Redfern, 2020[35]	South Korea	Patients with or at risk for CVD	RCT	934	486	5.3	67	368/118	448	3.8	68	348/100
15	Sanders, 2020[36]	USA	HIV	RCT	359	180	10	52	99/63	179	11.1	52	89/72
16	Saravanan, 2024[37]	USA	Healthy elderly individuals	Pre–post	13	13	0	75	2/11	N/A	N/A	N/A	N/A
17	Spindler, 2022[38]	Denmark	Heart failure	RCT	137	67	23.9	62	51/16	70	34.3	61	54/16
18	Vazquez, 2023[39]	USA	Healthy elderly individuals	RCT	466	233	14.6	70	79/154	233	14.6	71	75/158
19	Watkins, 2013[40]	USA	Healthy elderly individuals	RCT	172	172	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20	Yun, 2022[41]	Spain	Heart failure	RCT	178	81	N/A	N/A	N/A	81	N/A	N/A	N/A
21	Cheng, 2024[42]	Taiwan	Diabetes	RCT	92	46	11	65	10/36	46	2	60	23/23

N/A, not applicable; HIV, human immunodeficiency virus; CV, cardiovascular; CVD, cardiovascular disease; RCT, randomized controlled trial.

Table 2 Intervention characteristics

	Author, year	Intervention group	Comparison group	Intervention frequency	Intervention duration	Technology	Delivery of intervention
1	Bevilacqua, 2021[22]	Educational programme	N/A (pre–post)	Weekly or twice a week, 90 min	4 weeks	Computer or tablet	In person
2	Bo Xie, 2011[23]	Educational programme (collaborative learning)	Educational programme (individualistic learning)	2 times/week, 120 min	2 weeks	Computer	In person
3	Bo Xie, 2011[24]	Educational programme (collaborative learning)	N/A (pre–post)	2 times/week, 120 min	4 weeks	Computer	In person
4	Bo Xie, 2011[25]	Educational programme (collaborative learning)	Educational programme (individualistic learning)	1 time, 120 min	1 time	Computer	In person
5	Carroll, 2019[26]	Educational programme (collaborative and inidvidualistic learning)	Absence of intervention	Weekly, 90 min (+*ad libitum* access to URHealth App)	6 weeks: training sessions; 52 weeks: URHealth App	iPod, ePHR	In person
6	Chang, 2021[27]	Educational programme	N/A (pre–post)	Weekly, 120 min	5 weeks	Computer	In person
7	Chiu, 2016[28]	Educational programme	N/A (pre–post)	Weekly, 90 min	8 weeks	Tablet and smartphone	In person
8	De Main, 2022[29]	Educational programme (computer-based)	Educational programme (paper-based)	Twice a week, 120 min	2 weeks	Computer	In person
9	Guo, 2023[30]	Educational programme	Absence of intervention	1 time	30–60 min	Computer	In person
10	Lee, 2019[31]	Educational programme	N/A (pre–post)	N/A	Not provided	Computer and smartphone	In person
11	Lyles, 2019[32]	Educational programme (in person)	Educational programme (online)	Not provided	12–26 weeks	Link to view videos	In person
12	Nahm, 2019[33]	Educational programme	Absence of intervention	Weekly	3 weeks	Learning management system, ePHR	Online
13	Parker, 2022[34]	Learning-by-doing intervention	Absence of intervention	Daily	52 weeks	Smartphone	Online
14	Redfern, 2020[35]	Learning-by-doing intervention	Absence of intervention	Daily	52 weeks	Smartphone	Online
15	Sanders, 2020[36]	Educational programme	Absence of intervention	Weekly, 90 min	6 weeks	ePHR	In person
16	Saravan, 2024[37]	Educational programme	N/A (pre–post)	Weekly, 40 min	3 weeks	Tablet	In person
17	Spindler, 2022[38]	Learning-by-doing intervention	Absence of intervention	Daily	52 weeks	HeartPortal	Online
18	Vazquez, 2023[39]	Educational programme (collaborative learning)	Educational programme (individualistic learning)	Twice a week, 120 min	4 weeks	Computer	In person
19	Watkins, 2013[40]	Educational programme (collaborative learning)	Educational programme (individualistic learning)	Twice a week	2 weeks	Computer	In person
20	Yun, 2022[41]	Learning-by-doing intervention	Absence of intervention	Daily	26 weeks	Not provided	Not provided
21	Cheng, 2024[42]	Educational programme	Absence of intervention	Every 2 weeks, 90 min	12 weeks	Applications, wearable devices, health monitors	In person and via social media platform in between sessions

N/A, not applicable; ePHR, electronic personal health records.

studies ($n = 2$) combined collaborative mechanisms with individualistic approaches,[26,28] incorporating elements such as one-on-one coaching or independent task completion. Online tools were frequently employed to facilitate engagement in the intervention groups ($n = 5$)[33,34,35,38,41] offering interactive platforms, progress tracking, and gamification.

In contrast, comparison groups often employed individualistic mechanisms ($n = 4$),[23,25,39,40] such as independent task completion or self-paced learning. A significant portion of studies ($n = 9$) reported an absence of active engagement mechanisms in the comparison groups, where participants received no specific intervention.[26,30,33–36,38,41,42] A few studies ($n = 2$) used alternative methods, such as traditional paper-based training[29] or online training.[28]

Feedback and assessment

Studies utilized real-time, constructive feedback[23,27,29,39,40] and pre- and post-intervention assessments[22,24,28,30,34,35] to evaluate participant progress and programme impact. Methods included questionnaires, focus groups, task-based evaluations, and engagement tracking via digital platforms. Personalized and peer feedback were key approaches, with many studies incorporating qualitative and quantitative measures to capture participant experiences, attitudes, and skills. Long-term follow-ups assessed sustained behaviour changes and clinical outcomes. Technology tools, such as digital apps and DHL platforms, provided continuous monitoring and feedback, enhancing participant self-awareness and programme adaptability.

Outcomes and meta-analysis

Digital health literacy outcomes

Among the 21 studies, 17[22–36,39,40] utilized the eight-item eHEALS, two employed[38,42] the 35-item eHealth Literacy Questionnaire (eHLQ), one analysed qualitative data,[37] and another assessed traditional literacy and ICT (information and communication technology) skills as measures for enhancing digital health readiness (DHR).[38] Of these, 12 studies conducted measurements at measured at baseline (T0) and short-term follow-up (T1).[22–25,28,29,31,32,35,37,40,41] In addition, nine studies collected measurements at three time points: baseline (T0), short-term follow-up (T1), and long-term follow-up (T2).[26,27,30,33,34,36,38,39,42] Nine RCTs[23,29,33–36,38,40,42] provided between-group differences from T0 to T1. Three RCTs[25–26,32] did not report between-group differences from T0 to T1 but presented within-group effects, as did five pre–post studies.[22,24,27,28,31] One RCT[26] reported between-group differences from T0 to T2. *Table 3* presents the measured outcomes and a summary of results across all studies.

Among the studies with educational programmes as intervention ($n = 17$), 16 utilized eHEALS,[22–33,36,39,40] one utilized eHLQ,[42] and one reported only qualitative data.[37]

At the short-term follow-up, significant improvements in eHEALS were observed in five pre–post studies that implemented in-person education programmes,[22,24,27,30,31] while one study did not report any changes.[28] Furthermore, two RCTs demonstrated significant between-group differences, comparing an intervention group to a control group with absence of intervention.[36,42] In contrast, another RCT found no significant differences between the groups.[33]

For the long-term follow-up, two pre–post studies highlighted significant improvements in eHEALS over time.[27,30] Similarly, two RCTs identified significant between-group differences when comparing the intervention group with a control group with absence of intervention.[26,36] However, one RCT at this stage reported no significant changes between the intervention and control groups.[33]

Four RCTs specifically investigated the differences between individualistic training and collaborative training: two studies reported no significant differences between the groups[23,40] and two studies did not report on between-group differences.[25,39] Two RCTs found no significant differences in eHEALS scores between computer-based in-person education and either video-guided education[32] or paper-based education.[29]

Among the studies with learning-by-doing as intervention ($n = 4$), two RCTs[34,35] employed eHEALS to evaluate interventions delivered via smartphone applications and found no differences in overall eHEALS scores between the intervention group and comparison group with absence of intervention. One RCT[38] assessed the impact of telerehabilitation-based learning-by-doing interventions through an online portal using the eHLQ and found no significant difference between intervention group and comparison group with absence of intervention. An RCT[41] examined the impact of telemonitoring-based learning-by-doing interventions on DHR, evaluating traditional literacy and ICT skills as separate outcomes. The findings demonstrated that these interventions effectively reduced early heart failure events, regardless of participants' literacy or computer skills.

Eleven studies focused on healthy older adults, comprising 1347 participants, compared to 2848 participants in studies involving patients with chronic diseases. Of these 11 studies, five were RCTs and the remainder were pre–post intervention studies. One study (Saravan) reported only qualitative data, while the others used the eHEALS. Only one study reported outcomes at T2. In contrast, studies involving patients with chronic conditions more frequently reported long-term outcomes. These findings suggest that while digital health interventions (DHI) appear beneficial for healthy elderly individuals in the short-term, there is a lack of long-term data in this group, highlighting a need for more robust follow-up in future research.

Meta-analyses

Only 2[33,36] out of the 14 RCTs were included in the meta-analysis at T1, and 3[26,30,33,36] at T2, due to missing data or incompatible formats (e.g. no mean/SD). Excluded RCTs and reasons are listed in Supplementary material online, *Table S13*.The meta-analysis included only participants with chronic diseases, as all eligible studies focused on this group. *Figure 2* shows a significant difference in eHEALS scores at T1 between intervention and control groups (MD 3.30, 95% CI: 1.21–5.40, $I^2 = 0\%$, $P = 0.03$). Significant difference was also found between the groups at T2 (after long-term follow-up) (MD 2.18, 95% CI: 1.42–2.95, $I^2 = 1\%$, $P = 0.007$) (*Figure 3*). These results should be interpreted with caution due to a limited number of included studies and the variation in follow-up periods (3–12 months).

Risk of bias assessment

All 14 RCTs[23,25,27,29,32–35,38–42] analysed using ROB 2 tool and the 6 pre–post studies[22,24,27,28,30,31] assessed using the ROBINS-I tool exhibited an overall high risk of bias (see Supplementary material online, *Tables S10* and *S11*) primarily due to issues in outcome measurement and lack of assessor blinding.

In these studies, patient self-report was used for outcome measurement, introducing a substantial risk of bias. Conversely, the areas with the lowest risk of bias across all studies were those related to missing outcome data and deviations from the intended protocol.

Table 3 Outcome characteristics

	Author, year	Trial design	Outcome measure(s)	Timing of data collection	Mean (SD) T0 (baseline)	Mean (SD) T1 (last session)	Mean (SD) T2 (long-term)	*P*-value (T1–T0)	*P*-value (T2–T0)
1	Bevilacqua, 2021[22]	Pre–post	eHEALS	T1: 4 weeks T2: N/A	24.3 (8.9)[a]	28.4 (8.1)[b]	N/A[c]	$P < 0.001$	N/A
2	Bo Xie, 2011[23]	RCT	eHEALS	T1: 2 weeks T2: N/A	Not provided	Not provided	N/A	Pre–post intervention group: $P = 0.004$ Between group differences (individualistic vs. collaborative): $P = 0.06$	N/A
3	Bo Xie, 2011[24]	Pre–post	eHEALS	T1: 2 weeks T2: N/A	2.6 (0.8)	4.0 (0.5)	N/A	$P < 0.001$	N/A
4	Bo Xie, 2011[25]	RCT	eHEALS	T1: after 2 h T2: N/A	4.4 (0.8)	Not provided	N/A	Pre–post intervention group: $P < 0.001$ (between group differences not provided)	N/A
5	Carroll, 2019[26]	RCT	eHEALS	T1: 6/8 weeks T2: 52 weeks	Intervention: 28.5 (7.8) Control: 27.3 (8.6)	Not provided	Intervention: 29.8 (1.5) Control: 27.7 (1.4)	Not provided	Between group differences: $P < 0.001$
6	Chang, 2021[27]	Pre–post	eHEALS	T1: 5 weeks T2: 32 weeks	28.3 (1.1)	33.0 (0.6)	32.0 (0.9)	$P < 0.001$	$P < 0.001$
7	Chiu, 2016[28]	Pre–post	eHEALS	T1: 8 weeks T2: N/A	30.9 (5.1)	31.7 (5.4)	N/A	$P = 0.26$	N/A
8	De Main, 2022[29]	RCT	eHEALS	T1: 2 weeks T2: N/A	Intervention: 25.3 (6.9) Control: 23.0 (7.8)	Intervention: 33.3 (3.3) Control: 34.2 (4.0)	N/A	Pre–post intervention group: $P < 0.001$ Pre–post control group: $P < 0.001$ Between group differences: $P = 0.48$	N/A
9	Guo, 2023[30]	Pre–post (two groups)	eHEALS	T1: 30–60 min T2: 12 weeks	Intervention: 30.7 (4.9) Comparison: 31.8 (5.6)	Not provided	Intervention: 31.7 (4.3) Comparison: 32.2 (4.5)	N/A	Between group differences: $P = 0.001$
10	Lee, 2019[31]	Pre–post	eHEALS	T1: after 6 sessions (time not provided) T2: N/A	2.78 (1.62)	3.83 (0.86)	N/A	$P < 0.001$	N/A
11	Lyles, 2019[32]	RCT	eHEALS	T1: 12–26 weeks T2: N/A	14.4 (3.7)	16.2 (2.4)	N/A	Pre–post intervention group: $P < 0.001$ (between group differences not provided)	N/A
12	Nahm, 2019[33]	RCT	eHEALS	T1: 3 weeks T2: 16 weeks	Intervention: 30.6 (5.0) Control: 28.9 (5.4)	Intervention: 31.4 (5.2) Control: 29.5 (5.7)	N/A	Pre–post intervention group: $P = 0.19$ Between group differences: $P = 0.27$	Between group differences: $P = 0.50$

Continued

Table 3 *Continued*

	Author, year	Trial design	Outcome measure(s)	Timing of data collection	Mean (SD) T0 (baseline)	Mean (SD) T1 (last session)	Mean (SD) T2 (long-term)	*P*-value (T1–T0)	*P*-value (T2–T0)
13	Parker, 2022[34]	RCT	eHEALS	T1: 26 weeks T2: 52 weeks	Intervention: 27.4 (7.3) Control: 29.2 (6.3)	Intervention: 29.5 (6.1) Control: 29.4 (5.9)	N/A	Between group differences: $P = 0.25$	Between group differences: $P = 0.32$
14	Redfern, 2020[35]	RCT	eHEALS	T1: 52 weeks T2: N/A	Intervention: 27.0 (6.4) Control: 27.0 (6.4)	Not provided as a mean (SD)	Not provided as a mean (SD)	Pre–post intervention group: $P = 0.39$ Between group differences: $P = 0.02$	N/A
15	Sanders, 2020[36]	RCT	eHEALS	T1: 8 weeks T2: 26 weeks	Intervention: 28.5 (7.8) Control: 27.3 (8.5)	Intervention: 32.2 (5.6) Control: 28.8 (7.6)	Intervention: 32.4 (5.3) Control: 29.1 (7.3)	Between group differences: $P < 0.001$	Between group differences: $P < 0.001$
16	Saravan, 2024[37]	Pre–post	Qualitative data (no scale)	T1: 3 weeks T2: N/A	Qualitative data	Qualitative data	Qualitative data	Qualitative data	Qualitative data
17	Spindler, 2022[38]	RCT	eHLQ	T1: 24 weeks T2: 52 weeks	Separately analysed	Separately analysed	Separately analysed	Separately analysed	Separately analysed
18	Vazquez, 2023[39]	RCT	eHEALS	T1: 4 weeks T2: 26 weeks	Not provided	Not provided	Not provided	Not provided	N/A
19	Watkins, 2013[40]	RCT	eHEALS	T1: 2 weeks T2: N/A	Intervention: 3.7 (3.1) Control: 4.5 (23.0)	Intervention: 5.6 (3.3) Control: 6.8 (3.1)	N/A	Pre–post intervention group: $P < 0.001$ Between group differences (individualistic vs. collaborative): $P = 0.33$	N/A
20	Yun, 2022[41]	RCT	Traditional literacy + ICT skills	T1: 26 weeks T2: N/A	Separately analysed	Separately analysed	Separately analysed	N/A	Separately analysed
21	Cheng, 2024[42]	RCT	eHLQ	T1: 12 weeks T2: 26 weeks	Intervention: 91.0 (19) Control: 96.7 (18)	Intervention: 110.9 (12.0) Control: 96.8 (18.5)	Intervention: 111.2 (14.2) Control: 98.4 (14.2)	Between group differences: $P < 0.001$	N/A

RCT, randomized controlled trial; eHEALS, eight-item eHealth Literacy Scale; eHLQ, 35-item eHealth Literacy Questionnaire.
[a]T0: baseline measurement (prior to the intervention).
[b]T1: short-term follow-up (shortly after the intervention).
[c]T2: long-term follow-up measurement (at a later point in time after the intervention).

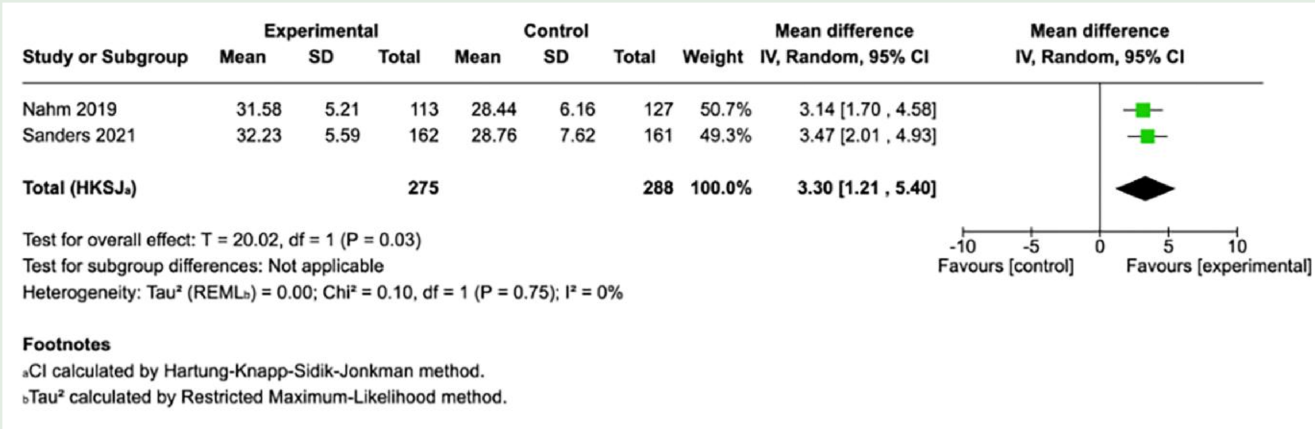


Figure 2 Meta-analysis of digital health literacy at T1.

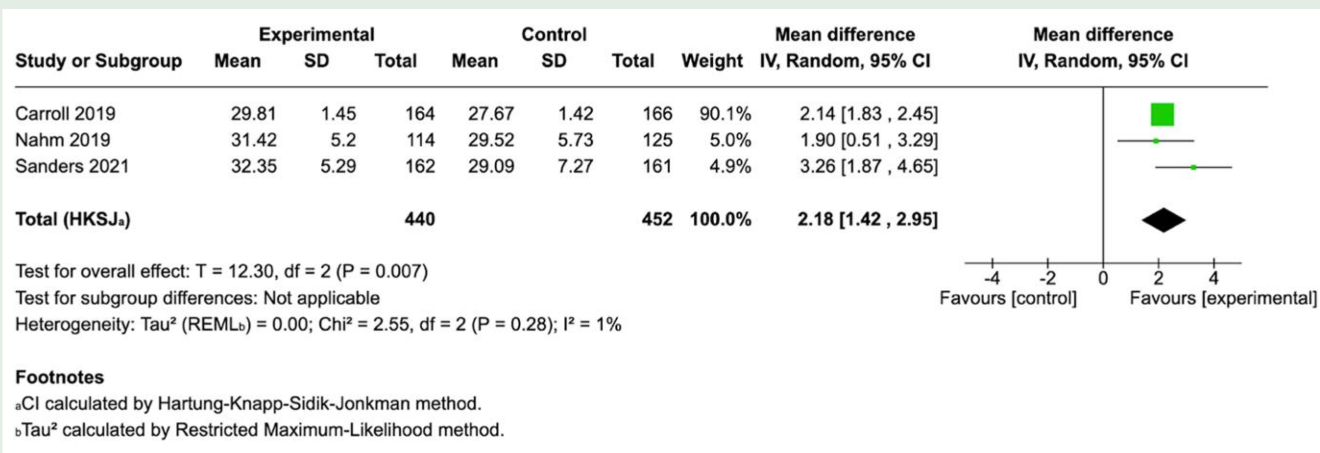


Figure 3 Meta-analysis of digital health literacy at T2.

Sensitivity analysis

We performed a leave-one-out sensitivity analysis to assess heterogeneity and evaluate the reliability of our findings by comparing the sensitivity results with the main finding (see Supplementary material online, *Table S12*). Excluding Carroll and Nahm increased heterogeneity and eliminated group differences. However, when excluding the study by Sanders significant difference was still observed between the two groups (MD 2.13, 95% CI: 1.48–2.78, $I^2 = 0\%$, $P = 0.02$, Supplementary material online, *Table S12*).

Discussion

This systematic review and meta-analysis examined how educational methods impact DHL among adults with chronic diseases and healthy elderly individuals, and summarized implications for healthcare practice in enhancing patient DHL in secondary prevention contexts.

Two approaches to improving DHL were identified: direct educational methods and indirect learning-by-doing interventions. Direct methods provide structured programmes that provide theoretical and practical knowledge, while learning-by-doing emphasizes experiential learning through real-world applications, such as telemonitoring or smartphone-based interventions.

At short-term follow-up, several pre–post studies[22,24,27,30,31] reported significant improvements in eHEALS scores, particularly among healthy elderly individuals.[22,24,27,31] In-person format and interactive elements likely contributed to these consistent outcomes. Tailored interventions, addressing specific health conditions like diabetes, also proved effective.[30] However, one pre–post study 28 reported no significant improvement, possibly due to app-based training, which may have been less engaging for older adults unfamiliar with digital tools. Limited in-person interaction in such interventions might reduce overall impact.

Randomized controlled trials comparing educational interventions to the absence of intervention also yielded mixed results. Studies employing collaborative approaches, such as group discussions and interactive exercises,[36,42] tended to report significant improvements, underscoring the value of active learning strategies.

At long-term follow-up, the positive effects of educational interventions appeared to be sustained, with significant between-group differences observed in some studies.[27,30,36] Although the magnitude of effect was smaller compared to short-term follow-up, the persistence of benefit supports the potential value of continued engagement or reinforcement over time. However, inconsistencies, such as the lack of improvements in Nahm's study,[33] emphasize the critical role of intervention delivery formats and participant engagement in achieving meaningful outcomes.

In our meta-analysis, the observed improvement in eHEALS scores, though statistically significant, may not be clinically meaningful on its own. However, in populations with low baseline digital skills, even modest gains could signal meaningful progress towards digital inclusion and better health decisions. While the improvement is relatively small, its potential cumulative effect, especially if maintained through ongoing intervention, should not be overlooked. Given the scalability and low cost of digital tools, such interventions may still offer substantial public health value, making even the modest improvements in DHL both acceptable and worthwhile.

No significant differences were observed between collaborative and individualistic learning, suggesting that the success of collaborative approaches may rely heavily on factors such as the quality of facilitation and the level of participant engagement.

The meta-analysis confirms the effectiveness of educational interventions, with significant improvements in eHEALS scores observed at both short- and long-term follow-ups. This suggests that educational methods have an immediate impact on DHL while also providing lasting benefits. The significant short-term effects indicate that participants can quickly benefit from educational programmes, while the sustained improvements highlight the potential for long-term gains. Although the mean difference at T2 was smaller than at T1, this reduction should be interpreted cautiously, as the study contributing data at T2 included one additional trial not present at T1. Therefore, while the magnitude of effects across time points cannot be directly compared, the findings indicate that the intervention continued to provide benefit relative to control over time.

Learning-by-doing interventions showed limited effectiveness in improving DHL, with most studies reporting no significant between-group differences. The reliance on self-guided learning and digital tools may have hindered participants with low baseline digital skills. However, these interventions demonstrated potential to improve clinical outcomes, even if their impact on DHL was minimal.

A recent systematic review and meta-analysis by Barbati *et al.*[15] also evaluated the effectiveness of DHL interventions but included a broader population, incorporating younger individuals. While their meta-analysis reported significant improvements in eHEALS scores, these results were largely driven by studies involving younger participants, suggesting that younger populations may acquire digital skills more easily. In contrast, our findings demonstrate that significant improvements in DHL can also be achieved among patients with chronic diseases and healthy elderly individuals. This highlights the importance of tailored educational strategies that effectively support older adults and those with chronic conditions in acquiring and sustaining digital health literacy.

Unlike Barbati *et al.*,[15] this review specifically focused on educational methods for DHL improvement in healthy elderly individuals and patients with chronic disease. This targeted approach is crucial for addressing the specific barriers these populations face in accessing and using digital health tools. Improving DHL for DHI is essential to prevent the rise of a digital health divide.[43] Digital health is often proposed as a potential solution to increase access to healthcare.[44] It is well established that patients with higher age, lower education level, lower socioeconomic status, or from an ethnic minority, have lower access to healthcare.[45] The same factors are linked with lower DHL.[46] It is crucial to ensure that digital solutions aimed at improving access to healthcare reach those who need them most. To do this, the first step is to assess patients' ability to use digital health technology and determine if they are suitable for digital health programmes.[47] Patients with low DHL should be offered interventions to improve their digital skills. Secondly, it is important to evaluate how easily patients can learn and adapt to these interventions, tailoring them to their skill and knowledge levels.[48] The recently developed Digital Health Readiness Questionnaire (DHRQ) measures both DHR and capacity to learn.[48] This information could help personalize educational interventions to better meet patients' needs in the future.

A review by Pourrazavi *et al*. highlighted the importance of self-efficacy as a tool to improve DHL.[49] Moreover, a recent study by Busse *et al*. proposed didactic sessions, workshops, collaborative learning, and peer tutoring models as potential interventions to increase knowledge and improve self-efficacy.[45] However, these learning opportunities often take place with the use of technology that leads to a digital divide. Patients with lowest access to technology and lowest DHL levels will then again miss out. Therefore, it is necessary to implement educational interventions that do not require digital applications.[49]

Lastly, it is important to not only provide education at the start of a DHI but also to ensure sufficient practical and technological support throughout the intervention. Furthermore, follow-up should be advised, as it may play a crucial role in improving DHL and reinforcing the messages and learning from the intervention. Follow-up allows for continuous engagement, addressing any challenges patients may face, and sustaining the benefits of the intervention over time.

Although this review focused on patient-reported outcomes, it is important to acknowledge that caregivers can play a critical role in supporting digital health tasks. In some contexts, improving caregivers' DHL may indirectly enhance patients' ability to access, understand, and act on health information online.[50]

As most included studies were conducted in the USA, caution is needed when generalizing findings internationally. Cultural and healthcare system differences can impact the effectiveness and implementation of DHI, meaning that successful strategies in one country may not directly translate to another. For example, many low- and middle-income countries have underdeveloped digital infrastructure, and individuals with lower socioeconomic status often face limited access to online resources, reducing the effectiveness of web-based interventions. In such settings, face-to-face or low-tech solutions may be the only viable option, emphasizing the need to tailor digital health strategies to local contexts and available resources. These factors highlight the importance of formal oversight or accreditation of DHI at both the individual and population level to ensure quality and effectiveness across healthcare systems. At the policy and system level, supportive frameworks are essential to enable broad DHI implementation. A recent commentary on equitable telehealth stressed that individual, community, and policy-level actions must accompany technological advances to ensure sustainable and inclusive adoption.[51]

Future research should continue exploring innovative educational methods to enhance DHL among people with chronic disease and elderly to improve uptake, adherence, and effectiveness of digital DHI.

Strengths and limitations

This systematic review and meta-analysis has several limitations. First, high heterogeneity in intervention design, duration, and outcomes limited the ability to identify the most effective educational methods. Second, the reliance on self-reported tools such as eHEALS introduced bias and may not capture objective DHL improvements. Although eHEALS is widely used, it has been criticized for not addressing the dynamic and social dimensions of digital health.[52] Future studies should include objective assessments like performance-based tasks or tools like the Digital Health Literacy Instrument (DHLI), which better reflect users' ability to search, evaluate, and apply online health information.[53] Triangulation with system usage data (e.g. log files, time on tasks, and feature use) may further strengthen validity.[54] Third, the predominance of studies from high-income countries limits generalizability to low- and middle-income settings. Fourth, the inclusion of studies with varied designs, including those without control groups, reduced comparability, while inconsistent follow-up durations hindered long-term effect evaluation. Fifth, potential publication bias and exclusion of non-peer-reviewed literature may have led to missing relevant data. Finally, most included studies did not involve participants with CVD. Although our primary objective was to evaluate DHL interventions in the context of cardiovascular secondary prevention, the limited availability of such studies required us to broaden the scope to other chronic conditions and older adults. As a result, applicability to cardiovascular care is limited, warranting further disease-specific research. Future research should address these limitations by employing standardized outcomes, broader population, longer follow-up periods, and disease-specific focus.

Conclusion

This systematic review and meta-analysis highlights the effectiveness of educational methods in improving DHL among older adults and individuals with chronic diseases. Significant improvements in eHEALS scores at both short- and long-term follow-ups suggest immediate and sustained benefits. However, high heterogeneity and variable follow-up periods indicate the need for more standardized intervention designs and evaluation methods. Future research should address foundational digital skills and ensuring equitable access to technology to maximize the impact of digital DHI. Addressing the digital health divide is critical, particularly for individuals with low digital literacy, socioeconomic challenges, or limited access to technology. Personalized educational approaches, tailored to patients' digital readiness and learnability, may help bridge this gap and maximize the benefits of DHI. Implementing educational methods that do not rely solely on digital tools can further ensure inclusivity. Future research should focus on standardizing DHL measurement tools, evaluating long-term effects of interventions, and expanding the geographic and socioeconomic diversity of study populations. Innovative and inclusive strategies are essential to enhance DHL, enabling broader participation and improving the outcomes of DHI in secondary prevention care.

Supplementary material

Supplementary material is available at *European Journal of Preventive Cardiology*.

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Author contribution

S.E.K. and P.D. contributed to the conception and design of the work. S.E.K. developed and registered the protocol on PROSPERO and co-ordinated the search strategy. S.E.K. and L.X. conducted the literature screening. Data extraction was performed by S.E.K., L.X., and J.R. B.A. and O.B. assessed the risk of bias. Meta-analyses were performed by J.R. and L.X. The first draft of the manuscript was written by S.E.K., L.X., B.A., G.B., M.S., and O.B. All authors critically revised the manuscript for important intellectual content. All authors gave final approval and agree to be accountable for all aspects of the work, ensuring the integrity and accuracy of the analysis.

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Data availability

The data underlying this article are available in the article and in its Supplementary material online: all data analysed in this review were extracted from previously published studies, which are fully referenced in the manuscript. No new data were generated or collected by the authors. Extracted data and summary tables used in the meta-analysis are available in the Supplementary material online.

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