



# Health literacy, oral diseases, and contributing pathways: results from the Lifelines Cohort Study

Trishnika Chakraborty<sup>a,\*</sup>, Marise S Kaper<sup>b</sup>, Josue Almansa<sup>a</sup>, Annemarie A Schuller<sup>b,c</sup>,  
Sijmen A Reijneveld<sup>a</sup>

<sup>a</sup> University Medical Center Groningen, University of Groningen, Department of Health Sciences, Groningen, the Netherlands

<sup>b</sup> University Medical Center Groningen, University of Groningen Centre for Dentistry and Oral Hygiene, Groningen, the Netherlands

<sup>c</sup> TNO Child Health, Leiden, the Netherlands

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## ABSTRACT

**Objective:** Health literacy (HL), the ability to deal with information related to one's health, may affect oral health via several routes. Therefore, this study aimed to examine the association of HL with oral diseases, and whether this association is mediated by oral health behaviour and dental care utilisation.

**Methods:** We included 26,983 participants from the prospective multigenerational Dutch Lifelines Cohort Study to estimate the association between limited health literacy, and self-reported oral health outcomes (edentulism and gingivitis), and mediation by oral health behaviour and dental care utilisation. Structural equation modelling was used to assess HL's direct, indirect, and total effects on oral health outcomes.

**Results:** Limited health-literate participants had increased odds of having poor oral health outcomes, i.e. edentulism (odds ratio: 1.41; 95 %-confidence interval: 1.24 to 1.58) and gingivitis (1.22; 1.14 to 1.30). After adjustment for age, income, and education, brushing behaviour and dental care utilization showed a significant mediation effect. Brushing behaviour mediated 7.4 % of the association between HL and edentulism and 6.7 % for gingivitis. Dental visits accounted for 38.0 % of the association between HL and edentulism and 16.4 % for gingivitis.

**Conclusions:** Limited HL makes edentulism and gingivitis more likely, with poor oral health behaviour and inadequate dental care utilisation being important mediators. The findings suggest that interventions should focus on helping dental professionals recognize patients with limited HL and providing training in patient-centered communication to improve oral health outcomes.

**Clinical Significance:** This study demonstrates that limited health literacy significantly increases the risk of edentulism and gingivitis, mediated by inadequate oral health behaviours and dental care utilization. These findings highlight the need for targeted interventions to improve HL, thereby enhancing oral health outcomes and reducing disparities in clinical dental practice.

## 1. Introduction

The 2019 Global Burden of Disease Study revealed that approximately 3.5 billion people worldwide, approximately 50 % of the world population, suffers from oral conditions [1,2]. Given that oral diseases are largely preventable and can be treated in early stages, adequate self-management competencies can help to effectively maintain oral health. In this context, adequate health literacy (HL) plays a central role in the self-management of people.

HL is defined as “the degree to which people can access, understand, appraise, and communicate information to engage with the demands of different health contexts to promote and maintain good health across the life course” [3]. Adequate HL is crucial for understanding health information which is related to maintenance of overall good health in the long term [4,5]. Limited health literacy (LHL) has negative impacts on chronic diseases due to challenges in disease management, limited use of preventive care, and low adherence to health-promoting behaviour [4]. Large, representative samples reported that limited health literacy (LHL)

\* Corresponding author at: Department of Health Sciences, University of Groningen, University Medical Center Groningen, Hanzeplein 1, P.O. Box 30.001, FA10, 9700 RB Groningen, the Netherlands.

E-mail address: [t.chakraborty@umcg.nl](mailto:t.chakraborty@umcg.nl) (T. Chakraborty).

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affects 47 % of European adults (EU) [3,5]; and 24 % of adults in the Netherlands [6].

HL may be an important determinant of oral diseases, however, until now, very few studies have specifically assessed the association between HL with oral conditions [7,8]. Two systematic reviews concluded that the evidence on the association between oral health literacy and oral conditions in adults is inconclusive, highlighting significant limitations in existing studies [9,10]. These limitations include the use of non-representative or non-probabilistic samples, small sample sizes, and reliance on cross-sectional study designs in the included 10 studies [9, 10]. Moreover, many studies were restricted to clinical settings, which further limits the generalizability of their findings [10]. Consequently, there is a need for high-quality research that employs more robust methodologies and includes representative populations to better understand the relationship between HL and oral health outcomes.

Currently, evidence is lacking on the associations between HL and potential mediators, such as oral health behaviour, dental care utilization, and oral conditions. Such evidence is pivotal for oral health promotion and reducing oral health inequalities amongst individuals with LHL, and to revert the ‘dental treatment delivery’ model to the ‘preventive care’ model [2]. By understanding the associations between HL, oral health behaviour, dental care utilization, and oral conditions, better tailored preventive interventions and promotion of better long-term oral health outcomes can be achieved [4,8,10,11]. Therefore, this study aimed to examine the association between HL with oral diseases, and whether this association is mediated by oral health behaviour and dental care utilisation, as specified in Fig. 1.

## 2. Methods

### 2.1. Study design and population

Data were used from the Lifelines Cohort Study, a multi-disciplinary prospective population-based cohort study examining in a unique three-generation design the health and health-related behaviours of 167,729 persons living in the North of The Netherlands [12,13]. It employs a broad range of investigative procedures in assessing the biomedical, socio-demographic, behavioural, physical, and psychological factors that contribute to the health and disease of the general population, with a special focus on multi-morbidity and complex genetics [13]. A detailed description of the recruitment strategy and data collection has been previously mentioned by Stolk et al. [12]. From the entire sample of 152,336, only a part of them were offered HL questionnaire at baseline (1C) between 2006 and 2013 and self-reported questionnaire about oral conditions (such as tooth loss, bleeding gums, loose teeth, dental pain, or dry mouth) in the third assessment (3A) wave between 2019 and 2023. Hence, our included sample ( $n = 26,983$ ) were the participants who completed both questionnaires on HL and oral conditions. We checked that the analyses sample was representative of the Lifelines baseline sample, as shown in the Appendix 1.

The Lifelines Cohort Study follows the conventions set forth in the

Declaration of Helsinki. The University Medical Center Groningen’s Medical Ethics Committee approved the Lifelines Cohort Study (approval number: METc 2007/152 and METc 2019/571), and all subjects provided written informed consent.

## 3. Measures

### 3.1. Oral health outcomes

Oral health outcomes regarded edentulism and gingivitis, based on previous studies [14–19]. These were assessed with a self-report questionnaire about oral conditions in the third assessment wave (3A). Edentulism represents the cumulative oral health over the lifetime of an individual. Edentulism was based on three questions, about the presence of teeth in the upper jaw and lower jaw, and the count of teeth in the mouth. We used “gingivitis” as our second outcome, as it can represent the status of oral hygiene. Responses to a question regarding bleeding gums were dichotomized into gingivitis “absent” and “present”. Studies have validated self-reported oral health conditions against clinical assessments, showing reasonable accuracy for certain measures, especially edentulism and other easily observable conditions [20–23]. Appendix 2 provides a detailed overview list of the operationalization of oral health outcomes.

### 3.2. Health literacy (HL)

HL was measured at baseline with the three validated self-report questions from Chew et al., which reliably identified inadequate HL with strong sensitivity and specificity (ROC value of 0.74), using Short Test of Functional Health Literacy in Adults (S-TOFHLA) and the Rapid Estimate of Adult Literacy in Medicine (REALM) as criterion [24]:

1. How often do you have trouble understanding your medical situation because you have difficulty with the written information?
2. How sure are you of yourself when you fill out medical forms?
3. How often does someone help you with reading the information materials from the hospital or another healthcare provider?

Participants responded to this health literacy questionnaire using a Likert-type scale (1 to 5). After reversing scores for the first and third question and summing all responses, a health literacy score of 3 to 15 was derived, dichotomized as limited (3 to 12) vs. adequate (13 or more), based on previous studies using Lifelines database [3,25]. This yields rates of LHL comparable to other large validated scale surveys in the Netherlands that use longer validated scales [3,25]. HL was measured with a focus on functional HL which may have led to an underestimation of the full effects of low HL, such as communicative and critical literacy.

### 3.3. Mediators

Mediators included *oral health behaviour* and *dental care utilization*. *Oral health behaviour* was measured through questions about brushing behaviour and meal moments in the third assessment wave, and smoking in the second assessment wave. Brushing behaviour was dichotomized as ‘inadequate’ (less than twice/day) vs ‘adequate’ (>2/day), based on national and international recommendations [18,19,26]. Meal moments, which included daily main meals and snacks, were dichotomized as inadequate (>7/day) vs. adequate (maximum of 7/day), following Dutch national recommendations [27,18]. Smoking behaviour was defined as ‘smoker’ if the participant reported any smoking in the past month, versus ‘non-smoker’ [28]. *Dental care utilization* was measured as annual dental visits in the third assessment wave, dichotomized as “recent” (at least one annual visit) vs. “not recent” (less than one annual visit), based on prior research [29].



Fig. 1. Overview of research questions.

3.4. Background variables

Background data, age, sex, ethnicity, education, and household income, were extracted from the baseline questions. Age was used in quartiles in the analyses models (18–30, 31–47, 48–64, +65). Sex (male or female) and ethnicity (native or immigrant) were dichotomized. The highest educational level (education) was classified according to the International Standard Classification of Education, in eight categories. These were recoded into three categories: low (maximum junior general secondary education); intermediate (secondary vocational education or work-based learning to pre-university secondary education); and high (higher vocational education; university education) [15,25]. Net household income was measured with an 8-item ordinal scale (from <750 euros to >3500 euros), and the options “I do not know”, and “I would rather not answer this question”. To construct the equivalized household income (household income), net household income in Euros was divided by the square root of the number of people living on this income [25]. Variables such as employment status, supplementary dental insurance, reason for dental service utilization, and delayed treatment due to cost did not substantially influence our findings and were therefore not included in the adjustments.

3.5. Data handling and analysis

The analyses were performed in three steps. First, we described the demographic and background characteristics of the included sample by dental status (i.e. edentulous individuals vs dentate individuals). We used chi-square tests to assess differences in categorical variables and Mann-Whitney U tests for continuous variables between individuals’ dental status. Second, we explored the association between HL and oral health outcomes using binomial logistic regression models; the analyses were adjusted for age, sex, ethnicity, and household income. The regression models were performed using complete cases. Third, we assessed mediation as the direct and indirect effects of our two mediator blocks (oral health behaviour and dental care utilization) on HL and primary oral health outcomes using structural equation modelling

(SEM).

The strength of the direct and mediation effects (mediator or group of mediators together) was expressed in terms of the percentage of the estimates, with respect to the total effect. The total effects were calculated from regression models without using mediators. The models accounted for covariance among mediators and oral health outcomes, addressing their correlations. Maximum likelihood (ML) testing was used to calculate these values. SEM models utilized probit regression for binary dependent variables (mediators and outcomes) [30]. In our study, traditional fit indices like CFI and TLI were not calculated because they are not applicable for probit regression models with ML estimation in saturated models, where the model inherently fits the data perfectly. Instead, our focus was on accurately estimating the direct, indirect, and total effects, with robust confidence intervals obtained via 5000 bootstrap replications to validate the mediation pathways. In the SEM models, we assumed missing data to be missing completely at random, thus individuals with complete data were used to estimate these analyses. We checked the distribution of demographic variables (age and sex) in complete cases ( $n = 16,078$  for edentulism and  $n = 16,074$  for gingivitis) compared to the included sample ( $n = 26,983$ ) and individuals with non-missing values within this sample, and we found no significant differences. Data preparation and analyses were conducted using R version 3.6.2, and the mediation analyses (SEM) were done with package Lavaan 0.6 – 17 [31].

4. Results

4.1. Sample characteristics

Our total sample consisted of 26,983 eligible participants (mean age of 48 years, 60 % female, and 24 % had LHL). From this sample, 26,867 participants were included for descriptives, stratified by edentulism, as shown in Table 1. Of the edentulous participants, 37.0 % had LHL contrasting with the dentate group where 22.8 % had LHL. The descriptives of analyses sample can be found in Appendix 1.

Table 1  
Description of the sample, by dental status (edentulous vs dentate).

| Variables                     | Edentulous (n = 2651) | Dentate (n = 24,216) | Total (n = 26,867) | p-value <sup>b</sup> |
|-------------------------------|-----------------------|----------------------|--------------------|----------------------|
| Sex                           |                       |                      |                    |                      |
| Male                          | 1292 (48.7 %)         | 9440 (39.0 %)        | 10,732 (40.0 %)    | < 0.001              |
| Female                        | 1359 (51.3 %)         | 14,769 (61.0 %)      | 16,128 (60.0 %)    |                      |
| Age at TI                     |                       |                      |                    |                      |
| Mean (SD)                     | 58 (8)                | 46 (11)              | 48 (11)            | < 0.001              |
| Median (Q1, Q3)               | 59 (52, 64)           | 47 (40, 53)          | 48 (41, 56)        |                      |
| Ethnicity                     |                       |                      |                    | 0.001                |
| Immigrants                    | 30 (1.1 %)            | 497 (2.1 %)          | 527 (2.0 %)        | < 0.001              |
| Native                        | 2604 (98.9 %)         | 23,587 (97.9 %)      | 26,191 (98.0 %)    |                      |
| Household income <sup>a</sup> |                       |                      |                    |                      |
| Mean (SD)                     | 1577 (552)            | 1646 (570)           | 1640 (569)         | < 0.001              |
| Median (Q1, Q3)               | 1591 (1237, 1944)     | 1625 (1237, 1944)    | 1625 (1237, 1944)  |                      |
| Education                     |                       |                      |                    | < 0.001              |
| High                          | 387 (15.2 %)          | 8987 (38.1 %)        | 9374 (35.8 %)      | < 0.001              |
| Intermediate                  | 2043 (80.0 %)         | 14,458 (61.1 %)      | 16,501 (63.0 %)    |                      |
| Low                           | 123 (4.8 %)           | 200 (0.8 %)          | 323 (1.2 %)        |                      |
| Health literacy level         |                       |                      |                    | <0.001               |
| Adequate                      | 1671 (63.0 %)         | 18,704 (77.2 %)      | 20,375 (75.8 %)    | < 0.001              |
| Gingivitis                    |                       |                      |                    |                      |
| Absent                        | 2322 (88.0 %)         | 15,286 (63.2 %)      | 17,608 (66.0 %)    |                      |
| Present                       | 314 (12.0 %)          | 8919 (36.8 %)        | 9233 (34.0 %)      | 0.001                |
| Oral health behaviours        |                       |                      |                    |                      |
| Inadequate brushing           | 1215 (46.0 %)         | 5602 (23.1 %)        | 6817 (25.4 %)      |                      |
| Max 7 meal moments            | 2067 (89.7 %)         | 19,204 (89.5 %)      | 21,271 (89.5 %)    | 0.795                |
| Smoker                        | 279 (12.5 %)          | 2062 (10.9 %)        | 2341 (11.1 %)      | 0.001                |
| Dental care utilization       |                       |                      |                    | < 0.001              |
| Not recent dental visits      | 1436 (54.2 %)         | 2167 (9.0 %)         | 3603 (13.4 %)      |                      |

<sup>a</sup> Household income is calculated in Euros divided by the square root of the number of individuals who live off the income.  
<sup>b</sup> p-values from testing the difference between 2 groups using Chi-Square tests for categorical or Mann-Whitney U tests for numerical data.

**Table 2**  
Likelihood of poor oral health outcomes for limited vs. adequate health literacy: odds ratios (OR) and 95 % confidence intervals (CI).

| Oral health outcomes |         | HL <sup>a</sup> (%)      |                       | Crude OR (CI)     | Adjusted OR (CI) <sup>b</sup> |
|----------------------|---------|--------------------------|-----------------------|-------------------|-------------------------------|
|                      |         | Adequate 12,432 (77.3 %) | Limited 3646 (22.7 %) |                   |                               |
| <b>Edentulism</b>    | Absent  | 11,393 (91.6)            | 3102 (85.1)           | 1.92 (1.72; 2.14) | 1.41 (1.24; 1.58)             |
|                      | Present | 1039 (8.4)               | 544 (14.9)            |                   |                               |
| <b>Gingivitis</b>    | Absent  | 8343 (67.1)              | 2334 (64.1)           | 1.14 (1.05; 1.23) | 1.22 (1.14; 1.30)             |
|                      | Present | 4086 (32.9)              | 1309 (35.9)           |                   |                               |

<sup>a</sup> The reference category for the odds ratio shown was “adequate” HL.  
<sup>b</sup> Adjusted for age, education, and household income.

4.2. Association of HL with oral health outcomes

Limited health literate participants were more likely to report edentulism and gingivitis, in crude and adjusted analysis. Adjusted odds ratios, OR (95 %-confidence intervals, CI) were 1.41 (1.24; 1.58) and 1.22 (1.14; 1.30), respectively, as shown in Table 2. The models were adjusted by age, household income, and educational level.

4.3. Mediation between HL and oral health outcomes

The total effects of LHL on poor oral health outcomes (edentulism and gingivitis) were mediated by oral health behaviour and dental care utilization, as summarized in Table 3 and Appendix 3. Regarding oral health behaviour, only brushing behaviour, was a significant mediator in both oral health outcomes.

Inadequate brushing behaviour mediated (indirect effect) the association of LHL with edentulism by 7.4 % and the association of LHL with gingivitis by 6.7 %. Smoking behaviour was significantly associated with edentulism and gingivitis. However, smoking behaviour did not mediate the associations between HL and edentulism and gingivitis.

Inadequate dental care utilization (dental visits) mediated the association between LHL and edentulism by 38.0 %. Dental care utilization inversely mediated 16.4 % of the total effect of LHL on gingivitis. This

suggests that participants who have recent dental visits are more likely to have gingivitis.

5. Discussion

This study demonstrated an association of LHL with oral diseases, namely edentulism and gingivitis. LHL participants were more likely to be edentulous and to have gingivitis, also after adjustment for age, education, and household income. These associations were significantly mediated by oral health behaviours (brushing behaviour) and dental care utilization. Notably, this is the first study to examine the mediating pathways between HL and oral diseases on a populational level.

This study found that LHL had an association with poor oral health outcomes, such as edentulism and gingivitis. Our findings confirm those of previous cross-sectional studies in West Africa (*n* = 208), USA (*n* = 150), Brazil (*n* = 248; *n* = 520), and Japan (*n* = 589) by demonstrating an association between limited oral health literacy with poor oral hygiene status and increased prevalence of oral diseases [32,33]. Although in this study a validated questionnaire on HL was utilized, yet our results aligned with the measurement using various oral health literacy questionnaires [32,33].

This association between LHL and oral health outcomes suggests that LHL has a causal impact on poor oral health status. This is likely due to

**Table 3**  
Mediation between limited health literacy LHL and poor oral health outcomes through oral health behaviour and dental care utilization.

|                                  |                     | Estimate <sup>b</sup> | CI <sup>b</sup> | P value <sup>b</sup> |
|----------------------------------|---------------------|-----------------------|-----------------|----------------------|
| <i>Edentulism</i>                |                     |                       |                 |                      |
| Total effect (direct + mediated) |                     | 0.180                 | 0.113; 0.248    | < 0.001              |
| Direct effect                    | Estimate            | 0.092                 | 0.027; 0.156    | 0.005                |
|                                  | Percentage          | 50.8                  |                 |                      |
| Mediators <sup>a</sup>           |                     |                       |                 |                      |
| Brushing behaviour               | Mediated (indirect) | 0.013                 | 0.005; 0.022    | 0.001                |
|                                  | Percentage mediated | 7.4                   |                 |                      |
| Meal moments                     | Mediated            | 0.004                 | −0.001; 0.009   | 0.121                |
|                                  | Percentage mediated | 2.3                   |                 |                      |
| Smoking behaviour                | Mediated            | 0.002                 | −0.004; 0.009   | 0.475                |
|                                  | Percentage mediated | 1.3                   |                 |                      |
| Dental visit                     | Mediated            | 0.069                 | 0.031; 0.107    | < 0.001              |
|                                  | Percentage mediated | 38.0                  |                 |                      |
| <i>Gingivitis</i>                |                     |                       |                 |                      |
| Total effect (direct+ mediated)  |                     | 0.095                 | 0.046; 0.144    | <0.001               |
| Direct effect                    | Estimate            | 0.109                 | 0.059; 0.158    | <0.001               |
|                                  | Percentage          | 74.51                 |                 |                      |
| Mediators <sup>a</sup>           |                     |                       |                 |                      |
| Brushing behaviour               | Mediated (indirect) | 0.010                 | 0.003; 0.016    | 0.003                |
|                                  | Percentage mediated | 6.7                   |                 |                      |
| Meal moments                     | Mediated            | 0.002                 | −0.001; 0.005   | 0.281                |
|                                  | Percentage mediated | 1.2                   |                 |                      |
| Smoking behaviour                | Mediated            | −0.002                | −0.006; 0.003   | 0.450                |
|                                  | Percentage mediated | 1.2                   |                 |                      |
| Dental visit                     | Mediated            | −0.024                | −0.038; −0.010  | < 0.001              |
|                                  | Percentage mediated | 16.4                  |                 |                      |

Note: Parameter estimates from Probit regressions. Bootstrap confidence intervals.  
<sup>a</sup> The reference categories for the mediators were: adequate brushing behaviour (≥ 2 times/day), maximum 7 meals a day (≤ 7 meal moments), non-smoker, and recent dental visits (at least 1 annual dental visit).  
<sup>b</sup> Adjusted for age, education, and household income. The household income was calculated as the net household income in Euros divided by the square root of the number of individuals who live off the income.

difficulties in understanding, analysing, and applying health information [34,35]. Importantly, research suggests that reversing health literacy skills is practically impossible [25]. Furthermore, as oral care is free for <18 years old in the Netherlands, it can be assumed that edentulism in the utilized dataset is related to adult oral health behaviour. Therefore, it can be concluded that LHL contributes to cumulative lifelong issues in oral health.

In this study, brushing behaviour mediated the association of HL with oral health outcomes. This finding implies that inadequate brushing behaviour was associated with LHL and poorer oral health outcomes. Both the understanding of health information and the motivation and self-efficacy are needed to process health information to support appropriate health decisions and adequate daily oral health behaviour [8,34,36–38]. Clinically, brushing frequency reduces plaque accumulation, which reduces the risk factors of poor periodontal conditions and thus reduces the risk of edentulism [39–42]. The mediating roles of meal moments and smoking behaviour were not statistically significant mediators. Although smoking behaviour is a known risk factor for edentulism, we found non-significant effect between HL and smoking (Appendix 4). Underreporting of smoking habits or the dominant influence of other oral health behaviours may have influenced our findings here. In short, our findings underscore that inadequate brushing is an important route regarding the poorer oral outcomes of LHL individuals.

Dental care utilization further mediated the relationship between LHL and oral health outcomes. This aligns with previous research showing that LHL individuals make less use of preventive care and have difficulty understanding the complex healthcare systems [21,23,39]. Additionally, frequent dental visits enhance individuals' awareness of early signs and symptoms of oral conditions [44,45]. However, further research is needed to disentangle these mediating pathways of dental care utilization.

In contrast to edentulism, a reverse relationship between frequent dental visits and the presence of gingivitis was found. This reverse causality could be explained by the fact that the gingivitis and dental visits were captured using self-reported assessments in the Lifelines cohort study. However, this finding could also be explained from a clinical perspective that individuals with existing gingivitis are more likely to visit the dentist due to their symptoms (such as, bleeding gums) rather than preventive intent. Likewise, recent literature indicates that dental visits alone are insufficient for reducing gingivitis, highlighting the importance of consistent oral hygiene practices alongside adequate dental visits [46].

Theoretical models like the Causal Pathways Model by Paasche-Orlow and Wolf (2007) and the Oral Health Literacy Framework (OHLF) provide insights into how HL impacts oral health outcomes [47]. Limited HL affects access to healthcare, patient-provider interactions, and self-care, impeding individuals' ability to understand oral health information and engage in preventive care. The OHLF highlights that individuals with higher oral HL are better equipped to apply health information effectively, supporting preventive behaviours and timely care. In contrast, LHL individuals may struggle with comprehending health information, reducing their ability to maintain adequate oral hygiene and seek timely care, thus exacerbating their oral health issues over time [48–50]. These frameworks highlight the importance of HL and aligns with this study's findings on the mediation effects of brushing behaviour and dental care utilization.

### 5.1. Strengths and limitations

This study has several major strengths, including its longitudinal design, large sample size, utilization of two crucial oral health outcomes ('gingivitis' for oral hygiene status in the present moment and 'edentulism' for cumulative oral health status), and standardized data collection coupled with mediation analysis, which enhances the robustness and rigour of our findings.

This study also has some limitations. First, oral health outcomes,

particularly gingivitis, and dental care utilization were self-reported, which may have introduced measurement error due to social desirability and recall bias. Although we included cross-check questions to validate our primary outcome 'edentulism reporting', residual confounding from self-reported measures remains possible, as participants may have underreported behaviours like smoking, which is a known risk factor for poor oral health. Second, loss to follow-up could introduce attrition bias, although the differences between included and excluded populations were minor, suggesting limited impact on overall results. Third, HL was assessed primarily through a functional HL measure, which may have led to underestimating the effects of low HL, as other components like communicative and critical literacy were not evaluated.

### 5.2. Implications

Our findings show a consistent negative association between LHL and oral health, which suggests that interventions to improve HL could have a considerable impact on improving oral health. In the realm of dental practice, patients with LHL have a limited understanding of oral health and the long-term consequences of poor oral health conditions, such as edentulism [29]. Therefore, targeted educational interventions aimed at improving HL of the patients could significantly enhance these behaviours, thereby reducing the prevalence of oral conditions [29,34, 43]. Given the high impact of LHL on oral health, there is an urgent need to develop patient centered communication training for dental professionals. Such trainings should aim to mitigate the effects of LHL by addressing the mechanisms through which it influences oral health outcomes. These interventions, such as communication training for dental professional and oral health education programs for LHL patients, should be tested for effectiveness in improving behaviours and reducing oral disease prevalence.

Future studies should prioritize longitudinal research to establish causality between HL and oral health outcomes. Moreover, exploring the role of health systemic solutions, such as dental supplementary insurance, and structural public health measures (e.g., fluoridation of drinking water) could provide broader insights into mitigating LHL's effects on oral health. The limited availability of clinical data on oral conditions, such as dental caries, oral cancer, and periodontal disease, highlights the need for regular community based oral health monitoring studies in the Netherlands. These approaches would help policymakers design evidence-based strategies to improve oral health outcomes at both individual and population levels.

## 6. Conclusion

This study demonstrated an association between LHL with oral diseases. Limited health-literate participants were more likely to be edentulous and have gingivitis. This association was significantly mediated by oral health behaviours (brushing behaviour) and dental care utilization. The findings therefore suggest that interventions should focus on helping dental professionals recognize patients with limited HL and on providing training in patient-centered communication to improve oral health outcomes.

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## CRediT authorship contribution statement

**Trishnika Chakraborty:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Marise S Kaper:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Josue Almansa:** Writing – review & editing, Validation, Software, Methodology, Formal analysis. **Annemarie A Schuller:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Sijmen A Reijneveld:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jdent.2024.105530](https://doi.org/10.1016/j.jdent.2024.105530).

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