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Association between digital health literacy and physical activity levels among individuals with and without long-term health conditions: Data from a cross-sectional survey of 19,231 individuals

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Abstract

Objectives: This study explored associations between digital health literacy and physical activity levels and assessed potential interactions of long-term health conditions.

Methods: A cross-sectional survey was sent to 34,000 inhabitants in Region Zealand, Denmark. The survey included items on physical activity levels and three electronic Health Literacy Questionnaire (eHLQ) scales (1, 4, and 5). Associations were assessed by logistic regression and adjusted for confounders.

Results: A total of 19,231 participated in the survey. Positive associations were found between higher digital health literacy and being active >30 min./week at moderate-to-vigorous intensity (eHLQ 1: OR 1.24, $p < 0.001$; eHLQ 4: OR 1.13, $p = 0.012$; eHLQ 5: OR 1.25, $p < 0.001$), compliance with the World Health Organization minimum recommendations for physical activity (eHLQ 1: OR 1.33 $p < 0.001$; eHLQ 4: OR 1.08 $p = 0.025$; eHLQ 5: OR 1.32, $p < 0.001$), and self-reported physical active (eHLQ 1: OR 1.50 $p < 0.001$; eHLQ 4: OR 1.24 $p < 0.001$; eHLQ 5: OR 1.54 $p < 0.001$), even when fully adjusted for covariates. No significant interaction was found for long-term health conditions. However, individuals with more long-term health conditions exhibited the lowest digital health literacy scores (9% to 19% scored <2.0).

Conclusion: A higher digital health literacy is positively associated with higher physical activity levels. This highlights the importance of screening and promoting digital health literacy in managing digital health and digital physical activity interventions. Future research should explore strategies and targeted interventions to enhance digital health literacy and improve health outcomes.

Keywords

Digital health literacy, physical activity, chronic conditions, long-term health conditions, health survey, cross-sectional

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Introduction

Worldwide, about half of the adult population suffers from one or more long-term health conditions, and the burden is rapidly increasing.[1–3] Together, long-term health conditions, such as musculoskeletal conditions, heart diseases, diabetes, pulmonary diseases, and mental health conditions, are the leading causes of global disability.[1,4] A range of these conditions are largely preventable and manageable through risk factor modification, such as engaging in regular physical activity.[5,6]

Physical inactivity poses a significant problem for society and causes various adverse physical and mental health effects.[7] Lack of regular physical activity is known to increase the risk of long-term health conditions such as obesity, heart disease, type 2 diabetes, and certain types of cancers.[5,7] The economic impact of physical inactivity is substantial, with reduced productivity, increased healthcare costs, and up to five million premature deaths every year.[8,9] Addressing the problem of physical inactivity is crucial to promoting overall wellbeing and ensuring a healthier future for individuals and communities.[10]

A rising responsibility rests on people with long-term health conditions to self-manage their conditions and actively alter their health behavior.[11] Healthcare shortages are an emerging problem, and the World Health Organization (WHO) has stated that digitally delivered healthcare may change health and how health services are delivered worldwide.[12] Digital health interventions that promote physical activity among people with long-term health conditions have shown potential.[13] Studies have also shown that individuals who use digital health tools reach higher physical activity levels.[14] However, a recognized and essential problem is inadequate uptake, acceptance, adoption, and adherence to digital health interventions.[15] Barriers like limited technology or internet access, privacy and security concerns, or low motivation or interest in digital health may impede engagement.[16,17] Importantly, some individuals may lack the knowledge or ability to navigate digital health services and utilize technology effectively, known as low eHealth literacy or digital health literacy. Digital health literacy is the motivation and skills to process and comprehend the given health information and the digital health solution and describes the capability to use digital health effectively.[18]

The importance of a sufficient level of digital health literacy is rising to the point that it may be necessary for actively participating in late modern life.[19] Low socioeconomic status, older age, poor health status, and low digital health literacy are key determinants that seem to be the reason for disparities in access to and utilization of digital health solutions, which may increase social, economic, and educational inequity.[19] With the prospects of using digital health interventions to promote physical activity, a deeper understanding of digital health literacy and its association with health-related behavior is needed. Previous research indicates a positive correlation between digital health literacy and health-related behaviors, including health-promoting activities and disease management.[20] However, consistency varies in associations with specific physical and psychosocial outcomes, particularly in older adults[21] and individuals dealing with long-term health conditions.[22] Information about the potential association between digital health literacy and physical activity levels and the possible interaction of long-term health conditions could be essential to guide future digital health interventions aimed at digitally improving physical activity. Further, it could diminish the risk of inequity and social exclusion due to low levels of digital health literacy or long-term health conditions. Moreover, it could help identify those who need support or alternative ways to use digital health services and technology, which may support the implementation of digital health in clinical practice.

Therefore, we examined the association between digital health literacy and physical activity levels using three electronic Health Literacy Questionnaire (eHLQ) scales and tested the interaction of long-term health conditions on the associations. We hypothesized that individuals with higher levels of digital health literacy would demonstrate higher physical activity levels.

Methods

Study design

This study is based on a cross-sectional survey, and reporting follows the ‘Strengthening the Reporting of Observational Studies in Epidemiology’ (STROBE) checklist.[23] For the STROBE checklist, please refer to supplementary material. Before analyses, a statistical analysis plan was developed and made publicly accessible (https://osf.io/9txzk).

Setting

The Danish National Health Survey (DNHS) is sent out every fourth year as a national strategy to monitor, provide data, and describe the health status development of the adult Danish population. Each of the five Danish regions collects a subsample of data into the database with the option to add additional variables beyond the basic DNHS. The key strength of the survey is the collection of a research database based on diverse questionnaire content, with a high number of respondents from the general population.[24] A detailed survey description can be found elsewhere,[24] and data can be reached at the DNHS website.[25] Data in this study is collected by Region Zealand, as part of the DNHS with additional items, gathered from a stratified, randomly selected sample of Region Zealand residents.[26]

Participants

The Danish Health Data Authority randomly draws the sample from the Danish Civil Registration System (CPR).[27] Region Zealand, then invited the 34,000 (aiming at 2000 per municipality) eligible inhabitants (over 16 years old) to participate in the survey. The survey was sent out using a mixed-mode approach (paper/web) from February 5 to May 12, 2021. Non-responders were sent up to two reminders. Completers were invited to enter a draw for prizes, but participants were not compensated in any other way.

Survey content

The Region Zealand 2021 survey consisted of 89 items.[28] It covered physical activity (the Nordic Physical Activity Questionnaire-short form[29] (NPAQ-short)), work-related physical activity, leisure time physical activity (Saltin-Grimby Physical Activity Level Scale[30] (SGPALS)), digital health literacy (selected scales from the eHealth Literacy Questionnaire[31] (eHLQ)), health literacy (selected scales from the Health Literacy Questionnaire[32] (HLQ)), quality of life (the 12-item Short-Form Health Survey v2[33] (SF-12 v2)), stress, morbidity (20 selected long-term conditions and symptoms), smoking, alcohol consumption, diet, transportation, sedentary behavior, sleep, healthcare contacts, social relations, isolation, loneliness (UCLA Loneliness score[34]), anthropometry, and socio-demography.

Objectives and variables of interest

Variables of interest were physical activity levels categorized as the most or least physically active at moderate-to-vigorous intensity, compliant or non-compliant with the WHOs minimum recommendations for physical activity, and self-reported physical activity (active or inactive), and the association with digital health literacy (eHLQ1, eHLQ4, and eHLQ5). Further, the interaction of having long-term health conditions on the associations between digital health literacy and moderate-to-vigorous physical activity level was tested using the variables of long-term health conditions categorized into the count of body systems with long-term health conditions or by somatic, mental health conditions, or a combination of the two.

Outcome

Physical activity items. The items on physical activity were measured using the NPAQ-short,[29] which assesses population-based physical activity levels in line with WHO recommendations, focusing on time and intensity. The NPAQ-short has demonstrated sound psychometric abilities. It has shown high reliability (Spearman's rho values of 0.82 and 0.80) for moderate-to-vigorous and vigorous activity and moderate criterion validity when confirmed against accelerometer data.[29]

Moderate-to-vigorous physical activity level. Moderate-to-vigorous physical activity was collected as categorical variables based on the self-reported time spent physically active at moderate-to-vigorous intensity. Physical activity level was dichotomized based on whether the participant was physically active at moderate-to-vigorous intensity for less than 30 min./week (category 1: 0–29 min.) or more than 30 min./week (category 2–5: 30–89 min., 90–149 min., 150–299 min., and >300 min.) to highlight those least active against those that are active.

Compliance with the WHOs minimum recommendations for physical activity. Compliance was based on WHOs minimum recommendations for physical activity for adults (≥150 min of moderate physical activity or ≥75 min of vigorous physical activity or an equivalent combination).[35] To form the compliance variable, moderate physical activity was calculated by subtracting vigorous physical activity from moderate-to-vigorous physical activity. Compliant was then calculated as (moderate physical activity/150 + vigorous physical activity/75) ≥ 1.0 and non-compliant as (moderate physical activity/150 + vigorous physical activity/75) < 1.0. This calculation was similar to the validation method of the NPAQ short.[29]

Self-reported physical activity (active or inactive). Data on active or inactive was collected as a categorical variable based on a recall of the last year of leisure-time physical activity answered on one of four categories on the SGPALS.[30] The SGPALS is a widely recognized tool for assessing leisure time physical activity and has been utilized by over 600,000 subjects, predominantly in the Nordic countries.[30] Its concurrent and predictive validity has been demonstrated in relation to aerobic capacity, movement analysis, and various health risk factors.[30,36] The variable was dichotomized into active (category 1–3: 1: 'Hard exercise and plays competitive sports regularly and several times a week'; 2: 'Do sports or do heavy gardening or the like at least 4 h per week'; or 3: 'Walks, cycles or does other light exercises at least 4 h a week (also include Sunday trips, light gardening and cycling/walking to work)') or inactive (category 4: 'Reading, watching television, or doing other sedentary activities').

Exposure

Digital health literacy. The eHealth Literacy Questionnaire (eHLQ)[37] is rooted in the eHealth literacy framework,[38] encompassing seven domains that assess an individual's or population's capacity to comprehend, use, and derive benefits from technology for health promotion and maintenance. The eHLQ comprises 35 items across seven scales and was developed simultaneously in Danish and English. The eHLQ scales have demonstrated sound psychometric ability with rigorous validation and reliability testing conducted across diverse populations. This has confirmed the instrument's robust construct, discriminant validity, and scale reliability. The eHLQ is highly valuable for profiling and understanding digital health literacy and is suitable for population surveys.[37] Additionally, eHLQ is the core of the READHY instrument, which has been used to report on technology readiness in cancer and diabetes rehabilitation.[39,40]

In the Region Zealand Health Survey, only three of the seven eHLQ scales were for use as the other scales were considered to be covered by alternative scales or irrelevant to the survey. Digital health literacy is, therefore, in this study assessed by scale 1: 'Using technology to process health information' (eHLQ 1), scale 4: 'Feel safe and in control' (eHLQ 4), and scale 5: Motivated to engage with digital services' (eHLQ 5). eHLQ 1 is under the Health Literacy Framework construct 'Ability to process information', while eHLQ 4 and 5 are under the same construct as the scale name. The three selected scales all have a Cronbach's alpha above 0.84.[37] The five items within each of the three scales were answered on a 4-point Likert scale ('strongly disagree' to 'strongly agree', scores ranging from 1 to 4). Lower scores represent lower digital health literacy.[37] Scale scores were calculated as the mean of the answered items, but the response was discarded if more than half of the items were not answered. In concordance with the eHLQ developer Lars Kayser and the Region Zealand Health Survey report,[41] a guideline cut-off of ≤ 2.0 and >2.0 to 2.5 was used to determine the levels of digital health literacy, which represents 'Insufficient (lowest scores)' and 'Insufficient' levels, respectively.[42]

Potential effect-modifiers

Body systems. Body systems were based on self-reported information on 20 selected long-term health conditions, a method used in several national surveys in the last decade.[43,44] Participants were asked if they had a condition for more than six months period and for each condition, they could answer one of three responses: 'No, I have never had it', 'Yes, I do have it', or 'Yes, I have had it'. The participants were then asked if they experienced sequelae from the condition and dichotomously answered as 'Yes' or 'No'. A long-term condition was registered as being present if a participant answered 'have', 'have had', or 'have sequelae' from the condition. The conditions were: (1) Asthma, (2) Allergy (not asthma), (3) Diabetes, (4) Hypertension, (5) Myocardial infarction, (6) Angina pectoris, (7) Brain hemorrhage or stroke, (8) Chronic bronchitis, emphysema, chronic obstructive pulmonary disease, (9) Osteoarthritis, (10) Rheumatoid arthritis, (11) Osteoporosis, (12) Cancer, (13) Migraine or frequent headaches, (14) Mental health condition that lasted less than six months, (15) Mental health condition that lasted more than six months, (16) Spinal hernia or other back conditions, (17) Cataracts, (18) Tinnitus (squealing, ringing in the ears), (19) Anxiety (social phobia, panic disorder, generalized anxiety or obsessive-compulsive disorder), or (20) Depression.

Each long-term health condition was then categorized under a body system according to the Willadsen et al. (2018) method (e.g., asthma and bronchitis are placed under the body system 'Lung').[45–47] The categorization was done to better represent the complexity of health conditions. This acknowledges the diverse treatments and healthcare structures individuals with multiple diagnoses may encounter. This approach captures the heightened complexity of medical conditions and healthcare management, providing a more comprehensive understanding of the health status, especially for those with multiple long-term health conditions.

In total, eight groups were formed: (1) Mental (temporary and long-term health disorder, depression, and anxiety); (2) Neurological (stroke and migraine); (3) Sensory organs (tinnitus and cataract); (4) Endocrine (diabetes); (5) Cardiovascular (hypertension, angina pectoris, and myocardial infarction); (6) Lung (asthma, bronchitis, and chronic obstructive pulmonary disease); (7) Musculoskeletal (osteoarthritis, rheumatoid arthritis, osteoporosis, spinal hernia, or other back conditions); and (8) Cancer. As the survey did not collect information on gastrointestinal and genitourinary diseases, the two body systems, gastrointestinal and genitourinary, were excluded. A count variable based on the number of involved body systems was categorized as 'None', 'One', 'Two', or 'Three or more body systems'.

Somatic and mental health conditions. The long-term conditions categorized under body systems were further categorized into three overall condition groups, categorized as 'None', 'Only somatic', 'Only mental', or 'Combined somatic and mental' health conditions (e.g., the body system 'Lung' was placed under 'Only somatic' health conditions, while 'Mental' was placed under 'Only mental' health conditions, but if an individual had both health conditions they were placed under 'Combined somatic and mental' health conditions).[48]

Covariates. The following covariates were selected as they have been proposed as potential independent risk factors for the outcome: age, sex, ethnicity, Body Mass Index (BMI), marital status, education level, and work status.[49] Age, sex, and ethnicity were collected from CPR. Age was calculated using the survey response date. Ethnicity was based on information on citizenship, country of birth, and parents' country of birth, and a distinction was made in the classification of ethnic background, but not between immigrants and descendants of immigrants ('Danish background', 'Western background', or 'Non-western background'). Self-reported data on body weight and height were calculated into BMI. Marital status was based on information from self-reported data and the CPR. Educational level was defined as the highest completed education: (1) Primary and lower secondary education (≤9 years), (2) upper secondary education (10–12 years), (3) higher education (≥ 13 years), and (4) under education. Finally, work status was based on self-reporting whether the participants worked and answered dichotomously ('Yes' or' No').

Other descriptive variables. Physical activity motivation is based on whether the participants wanted to become more physically active ('Yes','No', or 'Do not know'). Likewise, the need for physical activity support was based on whether the participants would like support to become more physically active and answered dichotomously ('Yes' or 'No'). Sedentary behavior was calculated as a binary variable based on hours and minutes spent sitting during the day with the cut-off of seven hours per day, sedentary (sitting >9 h/day) or non-sedentary (sitting <9 h/day).[50] The count of musculoskeletal pain was based on an item asking the participants if they have any of the mentioned (arms, hands, legs, knee, hip or joint, or back or lower back, or headache) forms of pain and discomfort bothered them within the last 14 days. The items are answered on a 3-point Likert scale. First, the item was dichotomized as the category 'Yes, a lot' and 'Yes, somewhat' were combined, and then a count variable was made based on each pain site and truncated to 'No pain site', 'One pain site', 'Two pain sites', or 'Three pain sites'. Loneliness was assessed following the UCLA Three-item Loneliness Scale. Each item is rated on a 3-point scale: 1 'Hardly ever'; 2 'Some of the time'; or 3 'Often'. All items are summed to give a total score (range 3–9). The 3–5 and 6–9 cut-offs represent 'Not lonely' and 'Lonely'. Quality of life was calculated based on the SF-12 v2 summary scores on physical and mental health functioning. A cut-off of <50 indicates a physical condition, while a cut-off of <42 may indicate clinical depression.

Statistical methods

Descriptive statistics are presented as numbers and percentages, mean and standard deviations, or median and interquartile range. Missing data are presented as numbers and percentages. All analyses are executed as available case analyses. A two-sided p-value of 0.05 was considered statistically significant. Statistical analyses were conducted in STATA version 17.0.

Logistic regression analyses assessed associations between digital health literacy for each of the three eHLQ scales and with physical activity levels categorized as (1) physically active for less or more than 30 min./week at moderate-to-vigorous intensity, (2) compliance with WHOs minimum recommendations for physical activity, and (3) Physical activity (active or inactive). The regression models were analyzed as an unadjusted model (crude) and also adjusted for covariates in two additional models: Model 1 was adjusted for a minimal number of covariates (age and sex), and Model 2 was fully adjusted (age, sex, ethnicity, BMI, marital status, educational level, and work status). Results are presented as odds ratio (OR) with a 95% confidence interval (CI). Sample weights were used in all analyses to account for non-response bias.

Interaction of the count of body systems, or somatic, mental health conditions, or the combination was added to the regression of the associations of digital health literacy for each of the three eHLQ scales and with being physically active for less or more than 30 min./week at a moderate-to-vigorous intensity, and the linearity was tested. Only Model 2 was used in the interaction analyses.

Results

Sample size and description of participants

Of the 34,000 invited, 19,231 participated in the survey (response rate 57%). The total group had a mean age of 55.6 years (18.2 SD), and 54% were female (Table 1). Only 25% of the participants reported no long-term health condition, while 22% reported having one, 18% two, and 35% had three or more long-term health conditions. Based on the count of body systems with long-term health conditions, the groups mainly differed in age, education level, working status, count of musculoskeletal pain sites, UCLA Loneliness score, and the SF-12 v2. The groups were older, with each extra body system involved. More participants in the group with three or more body systems involved had lower education, a higher percentage not working, more musculoskeletal pain sites, were more often self-perceived as isolated, and more often indicated a clinical depression or a physical condition compared to the other groups (Table 1).

Stratifying the participants by somatic or mental health condition(s) showed that 58% had somatic condition(s) only, 3% had mental health condition(s) only, and 14% had a combination of the two (see supplementary material, Table 1).

Missing items and non-responder analyses

Missing items in one or more of the three eHLQ scales were found in 11% of the participants. Non-responders were more often of non-Western background, living alone, had lower education levels, and were sedentary for more than nine hours daily, but were less likely to have pain, an

Table 1. Sociodemographic of the total group and the group stratified by the number of involved body systems in which they have a long-term condition.

	Total group	No body systems involved	One body system involved	Two body systems involved	More than three body systems involved
N	**19231**	**4735**	**5102**	**4484**	**4910**
Age on January 1. 2021, mean (SD)	55.6 (18.2)	47.7 (18.1)	54.1 (18.2)	58.5 (17.4)	61.9 (15.8)
Sex, n (%)					
Female	10459 (54.4%)	2347 (49.6%)	2755 (54.0%)	2542 (56.7%)	2815 (57.3%)
Male	8772 (45.6%)	2388 (50.4%)	2347 (46.0%)	1942 (43.3%)	2095 (42.7%)
Ethnicity, n (%)					
Danish background	18084 (94.0%)	4368 (92.2%)	4827 (94.6%)	4255 (94.9%)	4634 (94.4%)
Other western backgrounds	494 (2.6%)	138 (2.9%)	126 (2.5%)	120 (2.7%)	110 (2.2%)
Non-Western background	653 (3.4%)	229 (4.8%)	149 (2.9%)	109 (2.4%)	166 (3.4%)
BMI, mean (SD)	26.7 (5.3)	25.5 (4.6)	26.2 (4.9)	26.9 (5.2)	28.1 (6.0)
Marital status, n (%)					
Living with others (married or registered partnership)	12968 (67.4%)	3086 (65.2%)	3597 (70.5%)	3073 (68.5%)	3212 (65.4%)
Living alone (unmarried, divorced, widowed, dissolved registered partnership, or longest surviving of two partners)	6263 (32.6%)	1649 (34.8%)	1505 (29.5%)	1411 (31.5%)	1698 (34.6%)
Education level, n (%)					
Primary and lower secondary education	1864 (9.7%)	280 (5.9%)	452 (8.9%)	467 (10.4%)	665 (13.5%)
Upper secondary education	9446 (49.1%)	1823 (38.5%)	2524 (49.5%)	2395 (53.4%)	2704 (55.1%)
Higher education	4974 (25.9%)	1225 (25.9%)	1474 (28.9%)	1176 (26.2%)	1099 (22.4%)
Ongoing education	1368 (7.1%)	464 (9.8%)	444 (8.7%)	260 (5.8%)	200 (4.1%)
Missing	1579 (8.2%)	943 (19.9%)	208 (4.1%)	186 (4.1%)	242 (4.9%)
Working status, n (%)					
Not working	8294 (43.1%)	1068 (22.6%)	1953 (38.3%)	2205 (49.2%)	3068 (62.5%)
Working	9446 (49.1%)	2731 (57.7%)	2951 (57.8%)	2130 (47.5%)	1634 (33.3%)
Missing	1491 (7.8%)	936 (19.8%)	198 (3.9%)	149 (3.3%)	208 (4.2%)

(continued)

Table 1. Continued.

N	Total group 19231	No body systems involved 4735	One body system involved 5102	Two body systems involved 4484	More than three body systems involved 4910
Sedentary behavior with cut-off, n (%)					
Non-sedentary (sitting <9 h/day)	9221 (47.9%)	1777 (37.5%)	2493 (48.9%)	2299 (51.3%)	2652 (54.0%)
Sedentary (sitting >9 h/day)	7160 (37.2%)	1811 (38.3%)	2090 (41.0%)	1655 (36.9%)	1604 (32.7%)
Missing	2850 (14.8%)	1147 (24.2%)	519 (10.7%)	530 (11.8%)	654 (13.3%)
Count of musculoskeletal pain sites, n (%)					
No pain sites	12720 (66.1%)	4171 (88.1%)	3827 (75.0%)	2728 (60.8%)	1994 (40.6%)
One pain site	3273 (17.0%)	385 (8.1%)	805 (15.8%)	923 (20.6%)	1160 (23.6%)
Two pain sites	1926 (10.0%)	136 (2.9%)	329 (6.4%)	537 (12.0%)	924 (18.8%)
More than three pain sites	1312 (6.8%)	43 (0.9%)	141 (2.8%)	296 (6.6%)	832 (16.9%)
UCLA Loneliness Three-Item score with cut-offs, n (%)					
Lonely	1896 (9.9%)	229 (4.8%)	431 (8.4%)	464 (10.3%)	772 (15.7%)
Not lonely	15796 (82.1%)	3547 (74.9%)	4469 (87.6%)	3853 (85.9%)	3927 (80.0%)
Missing	1539 (8.0%)	959 (20.3%)	202 (4.0%)	167 (3.7%)	211 (4.3%)
SF-12 v2 – Mental component score with cut-offs, n (%)					
Indication of a clinical depression	4605 (23.9%)	659 (13.9%)	994 (19.5%)	1097 (24.5%)	1855 (37.8%)
No indication of a clinical depression	14591 (75.9%)	4068 (85.9%)	4100 (80.4%)	3384 (75.5%)	3039 (61.9%)
Missing	35 (0.2%)	8 (0.2%)	8 (0.2%)	3 (0.1%)	16 (0.3%)
SF-12 v2 – Physical component score with cut-offs, n (%)					
Indication of a physical condition	8373 (43.5%)	1571 (33.2%)	2006 (39.3%)	2025 (45.2%)	2771 (56.4%)
No indication of a physical condition	10803 (56.2%)	3150 (66.5%)	3083 (60.4%)	2443 (54.5%)	2127 (43.3%)
Missing	55 (0.3%)	13 (0.3%)	16 (0.4%)	12 (0.2%)	14 (0.3%)

BMI, Body mass index; SD, standard deviation; n, Numbers; SF-12 v2, Short form health survey 12 items.

indication of clinical depression, or physical condition on the SF-12 v2. Generally, those with missing items on the three eHLQ scales were also those with higher levels of missing items on physical activity (see supplementary material, Table 2). Therefore, the same characteristics were present for the 7% missing the moderate-to-vigorous physical activity item as those missing items on the three eHLQ scales. The only difference was that moderate-to-vigorous physical activity non-responders were often younger than non-responders on the three eHLQ scales (see supplementary material, Table 3).

eHLQ scores

The mean eHLQ score was 2.7 (SD 0.6) in eHLQ 1 and 5, but 2.9 (SD 0.5) in eHLQ 4. The percentages of insufficient digital health literacy levels were almost evenly spread among participants with none, one, two, or three or more body systems with long-term conditions for all three scales. However, the lowest scores were the highest (9% to 19%) among participants in the group with three or more body systems involved in all three scales but the highest in eHLQ 1 (Table 2). For responses on the included eHLQ scales, see supplementary material Figures 1 to 3 and Tables 4 to 6.

Physical activity levels

For moderate-to-vigorous physical activity level, 49% of the total group were active less than 30 min./week. Within this group, most participants had long-term conditions within three or more body systems. The same tendency was found for those non-compliant with WHOs minimum recommendation for physical activity and self-reported as inactive. However, more participants compliant with the WHOs minimum recommendation for physical activity and self-reported active were in the group with long-term conditions within one body system than in the two other groups. Of the total group, 65% wanted to become more physically active, with an equal percentage (27%) in the group with one body system and three or more body systems involved. Of the 34% that wanted support to become more physically active, most (29%) were in the group with three or more body systems involved (Table 2).

Main results

Association between digital health literacy and moderate-to-vigorous physical activity level. There was a significant association between digital health literacy on all three scales of the eHLQ and moderate-to-vigorous physical activity level, even when fully adjusted (Figure 1). The results support that higher digital health literacy scores were associated with being physically active for more than 30 min. weekly at moderate-to-vigorous intensity.

Association between digital health literacy and compliance with WHOs minimum recommendations for physical activity. For the association between digital health literacy and compliance with WHOs minimum recommendations for physical activity, a significant association was found in all analyses except for the crude analysis of eHLQ 4 ($p = 0.071$) (Figure 2). Again, the same direction of the association was found with those with higher digital health literacy scores having higher odds of compliance with the WHOs minimum recommendations for physical activity.

Associations between digital health literacy and self-reported active or inactive. The associations between digital health literacy and self-reported active or inactive showed the same results, with those having higher digital health literacy scores reported as active. Again, the associations were significant for all analyses (Figure 3).

Interaction analyses

Body systems. The analyses of the interaction of count of body systems with long-term health conditions on the association between digital health literacy on the three scales of the eHLQ and moderate-to-vigorous physical activity level showed that there was no interaction ($p = 0.6,15$, $p = 0.176$, and $p = 0.639$) of having none, one, two, or three or more body systems involved (see supplementary material, Figure 4). However, stratifying for the numbers of body systems with long-term health conditions showed significant associations between having long-term health conditions within one, two, and three or more body systems involved on all three eHLQ scales, except for eHLQ 4, where having two body systems involved was insignificant ($p = 0.651$).

Somatic and mental health conditions. Having either somatic, mental health condition(s), or a combination did not show any interaction ($p = 0.578$, $p = 0.541$, and $p = 557$) between the association of digital health literacy and moderate-to-vigorous physical activity level (see supplementary material, Figure 5) on all three eHLQ scales. Stratifying for somatic, mental health condition(s), or a combination only showed significant associations between having somatic condition(s) in eHLQ 1 and 5 ($p < 0.001$).

Sensitivity analyses

A sensitivity analysis, not defined in the analysis plan, of the association between digital health literacy using the three scales of eHLQ with cut-offs and if participants wanted support to become physically active showed slightly higher odds of having insufficient levels of digital health literacy when wanting support to become more physically active, see Supplementary material, Table 7.

Table 2. Digital health literacy and physical activity characteristics for the total group and the group stratified by the number of body systems in which they have a long-term health condition (number of body systems involved).

	Total group	No body systems involved	One body system involved	Two body systems involved	>Three body systems involved
N	**19231**	**4735**	**5102**	**4484**	**4910**
eHLQ subscale 1: Using technology to process health information, mean (SD)	2.7 (0.6)	2.8 (0.6)	2.7 (0.6)	2.7 (0.6)	2.6 (0.7)
eHLQ 1 with cut-offs					
Score <2.0 (Insufficient lowest score)	2754 (14.3%)	454 (9.6%)	712 (14.0%)	652 (14.5%)	936 (19.1%)
Score >2.0 to 2.5 (Insufficient)	2689 (14.0%)	608 (12.8%)	740 (14.5%)	625 (13.9%)	716 (14.6%)
Score >2.5	11937 (62.1%)	2667 (56.3%)	3356 (65.8%)	2968 (66.2%)	2946 (60.0%)
Missing	1851 (9.6%)	1006 (21.2%)	294 (5.8%)	239 (5.3%)	312 (6.4%)
eHLQ subscale 4: Feel safe and in control, mean (SD)	2.9 (0.5)	3.0 (0.6)	3.0 (0.5)	2.9 (0.5)	2.9 (0.6)
eHLQ 4 with cut-offs					
Score <2.0 (Insufficient lowest score)	1417 (7.4%)	290 (6.1%)	362 (7.1%)	332 (7.4%)	433 (8.8%)
Score >2.0 to 2.5 (Insufficient)	1447 (7.5%)	295 (6.2%)	383 (7.5%)	322 (7.2%)	447 (9.1%)
Score >2.5	14532 (75.6%)	3149 (66.5%)	4064 (79.7%)	3596 (80.2%)	3723 (75.8%)
Missing	1835 (9.5%)	1001 (21.1%)	293 (5.7%)	234 (5.2%)	307 (6.3%)
eHLQ subscale 5: Motivated to engage with digital services, mean (SD)	2.7 (0.6)	2.8 (0.6)	2.7 (0.6)	2.7 (0.6)	2.6 (0.6)
eHLQ 5 with cut-offs					
Score <2.0 (Insufficient lowest score)	2615 (13.6%)	438 (9.3%)	654 (12.8%)	616 (13.7%)	907 (18.5%)
Score >2.0 to 2.5 (Insufficient)	3092 (16.1%)	610 (12.9%)	838 (16.4%)	771 (17.2%)	873 (17.8%)
Score >2.5	11520 (59.9%)	2656 (56.1%)	3270 (64.1%)	2815 (62.8%)	2779 (56.6%)
Missing	2004 (10.4%)	1031 (21.8%)	340 (6.7%)	282 (6.3%)	351 (7.1%)
Self-reported weekly time spent on moderate-to-vigorous physical activity, n (%)					
<30 min.	4449 (23.1%)	698 (14.7%)	1026 (20.1%)	1099 (24.5%)	1626 (33.1%)
30–89 min.	4698 (24.4%)	927 (19.6%)	1279 (25.1%)	1211 (27.0%)	1281 (26.1%)
90–149 min.	3038 (15.8%)	718 (15.2%)	917 (18.0%)	722 (16.1%)	681 (13.9%)

(continued)

Table 2. Continued.

N	Total group 19231	No body systems involved 4735	One body system involved 5102	Two body systems involved 4484	>Three body systems involved 4910
150–299 min.	3475 (18.1%)	896 (18.9%)	1048 (20.5%)	803 (17.9%)	728 (14.8%)
>300 min.	2313 (12.0%)	609 (12.9%)	696 (13.6%)	546 (12.2%)	462 (9.4%)
Missing	1258 (6.5%)	887 (18.7%)	136 (2.7%)	103 (2.3%)	132 (2.7%)
Moderate-to-vigorous physical activity level, n (%)					
Physical active <30 min/wk	4449 (23.1%)	698 (14.7%)	1026 (20.1%)	1099 (24.5%)	1626 (33.1%)
Physical active ≥30 min/wk	4698 (24.4%)	927 (19.6%)	1279 (25.1%)	1211 (27.0%)	1281 (26.1%)
Missing	10084 (52.4%)	3110 (65.7%)	2797 (54.8%)	2174 (48.5%)	2003 (40.8%)
Self-reported weekly time spent on vigorous physical activity, n (%)					
<30 min.	11457 (59.6%)	2074 (43.8%)	3067 (60.1%)	2888 (64.4%)	3428 (69.8%)
30–59 min.	2935 (15.3%)	710 (15.0%)	833 (16.3%)	717 (16.0%)	675 (13.7%)
60–89 min.	1469 (7.6%)	421 (8.9%)	444 (8.7%)	320 (7.1%)	284 (5.8%)
90–149 min.	995 (5.2%)	306 (6.5%)	319 (6.3%)	196 (4.4%)	174 (3.5%)
>150 min.	860 (4.5%)	285 (6.0%)	251 (4.9%)	194 (4.3%)	130 (2.6%)
Missing	1515 (7.9%)	939 (19.8%)	188 (3.7%)	169 (3.8%)	219 (4.5%)
Compliance with WHOs minimum recommendations for physical activity, n (%)					
Non-compliant	10425 (54.2%)	1882 (39.7%)	2728 (53.5%)	2620 (58.4%)	3195 (65.1%)
Compliant	7264 (37.8%)	1910 (40.3%)	2182 (42.8%)	1687 (37.6%)	1485 (30.2%)
Missing	1542 (8.0%)	943 (19.9%)	192 (3.8%)	177 (3.9%)	230 (4.7%)
Saltin-Grimby Physical Activity Level Scale, n (%)					
Regular hard physical training for competitive sports	451 (2.3%)	181 (3.8%)	142 (2.8%)	74 (1.7%)	54 (1.1%)
Regular physical activity and training	3212 (16.7%)	973 (20.5%)	1008 (19.8%)	708 (15.8%)	523 (10.7%)
Some light physical activity	10849 (56.4%)	2228 (47.1%)	3009 (59.0%)	2747 (61.3%)	2865 (58.4%)

(continued)

Table 2. Continued.

	Total group	No body systems involved	One body system involved	Two body systems involved	>Three body systems involved
N	**19231**	**4735**	**5102**	**4484**	**4910**
Physically inactive	3443 (17.9%)	463 (9.8%)	807 (15.8%)	846 (18.9%)	1327 (27.0%)
Missing	1276 (6.6%)	890 (18.8%)	136 (2.7%)	109 (2.4%)	141 (2.9%)
Self-reported physical activity (active or inactive), n (%)					
Inactive	3443 (17.9%)	463 (9.8%)	807 (15.8%)	846 (18.9%)	1327 (27.0%)
Active	14512 (75.5%)	3382 (71.4%)	4159 (81.5%)	3529 (78.7%)	3442 (70.1%)
Missing	1276 (6.6%)	890 (18.8%)	136 (2.7%)	109 (2.4%)	141 (2.9%)
Sedentary behavior with cut-off, n (%)					
Non-sedentary (sitting <9 h/day)	9221 (47.9%)	1777 (37.5%)	2493 (48.9%)	2299 (51.3%)	2652 (54.0%)
Sedentary (sitting ≥9 h/day)	10010 (52.1%)	2958 (62.5%)	2609 (51.1%)	2185 (48.7%)	2258 (46.0%)
Self-perceived exercise habits, n (%)					
Tolerable to bad	6603 (34.3%)	981 (20.7%)	1553 (30.4%)	1681 (37.5%)	2388 (48.6%)
Good to very good	11347 (59.0%)	2853 (60.3%)	3407 (66.8%)	2706 (60.3%)	2381 (48.5%)
Missing	1281 (6.7%)	901 (19.0%)	142 (2.8%)	97 (2.2%)	141 (2.9%)
Would like to become more physically active, n (%)					
Yes	11541 (60.0%)	2411 (50.9%)	3163 (62.0%)	2808 (62.6%)	3159 (64.3%)
No	4035 (21.0%)	1015 (21.4%)	1204 (23.6%)	967 (21.6%)	849 (17.3%)
Do not know	2234 (11.6%)	384 (8.1%)	552 (10.8%)	578 (12.9%)	720 (14.7%)
Missing	1421 (7.4%)	925 (19.5%)	183 (3.6%)	131 (2.9%)	182 (3.7%)
Would like support to become more physically active, n (%)					
Yes	3904 (20.3%)	587 (12.4%)	917 (18.0%)	969 (21.6%)	1431 (29.1%)
No	7638 (39.7%)	1828 (38.6%)	2248 (44.1%)	1836 (40.9%)	1726 (35.2%)
Missing	7689 (40.0%)	2320 (49.0%)	1937 (38.0%)	1679 (37.4%)	1753 (35.7%)

eHLQ: eHealth Literacy Questionnaire; IQR: interquartile range; n, Numbers; SD: standard deviation.

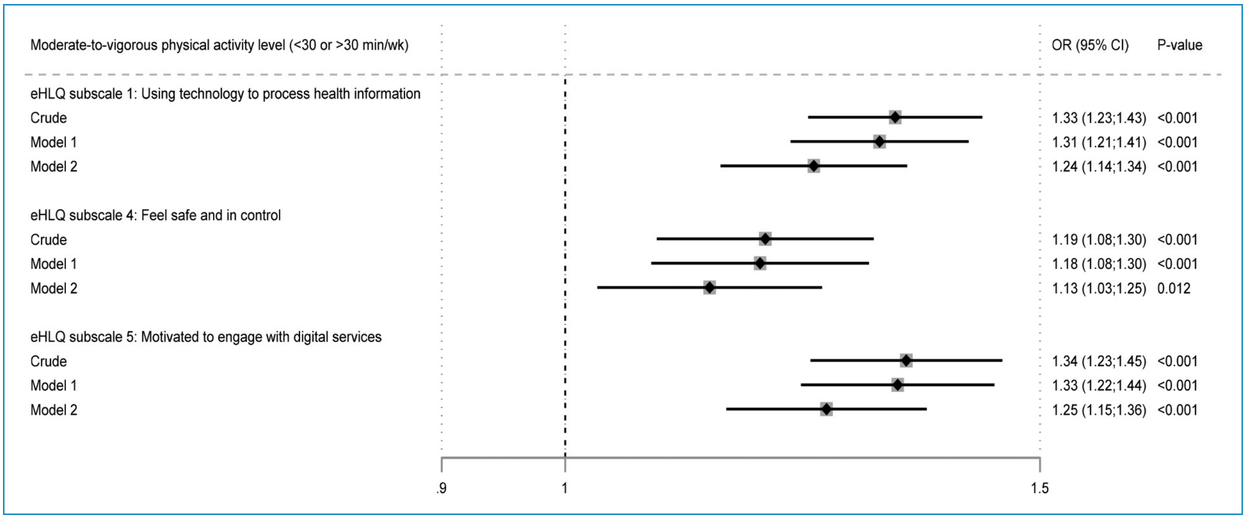

Figure 1. Logistics regressions of the associations between digital health literacy and physical activity level. Min: minutes; wk: week; OR: Odds ratio; CI: confidence interval; eHLQ: eHealth Literacy Questionnaire Crude, unadjusted analysis; Model 1, adjusted for age and sex; Model 2, adjusted for age, sex, ethnicity, Body-mass-index, marital status, education level, and work status. All models were analyzed using sample weights.

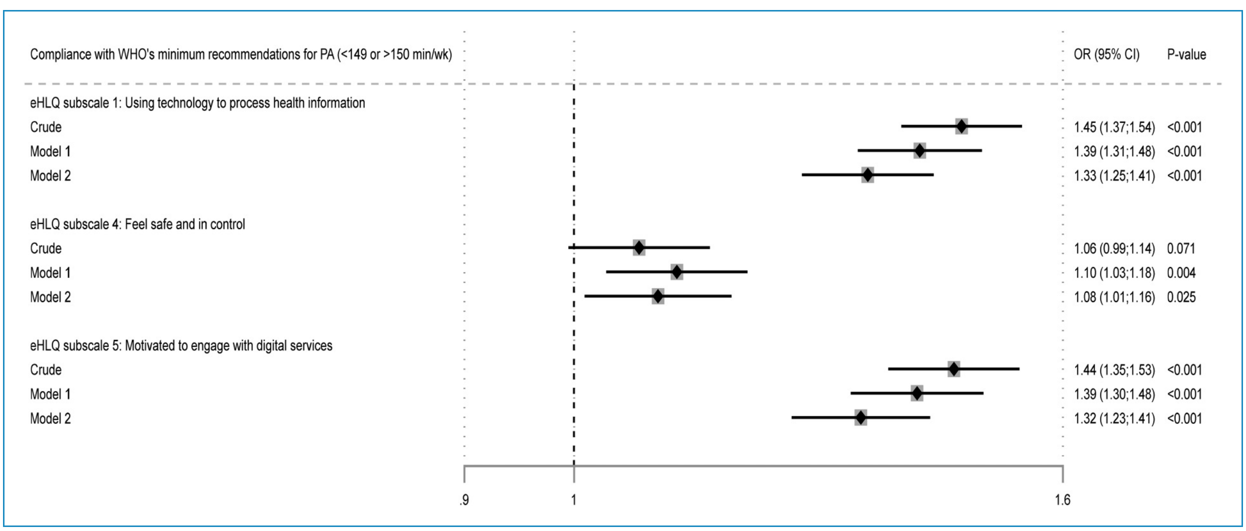

Figure 2. Logistics regressions of the associations between digital health literacy and compliance with WHOs minimum recommendations for physical activity. WHO: World Health Organization; PA: Physical Activity; Min: minutes; wk: week; OR: Odds ratio; CI: Confidence Interval Crude, unadjusted analysis; Model 1, adjusted for age and sex; Model 2, adjusted for age, sex, ethnicity, Body-mass-index, marital status, education level, and work status. All models were analyzed using sample weights.

Discussion

Principal findings

Our study is the first to assess the association between digital health literacy and physical activity levels in a larger survey among participants with and without long-term health conditions. Our overall results indicate that only a lower percentage of the participants had insufficient levels of digital health literacy according to the pre-defined cut-offs. However, individuals with three or more body systems with long-term health conditions were likelier to have the lowest scores and insufficient levels of digital health literacy. The results also showed an association between lower digital health literacy scores and lower moderate-to-vigorous physical activity levels, non-compliance with the WHOs minimum physical activity recommendations, and self-reported inactive, even when fully adjusted for covariates. Nevertheless, the number of body systems with long-term health, somatic, mental health conditions, or a combination,

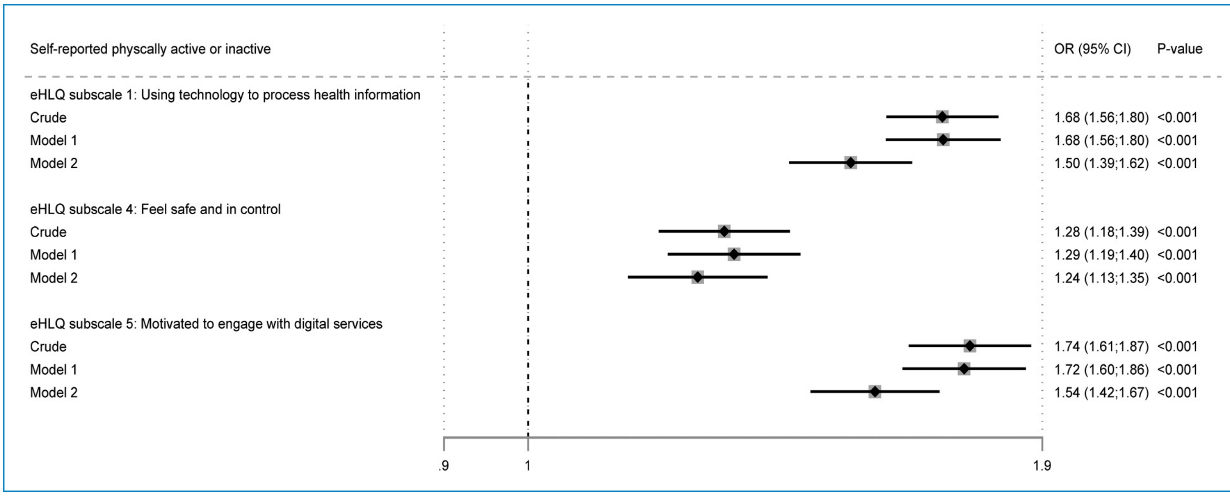

Figure 3. Logistics regressions of the associations between digital health literacy and self-reported active or inactive based on the Saltin-Grimby Physical Activity Level Scale. OR, Odds ratio; CI, Confidence Interval Crude, unadjusted analysis; Model 1, adjusted for age and sex; Model 2, adjusted for age, sex, ethnicity, Body-mass-index, marital status, education level, and work status. All models were analyzed using sample weights.

did not seem to interact with the association between digital health literacy and moderate-to-vigorous physical activity level. Our findings highlight the potential for digital health literacy to be an important determinant of physical activity behavior and the need to expand the knowledge around physical activity, digital health literacy, and long-term health conditions.

Findings in comparison with prior work

Digital health literacy level. Although assessing digital health literacy is still in its early stages,[51] it is increasingly essential for meaningful participation in late modern life, especially within the healthcare sector, as technology has become a more significant part of care and (self-)management of long-term health conditions.[19,52] Individuals with higher digital health literacy may be better equipped to access and utilize digital health information. In contrast, individuals with multiple long-term health conditions may face additional challenges in retrieving and utilizing digital health information as more information applies to each condition.[3] Our results indicated that the lowest and insufficient levels of digital health literacy were more common among those with three or more body systems involved with long-term health conditions. However, age is a factor in multiple long-term health conditions and may also pose a factor when assessing digital health literacy.[53] Conversely, our findings were robust even when adjusted for age. Further, we did not find that having long-term health conditions within more body systems interacted with the association between digital health literacy and moderate-to-vigorous physical activity level. Stratifying the number of body systems with long-term health conditions showed higher digital health literacy odds when physically active at moderate-to-vigorous intensity for more than 30 min. weekly, when having one, two, or three or more body systems.

Our results showed that most participants had high digital health literacy scores despite having long-term health conditions, but other studies have found diverse results. One study found similar eHLQ results in Danish medical outpatients users of digital health services,[54] while another study found higher scores in Danish heart failure patients participating in a telerehabilitation program at six months follow-up,[55] whereas another study found lower scores in Australian women with breast cancer.[56] We assessed digital health literacy across conditions and only used three of the seven scales from the eHLQ, which limits cross-study comparisons.

Association between digital health literacy and physical activity. In line with our study, a meta-analysis revealed a moderate positive correlation between eHealth literacy and health-related behaviors.[20] Although a positive moderate effect was observed, particularly in health-supporting behaviors, including physical activity,[20] most of the included studies target multiple health behaviors, so physical activity could not be isolated. Other studies that have assessed digital health engagement have found that rare Internet users, compared to non-users, were less likely to be physically active and that Internet use was associated with having fewer chronic conditions, disabilities, and visits to healthcare facilities.[57] Another study found that digital health literacy was an essential mediating factor for health behaviors in people over 60.[58] Among people with diabetes, a study found that more than half of the participants were prone to using digital solutions when engaging in exercise, and those who did not score significantly lower on the eHLQ 1 and eHLQ 5 scales.[53] Studies that have assessed digital health literacy among college students found that higher eHealth Literacy Scale scores correlated with those who exercised regularly.[59] While another study found that higher levels of digital health literacy prompted students to adopt multiple positive health behaviors, including being physically active.[60]

A systematic review of 19 observational studies found a clear positive association between higher health literacy and higher physical activity levels in healthy adults.[61] However, there is no direct comparison between health literacy and digital health literacy, but one would expect these forms of literacy to have overlapping constructs as does physical literacy. Health literacy broadly covers knowledge, personal skills, and confidence to take action to improve personal health.[62] Hence, other elements may likely explain the associations found in our study. A recent study identified self-efficacy and self-care ability as mediators of the relationship between digital health literacy and health promotion behaviors.[63] Also, self-efficacy is a variable found to correlate consistently with physical activity.[64]

Despite this, our cross-sectional study design does not provide evidence of a causal relationship between factors and physical activity. The association between higher digital health literacy and higher physical activity levels could also simply be supported by the practical integration of technology into active lifestyles, along with the concurrent development of skills in seeking, using, interpreting, and critically assessing digital health information.[19]

Future research should assess these and other mediators and overlaps between health literacy and digital health literacy constructs. Further, a key area for future exploration should focus on the causality between digital health literacy and physical activity levels by measuring digital health literacy before and after the participation in a digital physical activity intervention.

Methodological considerations

Methodological considerations should be taken into account when interpreting our study's results. Categorizing physical activity levels (e.g., more or less active) may lack specificity and may not capture the nuances and variations in different activity types and intensities. Assessing compliance based on a single set of recommendations does not account for variation in physical activity needs or abilities due to age, health conditions, or physical limitations, and it does not consider the specific context in which physical activity occurs. Considering activity levels over a specific period, such as a week or a month, challenges compliance assessment as an individual's activity patterns may vary over this period. Additionally, the SGPALS primarily assesses aerobic or endurance activities and is limited in adequately capturing other essential dimensions of physical activity, including strength training, flexibility exercises, and activities of daily living. This narrow focus may not provide a comprehensive overview of an individual's overall physical activity profile.

Further, when assessing physical activity by self-report, the possibility of recall and social-desirability bias may be present, with the tendency to overestimate physical activity levels. Further, physical activity was measured through multiple tools that may reflect different subsets of physical activity (e.g., exercise). These biases could have been eliminated using objective measurement tools. Objective physical activity measures could also have provided data that would allow for distinguishing between different types of physical activities (e.g., walking, running, cycling) and information on each activity's intensity level (e.g., moderate, vigorous). In future research, this detailed information will be valuable for understanding the specific health benefits of different physical activity types and intensities and their association with digital health literacy.

Using the guideline cut-offs for eHLQ may lack specificity and lead to misclassification of the different outcome groups. Nevertheless, using a different threshold may also limit cross-study comparisons. It is essential to establish evidence-based cut-off values for the levels of digital health literacy to ensure that the cut-offs have clinical relevance and practical applicability, so we encourage future studies to explore these thresholds.

Limitations

Firstly, cross-sectional studies are limited in their ability to establish causality. It is impossible to determine whether digital health literacy levels cause or consequence of physical activity levels based on a single cross-sectional study. Secondly, there may be potential biases in participant data collection, recruitment, and selection. For example, participants with higher digital health literacy or physical activity levels may be more likely to participate in the study, which could lead to an overestimation of the association between digital health literacy and physical activity level. In contrast, people with more burdensome long-term health conditions may also be less likely to participate, which could lead to an underestimation of the association. Further, collecting data in both paper and electronic versions may introduce some variability in the responses, but it could also be a strength, as it may secure more participants, especially among those with lower digital health literacy. Thirdly, confounding factors, such as access, use, self-efficacy, or motivation for physical activity or technology use, may influence the association between digital health literacy and physical activity levels but were not measured in the survey. Fourthly, Dichotomization of our physical activity data was employed to obtain an even distribution, aiming to maintain balanced groups for meaningful comparisons in our sample. However, the dichotomization approach introduces a limitation, as it may oversimplify the nuanced nature of continuous data, potentially limiting the depth of our analysis. Also, we only had data from three scales of the eHLQ, so we could not do a complete evaluation of all facets of digital health literacy, and the association with physical activity levels may differ depending on the other constructs of the eHLQ scale. Finally, the generalizability of the findings may be limited, as the study sample may not represent the broader population, as the survey was restricted to one out of five Danish regions. Therefore, caution should be taken when extrapolating the results to other populations or settings. However, the study is based on a larger random sample, and all analyses were done using sample weights to strengthen the results and heighten representativeness.

Clinical implications

The study findings have several implications for health promotion interventions. Findings highlight that when addressing physical inactivity, an essential component of evidence-based prevention and treatment of long-term health conditions,[5,7] digital health literacy can challenge a successful implementation of digital health interventions, especially among those with more long-term health conditions and those who need to increase their physical activity level the most. Health interventions that use a digital health solution to increase physical activity among individuals with long-term health conditions may be at risk of failing and must be supported by efforts to improve digital health literacy. At the same time, individuals with multiple long-term health conditions showed lower digital health literacy and physical activity levels, amplified among those who wanted support to become more physically active, revealing a critical group to target. So, among those with the greatest potential for increasing physical activity, it is crucial to consider applying strategies to address digital health literacy when using digital health intervention or offering alternative non-digital interventions. This emphasizes the importance of providing tailored education and resources to support individuals with multiple long-term health conditions to manage their health effectively and also points to the need for targeted interventions to improve this population's digital health literacy.[3]

Conclusion

Higher digital health literacy is positively associated with higher physical activity levels. Our findings underscore the importance of screening for and promoting digital health literacy as a critical component of effective digital health management when used to promote physical activity. This may be especially true for individuals with more long-term health conditions. It further shows the potential for digital health literacy to be an important determinant of physical activity behavior. Promoting digital health literacy may positively impact physical activity levels and, in that way, benefit health. Future research should continue to investigate strategies for improving digital health literacy in this population and explore how targeted health interventions can improve health outcomes. Digital health interventions should aim to assess and increase digital health literacy and have a dual focus on digital health literacy and physical activity levels to improve overall health outcomes positively. We encourage future research to measure physical activity objectively and use complete and validated digital health literacy measures.

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Ethical approval: This study received approval from the Danish Data Protection Agency under Region Zealand's umbrella approval (REG-136-2022). All participants gave informed consent to participate in the survey. Participants <18 years of age gave informed consent in the same manner as participants >18, as consent from a legally authorized representative is only needed for people >15 years in Denmark.

Guarantor: STS.

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