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ORIGINAL ARTICLE
Digital health—other

The association of electronic health literacy with behavioural and psychological coronary artery disease risk factors in patients after percutaneous coronary intervention: a 12-month follow-up study

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Aims

Fundamental roadblocks, such as non-use and low electronic health (eHealth) literacy, prevent the implementation of eHealth resources. The aims were to study internet usage for health information and eHealth literacy in patients after percutaneous coronary intervention (PCI). Further, we aimed to evaluate temporal changes and determine whether the use of the internet to find health information and eHealth literacy were associated with coronary artery disease (CAD) risk factors at the index admission and 12-month follow-up of the same population.

Methods and results

This prospective longitudinal study recruited 2924 adult patients with internet access treated by PCI in two Nordic countries. Assessments were made at baseline and 12-month follow-up, including a *de novo* question *Have you used the internet to find information about health?*, the eHealth literacy scale, and assessment of clinical, behavioural, and psychological CAD risk factors. Regression analyses were used. Patients' use of the internet for health information and their eHealth literacy were moderate at baseline but significantly lower at 12-month follow-up. Non-users of the internet for health information were more often smokers and had a lower burden of anxiety symptoms. Lower eHealth literacy was associated with a higher burden of depression symptoms at baseline and lower physical activity and being a smoker at baseline and at 12-month follow-up.

Conclusion

Non-use of the internet and lower eHealth literacy need to be considered when implementing eHealth resources, as they are associated with behavioural and psychological CAD risk factors. eHealth should therefore be designed and implemented with high-risk CAD patients in mind.

Clinical trial registration

ClinicalTrials.gov NCT03810612 https://clinicaltrials.gov/ct2/show/NCT03810612

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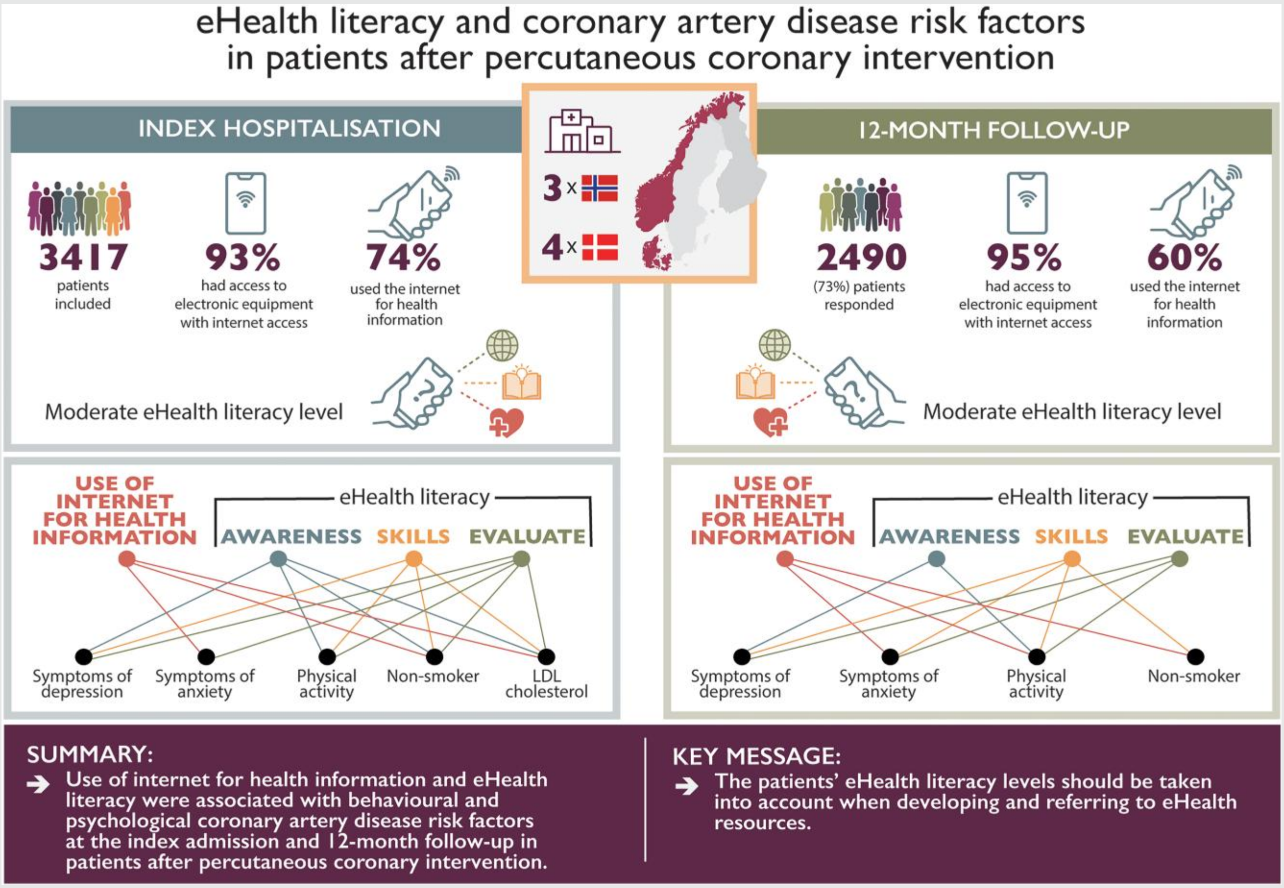
Graphical Abstract



Keywords eHealth literacy • Risk factors • Coronary artery disease • Secondary prevention • Percutaneous coronary intervention

Introduction

Electronic health (eHealth) resources are a major source of health information on cardiovascular medicine and care.[1] The World Heart Federation Roadmap for digital health in cardiology states that by 2030, eHealth has the potential to reduce premature mortality from non-communicable diseases by a third.[2] Furthermore, the majority of patients with coronary artery disease (CAD) fail to adopt lifestyle advice,[3] and a substantial proportion have a high burden of anxiety and depression symptoms after CAD events.[4]

Despite the proved efficacy of eHealth resources,[2,5] implementation is influenced by several patient-related barriers.[2] In addition to health-related factors, and not having a digitally connected home,[6–8] low acceptability and digital literacy are important hindrances.[2] Low health literacy has been found to be associated with CAD risk factors in patients who have undergone percutaneous coronary intervention (PCI)[9] and is a barrier to the large-scale deployment of eHealth.[1] It is therefore natural to draw attention to the importance of eHealth literacy when developing eHealth secondary prevention programmes.[10]

While health literacy represents the ability to access, understand, appraise, remember, and use information about health from general sources,[11] eHealth literacy represents these abilities when applied to electronic sources.[12] Evidence has shown negative associations between eHealth literacy and cardiovascular risk,[13] cardiac events, anxiety, and depression.[14] Moreover, eHealth literacy skills have been shown to increase during participation in eHealth programmes,[15,16] underpinning the importance and dynamic nature of eHealth literacy.[17] However, no studies have evaluated the associations of use of the internet for health information and eHealth literacy with CAD risk factors (e.g. hypertension, hypercholesterolaemia, diabetes, smoking, physical inactivity, anxiety, and depression symptoms) in patients treated by PCI. We therefore aimed to study internet usage for health information and eHealth literacy in patients after PCI. Further, we aimed to evaluate temporal changes and determine whether use of the internet to find health information and eHealth literacy were associated with CAD risk factors at the index admission and 12-month follow-up of the same population.

Methods

Study design and setting

In accordance with the aims, a prospective observational longitudinal study including adult patients undergoing PCI at seven large referral PCI centres in Norway and Denmark was conducted. Patients were screened for eligibility from June 2017 to May 2019 (CONCARD^{PCI} study).[18] Written informed consent was obtained. The study conformed to the ethical principles outlined in the Declaration of Helsinki and was approved by the Norwegian Regional Committee for Ethics in Medical Research (REK 2015/57) and the Data Protection Agency in the Zealand region for the Danish centres (REG-145-2017). The sample size calculated for the cohort study was based on time-to-first-event outcomes, as these required the most patients. To maintain a family-wise Type I error of 5% and 80% power using the method of Hsieh and Lavori for adjusted Cox regression models, a sample of 2550 patients was required. To adjust for losses to follow-up, we planned for a total of 3000 patients. Thus, all outcomes will have ≥80% power with alpha ≤0.05.[18] No additional *post hoc* power analyses were performed for the outcomes in this paper.

Study population and patient selection

The inclusion criteria were PCI treatment during the index hospital admission, age ≥18 years and living at home at the time of inclusion. Exclusion criteria were inability to speak Norwegian or Danish and inability to fill out the self-report questionnaire. Additionally, patients undergoing PCI without stent implantation and patients undergoing PCI related to transcatheter aortic or mitral valve implantation were excluded.

Data collection

Sociodemographic (self-reported) and clinical characteristics (Denmark: medical records; Norway: medical records and the Norwegian Registry of Invasive Cardiology) were collected during the index hospital stay after PCI. Self-reported *use of the internet for health information*, eHealth literacy, and CAD risk factors were collected at the index hospital stay and at the 12-month follow-up. Study nurses included the patients after the PCI procedure. Baseline self-reported data were collected during index hospitalization. At 12-month follow-up, all patients received postal, or electronic in the Danish centres, self-report questionnaires to administer at home.

Outcome measurements

Patient characteristics and clinical coronary artery disease risk factors

The sociodemographic data collected included age, sex, cohabiting status, education level (secondary school, vocational college, high school, and college/university), and work status (currently working, retired or other, e.g. full-time sick leave and seeking employment).

Clinical characteristics included medical history (anxiety and depression, CAD, diabetes, hypercholesterolaemia, and hypertension), clinical risk factors [systolic blood pressure, total cholesterol, and low-density lipoprotein (LDL) cholesterol], and indication for PCI (stable angina pectoris, unstable angina pectoris, non-ST-segment elevation myocardial infarction, or ST-segment elevation myocardial infarction).

Use of the internet for health information

De novo questions specifically developed for this study by the CONCARD^{PCI} investigators were used to assess patients' access to and use of the internet: (i) *Do you have access to electronic equipment with internet access?* and (ii) *Have you used the internet to find information about health*? The response options to both questions were 'yes' and 'no'.

eHealth literacy scale

The patients' level of eHealth literacy was measured using the eHealth literacy scale (eHEALS), which assesses patients' own perception of their knowledge, comfort, and perceived skills at finding, evaluating, and applying eHealth information.[12] Electronic health literacy scale contains eight items measured on a 5-point Likert scale with response options ranging from *strongly disagree* (1) to *strongly agree* (5).[12] The eight eHEALS items were summed for a mean score (8–40 scale).

The eHEALS questionnaire has been translated into Danish[19] and Norwegian and validated in both languages.[20] Both the Danish and Norwegian versions suggest a multidimensional construct. However, the Danish version had a high root mean square error of approximation in all the factor models. The Norwegian version[20] has shown sufficient psychometric properties and proposes a three-factor model consisting of (i) *awareness* (knowledge of what health information is available on the internet and where to find it) (Items 1 and 2); (ii) *skills* (skills and behaviour needed to assess health information) (Items 3–5); and (iii) *evaluate* (the ability to evaluate the health information once accessed) (Items 6–8), as proposed by Sudbury-Riley *et al.*[21] The subscales *awareness* (2–10 scale), *skills*, and *evaluate* (3–15 scales) were summed for mean scores and transformed to a 0–100 score to make the results more interpretable. The coefficients for eHEALS scales were reported per 10 points. A low score indicates that the respondent has difficulties, and a high score indicates greater eHealth literacy. The Cronbach's alpha value for the eHEALS subscales indicated good internal consistency at index admission and at 12-month follow-up (alpha ≥0.88 for all) (see Supplementary material online, *Table S1*).

Behavioural and psychological coronary artery disease risk factors

The patients' smoking status was classified as current smoker or non-smoker. To assess engagement in regular physical activity, the physical activity frequency, intensity, and duration (PAFID) questionnaire was used.[22] The PAFID contains three items on physical activity: (i) frequency [never (0), less than once per week (0.5), once per week (1), 2–3 times per week (2.5), or almost every day (5)]; (ii) duration of each exercise session [<15 min (7.5), 15–29 min (22.5), 30–60 min (45), or over 60 min (75)]; and (iii) intensity [low ('I take it easy, I don't get out of breath or break a sweat'), moderate ('I push myself until I'm out of breath or break into a sweat'), or high ('I practically exhaust myself')]. The number of minutes of physical activity is calculated as the average time spent per session multiplied by the average frequency of exercise per week multiplied by the weighted intensity [low (0.5), moderate (1), and high (2)] based on the values in brackets.

Symptoms of anxiety and depression were measured using the Hospital Anxiety and Depression Scale (HADS).[23] The HADS contains 14 items divided into two subscales, one for anxiety symptoms (HADS-A) and one for depression symptoms (HADS-D), each with seven items. All questions have a 4-point Likert scale response option from 0 (*no symptoms*) to 3 points (*highest symptom level*).[24] The HADS items were used to calculate a sum score using the half rule. The total sum score for each subscale ranges from 0 to 21, where higher scores represent a higher burden of anxiety and depression. In the regression analysis, the sum score was converted to a 0–100 scale to make the results more interpretable.

Data analyses

The patient characteristics are summarized as counts (*n*) and percentages (%) for categorical variables, and as mean and standard deviation (SD) for continuous variables. To compare the difference in sociodemographics, clinical data, and CAD risk factors between those who used the internet to access health information and those who did not, *t*-test and χ^2 test were used.

For missing data, the questionnaires eHEALS and HADS scores were computed by half rule, based on the mean of the valid items if at least half of the items in the scale were valid. For a sum score, this is subsequently multiplied by the total number of items.

Mixed effects models estimated *use of the internet for health information* and the eHealth literacy level (eHEALS total sum score and the three eHEALS scales *awareness*, *skills*, and *evaluate*) at index admission and 12-month follow-up and estimated the changes between those two timepoints. A proportion of patients reporting *use of the internet for health information* over time were investigated by logistic regression using generalized estimation equations with an exchangeable correlation structure to account for within-person clustering.

Adjusted linear regression models were used to estimate the associations of *use of the internet for health information* and eHealth literacy with the intensity-adjusted weekly physical activity score, HADS-A, and HADS-D

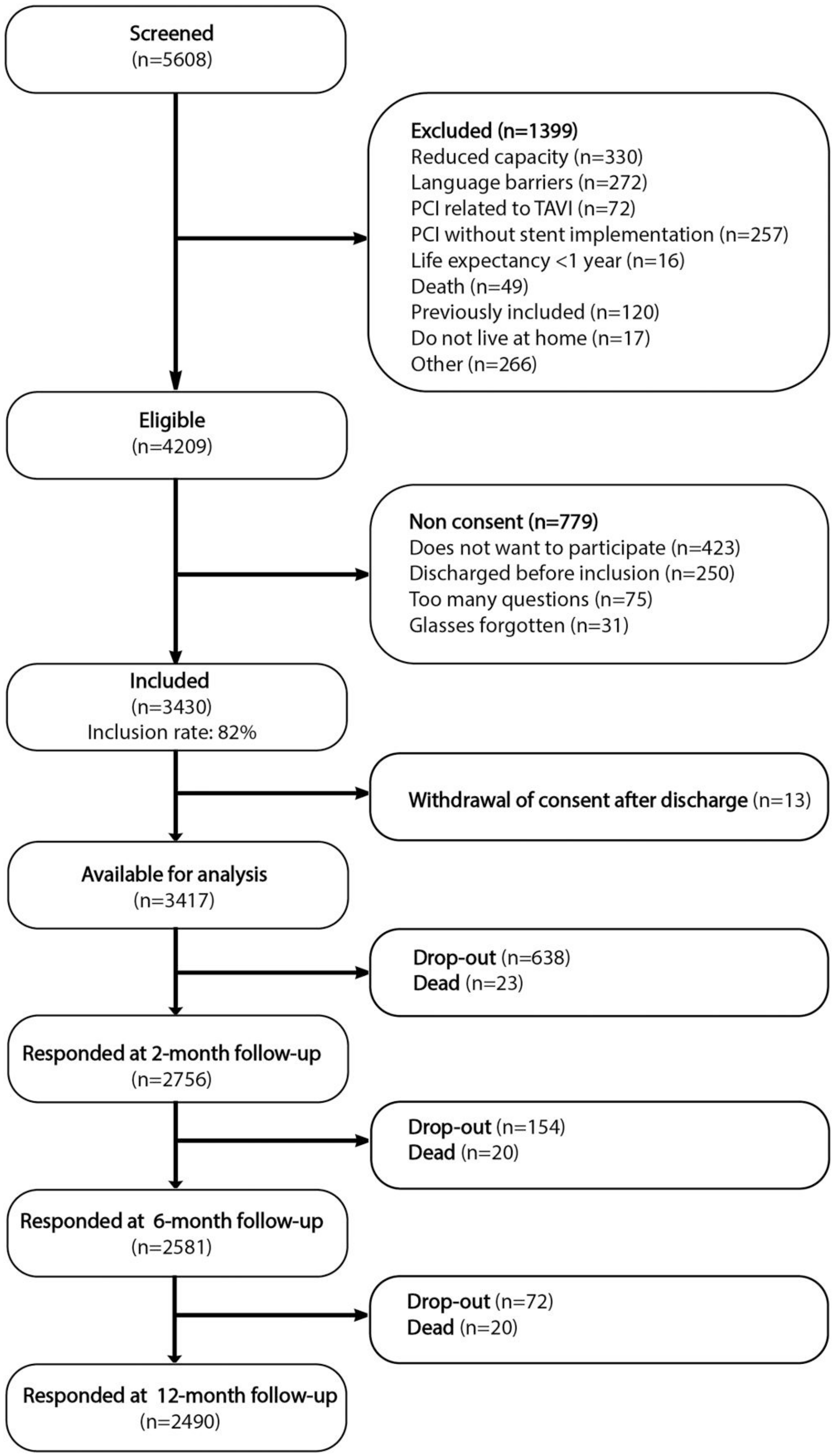


Figure 1 Flow chart describing the participants' enrolment and selection procedure of the CONCARD^{PCI} study, with detailed information about exclusions and discontinuations during the 12-month follow-up of the study.

Table 1 Demographic characteristics and coronary artery disease risk factors of patients who reported to have access to electronic equipment with internet access at the index admission for percutaneous coronary intervention (2924 of 3417 included patients, 85.6%)

	Total	Use of the internet for health information: Yes	No	*P*-value
Sample size	2924 (100)	2060 (74)	736 (26)	
Age (year), mean (SD)	66 (11)	64 (10)	67 (10)	<0.001
Sex				
Male	2342 (80)	1662 (74)	575 (26)	0.137
Female	582 (20)	398 (71)	161 (29)	
Country				
Danish	1275 (44)	892 (76)	280 (24)	0.013
Norwegian	1649 (56)	1168 (72)	456 (28)	
Ethnic background				
Ethnic Danish/Norwegian	2563 (92)	1804 (74)	645 (26)	0.147
Born in Denmark/Norway	97 (3.5)	61 (69)	28 (32)	
Immigrant	124 (4.5)	97 (81)	24 (19)	
Cohabitation				
Cohabitating	2172 (78)	1552 (75)	523 (25)	0.018
Living alone	630 (22)	419 (70)	181 (30)	
Education level				
Primary school	522 (18)	269 (53)	239 (47)	<0.001
Vocational school	1249 (43)	853 (72)	324 (28)	
High school	277 (10)	217 (81)	50 (19)	
College/university	831 (29)	693 (87)	107 (13)	
Employment status				
Working	1207 (42)	923 (80)	233 (20)	<0.001
Retired	1551 (54)	1020 (69)	460 (31)	
Other	135 (5)	98 (75)	32 (25)	
Medical history				
Anxiety and/or depression	305 (11)	220 (76)	71 (24)	0.440
Coronary artery disease[a]	1040 (36)	730 (75)	250 (26)	0.471
Diabetes	494 (17)	338 (72)	130 (28)	0.455
Hypercholesterolaemia	1344 (46)	939 (74)	331 (26)	0.829
Hypertension	1490 (51)	1047 (74)	360 (26)	0.366
PCI indication				
Stable AP	1135 (39)	807 (76)	262 (25)	0.027
NSTEMI/UAP	1145 (39)	806 (74)	280 (26)	
STEMI	643 (22)	446 (70)	194 (30)	
CAD risk factors				
Systolic blood pressure, mean (SD)	138 (24)	138 (23)	138 (23)	0.558
Total cholesterol, mean (SD)	4.7 (1.3)	4.7 (1.3)	4.7 (1.3)	0.731
LDL cholesterol, mean (SD)	2.9 (1.2)	2.9 (1.2)	3.0 (1.2)	0.711
Current smoker	480 (17)	309 (67)	155 (33)	<0.001
Non-smoker	2402 (83)	1724 (75)	566 (25)	
Physical activity, mean (SD)[b]	1.7 (1.9)	1.8 (1.9)	1.5 (1.7)	<0.001
HADS-D, mean (SD)	3.4 (3.3)	3.3 (3.3)	3.6 (3.5)	0.027
HADS-A, mean (SD)	4.9 (3.9)	5.0 (3.9)	4.7 (3.8)	0.032

Data are presented as *n* (%) if not stated elsewhere. The first column (total) shows the distribution related to the total, while the two other columns show the within category distribution. CAD, coronary artery disease; LDL cholesterol, low-density lipoprotein cholesterol; NSTEMI, non-ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; SD, standard deviation; UAP, unstable angina pectoris.

[a]Including previous coronary artery disease, myocardial infarction, PCI, and/or coronary artery bypass graft.

[b]Intensity-adjusted hours per week.

Table 2 Use of the internet for health information and eHealth literacy at the index admission for percutaneous coronary intervention ($n = 2924$) and 12-month follow-up ($n = 2282$) and the estimated change between those two timepoints

	Baseline		12 months				
	n	Mean (SD)	*n*	Mean (SD)	Estimate[a] (95% CI)	OR[b] (95% CI)	*P*-value
Use of the internet for health information, *n* (%)	2796	2065 (73.7)	2238	1347 (60.2)		0.54 (0.488–0.587)	<0.001
eHEALS total[c]	2739	27.27 (6.28)	2118	26.97 (5.98)	−0.27 (−0.53, −0.01)		0.041
eHEALS: awareness[d]	2749	61.68 (21.49)	2138	60.68 (20.87)	−0.96 (−1.911, −0.001)		0.050
eHEALS: skills[e]	2739	63.96 (20.71)	2114	61.35 (20.03)	−2.55 (−3.449, −1.650)		<0.001
eHEALS: evaluate[f]	2731	55.56 (22.10)	2115	56.27 (21.41)	0.875 (−0.078, 1.829)		0.072

CI, confidence interval; CAD, coronary artery disease; eHEALS, electronic health literacy scale; OR, odds ratio; SD, standard deviation.
[a]Mean difference estimated with mixed effect model.
[b]Odds ratio assessed by logistic regression using generalized estimation equations (GEE).
[c]eHEALS total (min score = 8; max score = 40).
[d]eHEALS: awareness (min score = 0; max score = 100).
[e]eHEALS: skills (min score = 0; max score = 100).
[f]eHEALS: evaluate (min score = 0; max score = 100).

at the index hospital stay for PCI and at 12-month follow-up. For each outcome (HADS-A, HADS-D, physical activity, and non-smoker), separate models for the independent variables (*use of the internet for health information* and the three eHealth scales) were adjusted for age, education, and sex. For each of these outcomes, all the independent variables were included with the same adjustment variables. The associations of use of internet for health information and eHealth literacy with being a non-smoker were estimated by logistic regression using complete case analyses. Bootstrapping with 10 000 replications was used to compute confidence intervals (CIs) for the difference in regression coefficients and odds ratios (ORs) at the index admission and 12-month follow-up. All of the analyses were assessed among patients who stated that they had access to electronic equipment with internet access.

Confirmatory factor analyses were used to validate the model fit for the three-factor model at the two measuring points for both the Norwegian and Danish patients (see Supplementary material online, *Tables S2* and *S3*).

The analyses were carried out using SPSS 24 (IBM Corp, NY, USA), R (R, Vienna, Austria), and Mplus (Computer software, version 7).

Results

Patient characteristics

In total, 3417 patients were included in the CONCARD[PCI] study (*Figure 1*). Among those, 2924 (86%) reported to have access to electronic equipment with internet access and were included in the analyses. Most patients were male (78%). The mean (SD) age was 66 (11) years. Participants who used the internet for health information were younger than the others (difference 3.8 years, $P < 0.001$; *Table 1*).

Use of the internet for health information and eHealth literacy

Over 70% of participants stated that they used the internet to find health information at the index admission for PCI compared with 50% at 12-month follow-up. The total eHealth literacy score showed a significant decrease from baseline to 12-month follow-up, and the subscale *evaluate* had the lowest score at both timepoints. There was a statistically significant decrease in the eHealth literacy subscales *awareness* and *skills* between the two timepoints (*Table 2*).

Association with coronary artery disease risk factors

The odds of being a smoker were significantly lower for those who used the internet to find health information at index admission and 12-month follow-up compared with users [OR 0.597 (95% CI 0.471–0.759) and OR 0.471 (95% CI 0.344–0.644)]. Further, those who used the internet for health information at 12-month follow-up reported 12.7 min more of intensity-adjusted physical activity per week (95% CI 1.1–24.3). Anxiety symptoms were significantly higher among those who used the internet for health information at index admission and at 12-month follow-up compared with non-users (*Tables 3* and *5*). Additionally, LDL cholesterol was significantly lower (difference 0.14 mmol/L) at the index hospital stay in those who used the internet for health information compared with non-users (*Table 4*).

The odds of being a smoker were significant lower with a higher score on the three eHealth literacy subscales at the index admission (OR ranging 0.915–0.936 per 10 units higher eHealth literacy score). At 12-month follow-up, the association remained significant for *skills*. However, the associations were numerically similar for the two other subscales (Model 1). After adding the variable for use of the internet for health information to the model (Model 2), the association remained significant for the eHEALS subscale *evaluate* (*Tables 3* and *5*).

The estimated weekly physical activity level at index admission and 12-month follow-up was 3–6 intensity-adjusted min higher per 10-unit higher score on the eHEALS in the two models (*Tables 3* and *5*).

At the index admission, higher eHealth literacy was significantly associated with fewer depression symptoms, which remained significant for the scales *awareness* and *skills* at 12-month follow-up. The scale *evaluate* was significantly associated with more depression symptoms at 12-month follow-up (*Tables 3* and *5*).

Anxiety symptoms were 0.5 points lower per 10-unit higher score on the eHEALS *evaluate* at the index admission, and 0.8 point higher per 10-unit higher score at 12-month follow-up (*Tables 3* and *4*). The negative differences between the regression coefficients at the index admission and at 12-month follow-up were significant (see Supplementary material online, *Table S4*). Additionally, anxiety symptoms were two points lower per 10-point higher score in *skills* at 12-month follow-up (*Tables 3* and *5*). Additionally, LDL cholesterol at the index hospital stay was 0.028–0.038 mmol/L lower per 10-unit higher score on all the eHEALS (*Table 4*).

Table 3 Association of the use of the internet for health information and eHealth literacy with symptoms of depression and anxiety, physical activity, and smoking status at the index admission

	HADS-D[a]		HADS-A[b]		Physical activity[c]		Smoker	
	Coef. (95% CI)	*P*-value	Coef. (95% CI)	*P*-value	Coef. (95% CI)	*P*-value	OR (95% CI)	*P*-value
Used the internet for health information								
Model 1	−0.963 (−2.365, 0.440)	0.178	1.724 (0.117–3.331)	0.036	0.168 (−0.003, 0.339)	0.053	0.598 (0.471–0.759)	<0.001
Model 2	1.289 (−0.338, 2.916)	0.120	2.625 (0.743–4.506)	0.006	−0.028 (−0.231, 0.175)	0.786	0.666 (0.504– 0.879)	0.004
eHEALS: awareness[d]								
Model 1	−0.622 (−0.900, −0.345)	<0.001	−0.141 (−0.463, 0.181)	0.390	0.066 (0.032–0.101)	<0.001	0.928 (0.884–0.975)	0.003
Model 2	0.236 (−0.279, 0.751)	0.368	0.300 (−0.295, 0.896)	0.523	−0.007 (−0.070, 0.057)	0.841	0.946 (0.865–1.034)	0.221
eHEALS: skills[d]								
Model 1	−0.887 (−1.177, −0.597)	<0.001	−0.304 (−0.641, 0.034)	0.078	0.085 (0.049–0.121)	<0.001	0.936 (0.889–0.985)	0.012
Model 2	−0.883 (−1.496, −0.270)	0.005	−0.272 (−0.981, 0.436	0.451	0.105 (0.029–0.181)	0.007	1.077 (0.968–1.197)	0.173
eHEALS: evaluate[d]								
Model 1	−0.793 (−1.065, −0.520)	<0.001	−0.517 (−0.834, −0.200)	0.001	0.056 (0.022–0.090)	0.001	0.915 (0.872–0.961)	<0.001
Model 2	−0.375 (−0.797, 0.047)	0.081	−0.668 (−1.156, −0.181)	0.007	−0.019 (−0.072, 0.033)	0.465	0.921 (0.855–0.992)	0.030

Data are based on the 2924 patients with internet access at the index admission for percutaneous coronary intervention. Corresponding *P*-values are shown. Model 1: adjusted for sex, age, and education level. Model 2: all the independent variables ('use of the internet to access health information' and the three eHealth scales), adjusted for age, education, and sex.

CI, confidence interval; CAD, coronary artery disease; eHEALS, electronic health literacy scale; HADS-A, Hospital Anxiety and Depression Scale anxiety; HADS-D, HADS depression.

[a]HADS depression (min score = 0; max score = 100).

[b]HADS anxiety (min score = 0; max score = 100).

[c]Intensity-adjusted hours per week difference.

[d]The coefficients for eHEALS scales are per 10 points.

Table 4 Association of the use of the internet for health information and eHealth literacy with systolic blood pressure, lipid panel, and diabetes at the index admission

	Systolic blood pressure		Total cholesterol		LDL cholesterol		Diabetes	
	Coef. (95% CI)	*P*-value	Coef. (95% CI)	*P*-value	Coef. (95% CI)	*P*-value	OR (95% CI)	*P*-value
Used the internet for health information								
Model 1	1.288 (−0.771, 3.347)	0.220	−0.073 (−0.195, 0.048)	0.236	−0.136 (−0.254, −0.017)	0.025	0.972 (0.768–1.232)	0.817
Model 2	2.243 (−0.174, 4.660)	0.069	−0.050 (−0.194, 0.094)	0.494	−0.099 (−0.238, 0.041)	0.165	0.881 (0.676–1.175)	0.414
eHEALS: awareness[a]								
Model 1	−0.175 (−0.588, 0.238)	0.406	−0.014 (−0.039, 0.011)	0.282	−0.038 (−0.062, −0.013)	0.002	0.997 (0.951–1.046)	0.909
Model 2	−0.685 (−1.450, 0.080)	0.079	−0.024 (−0.70, 0.022)	0.308	−0.024 (−0.069, 0.021)	0.294	0.935 (0.856–1.021)	0.134
eHEALS: skills[a]								
Model 1	−0.049 (−0.481, 0.383)	0.823	−0.010 (−0.037, 0.016)	0.432	−0.036 (−0.61, −0.011)	0.005	1.018 (0.968–1.071)	0.483
Model 2	0.126 (−0.785, 1.037)	0.913	−0.008 (−0.062, 0.047)	0.778	−0.003 (−0.056, 0.049)	0.903	1.076 (0.968–1195)	0.176
eHEALS: evaluate[a]								
Model 1	0.022 (−0.384, 0.484)	0.249	0.002 (−0.023, 0.026)	0.893	−0.028 (−0.052, −0.004)	0.020	1.024 (0.977–1.074)	0.319
Model 2	0.273 (−0.354, 0.900)	0.394	0.021 (−0.016, 0.059)	0.268	−0.005 (−0.042, 0.031)	0.769	1.015 (0.942–1.092)	0.702

Data are based on the 2924 patients with internet access at the index admission for percutaneous coronary intervention. Data for systolic blood pressure (mmHg), total cholesterol (mmol/L), and LDL cholesterol (mmol/L) are presented as regression coefficients and 95% confidence intervals (95% CI), while the odds ratio and 95% CI are presented for diabetes. Corresponding *P*-values are shown. Model 1: adjusted for sex, age, and education level. Model 2: all the independent variables (the three eHealth scales and 'use of the internet to access health information'), adjusted for age, education, and sex.

CI, confidence interval; eHEALS, electronic health literacy scale; HADS-A, Hospital Anxiety and Depression Scale anxiety; LDL cholesterol, low-density lipoprotein (LDL) cholesterol.

[a]The coefficients for eHEALS scales are per 10 points.

Table 5 Association between eHealth literacy and use of the internet for health information with symptoms of depression and anxiety, physical activity, and smoking status at 12-month follow-up

	HADS-D[a]		HADS-A[b]		Physical activity[c]		Smoker	
	Coef. (95% CI)	*P*-value	Coef. (95% CI)	*P*-value	Coef. (95% CI)	*P*-value	OR (95% CI)	*P*-value
Used internet for health information								
Model 1	0.615 (−0.941, 2.172)	0.426	2.021 (0.036–4.007)	0.046	0.212 (0.018–0.406)	0.032	0.471 (0.344–0.644)	<0.001
Model 2	1.400 (−0.265, 3.065)	0.099	1.722 (−0.407, 3 .851)	0.113	0.116 (−0.091, 0.323)	0.273	0.497 (0.357–0.691)	<0.001
eHEALS: awareness[d]								
Model 1	−0.356 (−0.709, −0.002)	0.049	0.231 (−0.221, 0.684)	0.316	0.064 (0.019–0.108)	0.005	0.942 (0.876–1.012)	0.104
Model 2	0.115 (−0.544, 0.774)	0.732	0.777 (−0.066, 1.620)	0.071	0.003 (−0.079, 0.085)	0.937	1.010 (0.885–1.153)	0.880
eHEALS: skills[d]								
Model 1	−0.554 (−0.929, −0.179)	0.004	−0.100 (−0.582, 0.382)	0.683	0.077 (0.030–0.124)	0.001	0.911 (0.854–0.995)	0.036
Model 2	−1.312 (−2.077, −0.565)	0.001	−1.983 (−2.950, −1.016	<0.001	0.060 (−0.034, 0.155)	0.209	0.927 (0.798–1.076)	0.318
eHEALS: evaluate[d]								
Model 1	0.098 (−0.252, 0.449)	0.582	0.768 (0.320–1.216)	0.001	0.052 (0.009–0.096)	0.018	0.962 (0.895–1.033)	0.283
Model 2	0.830 (0.351–1.309)	0.001	1.496 (0.883–2.109)	<0.001	0.009 (−0.050, 0.068)	0.769	1.036 (0.939–1.142)	0.481

Data are based on the 2282 patients with internet access at 12-month follow-up. Data for HADS and physical activity are presented as regression coefficients and 95% confidence intervals (95% CI), while the odds ratio and 95% CI are presented for smoking habits. Corresponding *P*-values are shown. Model 1: adjusted for gender, age, and education level. Model 2: all the independent variables (eHealth literacy scales *awareness*, *skills*, and *evaluate* and 'use of the internet to access health information'), adjusted for age, education, and sex.
CI, confidence interval; eHEALS, electronic health literacy scale; HADS-A, Hospital Anxiety and Depression Scale anxiety; HADS-D, HADS depression.
[a]HADS depression (min score = 0; max score = 100),
[b]HADS anxiety (min score = 0; max score = 100).
[c]Intensity-adjusted hours per week difference.
[d]The The coefficients for eHEALS scales are per 10 points.

Discussion

In this large-scale study evaluating patients treated by PCI, we found that 74% of the population who used the internet for health information and those with better eHealth literacy had lower levels of CAD risk factors at index admission and 12-month follow-up. Overall, one in three of those who used the internet for health information at index admission was a non-user at 12-month follow-up. The eHealth literacy scores were modest at both timepoints, although significantly lower at 12-month follow-up compared with the index admission. These findings indicate that the use of the internet for health information and eHealth literacy should be considered in daily clinical work as well as in future clinical studies.

eHealth characteristics in patients undergoing percutaneous coronary interventions

Compared with a previous study evaluating an eHEALS three-factor model on a sample of the US adults,[25] the population in this study had a lower eHealth literacy score on *awareness* of available health information on the internet. Further, the low score on *evaluate* indicates the patients' challenges in critically evaluating the health information available on the internet. A possible explanation for the reduced use of the internet for health information and lower eHealth literacy at 12-month follow-up compared with index admission may be that no organized eHealth programme was used in the present study. This underpins the Roadmap for Digital Health in Cardiology's message on how lacking implementation and context-specific adaptations are significant barriers to the implementation of eHealth resources.[2] The potential of addressing eHealth literacy to provide the best possible patient care is further supported by two studies that found increased eHealth literacy levels when evaluating eHealth programmes during patient follow-up.[15,16]

eHealth characteristics and traditional coronary artery disease risk factors

The results presented indicate that less use of the internet for health information and lower eHealth literacy constitutes challenges to improving CAD risk factors after PCI. Patients who used the internet to find health information were approximately half as likely to be smokers. Furthermore, LDL measured at index admission was significantly lower, and the level of physical activity at index admission and 12-month follow-up was higher among those who used the internet for health information (level of significance: physical activity at index admission $P = 0.053$, otherwise $P \leq 0.03$). In line with these findings, lower eHealth literacy was significantly associated with a lower level of physical activity and higher likelihood of being a smoker. The results are in line with previous findings from 300 participants and 399 non-participants in a cardiac telerehabilitation study showing that smoking and low exercise capacity were associated with non-participation.[8] To our knowledge, no studies have determined the associations between eHealth literacy and CAD risk factors in patients who have undergone PCI. However, lower health literacy in general has been shown to be associated with a lower level of physical activity, smoking, and a higher burden of both anxiety and depression at the index admission for PCI.[9] Thus, the current results extend the knowledge from previous general health literacy studies to eHealth literacy.

eHealth characteristics and psychological coronary artery disease risk factors

The symptom burden of anxiety was higher among those who used the internet for health information both at index admission and 12-month follow-up. Furthermore, lower eHealth literacy was significantly associated with more depression symptoms. To our knowledge, only one previous study has determined the associations between eHealth literacy and depression and anxiety symptoms. This found that psychological distress mediated the effect of eHealth literacy on medical adherence, quality of life, and risk of cardiac events.[14]

Interestingly, a higher score on the eHEALS *skills* was significantly associated with less depression symptoms, while a higher score on the scale *evaluate* was associated with more depression symptoms at 12-month follow-up. The same trend was identified for anxiety symptoms, indicating a paradoxical finding. One possible reason is that patients with depression and anxiety symptoms use the internet for health information to a greater extent than those with fewer symptoms. The finding may also be partly explained by subgroups that used the internet for health information but that were unable to evaluate the information in order to change their behaviour. The latter may constitute a clinical challenge in the follow-up of patients with CAD.

Clinical implications

The findings of this study underline that CAD patients' awareness of available health information on the internet, their confidence in evaluating it, and how they translate the knowledge into practical skills are important factors associated with their risk profile both at index admission and 12-month follow-up after PCI. Together with one previous study evaluating eHealth literacy with respect to future heart failure events,[14] these studies indicate that improving eHealth literacy may improve the patients' risk profile and thus prevent future cardiac events.

Ideally, eHealth programmes should be designed with a personalized interface, e.g. by addressing the subjects' risk in relation to future cardiac events.[2,16] However, the value of personal interaction between patients and healthcare providers indicates that eHealth is best utilized as an addition to traditional care. The finding concerning patients using the internet to a lesser extent for health information at 12-month follow-up may indicate that the PCI itself, or the interaction with the healthcare providers during the index admission, reduced the patients' need to extract information from eHealth resources after treatment. Although this may be a normal psychological response to the reduced burden of symptoms, it also highlights a non-utilized clinical potential of eHealth to optimize patients' perception of illness and future risk by improving adherence to therapy.[26] The patients' eHealth literacy level in this study was crucial to an optimal CAD risk profile. The challenge of identifying good health information from reliable sources and understanding conflicting information is well-known.[9,11,17] For patients with CAD, there is a need for readily available health information, including practical support on how to perform appropriate physical activity and how to succeed with smoking cessation.[5] Dedicated eHealth programmes may help to ensure that patients are well-informed and understand the consequences of their behaviour.[17] Insufficient technical skills and lack of confidence among patients must be taken into account for optimal implementation of eHealth.[8] Future research should evaluate personalized eHealth programmes designed for high-risk CAD patients in randomized control trials so as to best delineate the optimal way of improving patients' risk profile and thereby reduce future cardiac events.

Strengths and limitations

A major strength of this study is the design, which includes a large cohort of 3000 patients with CAD and uses standardized patient-reported outcome measures and structured data from medical records and registries. The multi-centric design, which includes participants directly after PCI at seven university hospitals in two Nordic countries (inclusion rate 82%), is another strength. Together, these strengths make the results generalizable to a large population of patients.

The study also has some limitations. In total, 26% of the patients with access to the internet at baseline did not respond to the 12-month follow-up. Those who did not respond to the follow-up invitation were more likely smokers, less physically active, and younger and lived alone at the time of the index admission (see Supplementary material online, *Table S5*). Thus, there may be some attrition bias related to the 12-month follow-up examination. Furthermore, blood pressure was only recorded once, and these measurements were therefore not optimized according to the guidelines.[27] Lastly, LDL was only measured during the index admission.

Conclusion

In CAD patients undergoing PCI, we found that those who did not use the internet to find health information and those with lower eHealth literacy had a worse risk profile, including smoking habits, LDL cholesterol, and physical activity. Lower eHealth literacy was also associated with more depression symptoms, while those who used the internet for health information had more anxiety symptoms at index admission and 12-month follow-up. The results presented extend previous results from general health literacy studies to the use of the internet for health information and eHealth literacy. As such, eHealth interventions supporting patients' adherence to therapy have the potential to improve care for patients with CAD after PCI and beyond. Future studies should assess the importance of eHealth literacy in personalized eHealth programmes targeting risk intervention and its effect on clinical outcomes.

Author contributions

G.B., H.D., B.F., T.W.L., and T.M.N. designed the study and analysis plan. T.M.N. was responsible for the data collection. G.B. performed the data analysis, with participation from T.W.L. G.B. drafted the manuscript. All co-authors contributed to the manuscript.

Supplementary material

Supplementary material is available at *European Heart Journal – Digital Health*.

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Data availability

Data are not available for others according to Norwegian data protection legislation. Analysis files (SPSS syntax, other) can be made publicly available from the PI upon reasonable request.

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