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Journal

Annals of Behavioral Medicine, 55(11)

ISSN

0883-6612

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Publication Date

2021-10-27

DOI

10.1093/abm/kaab006

Peer reviewed

Pathways Through Which Health Literacy Is Linked to Parental Oral Health Behavior in an American Indian Tribe

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Abstract

Background Health literacy (HL) is the "ability to find, understand, evaluate and put information to use to improve decision making and, ultimately, improve health and quality of life." Parents with limited HL are less likely to follow recommended parental oral health behaviors. Purpose We tested a theoretical framework designed to clarify mechanisms through which HL may influence parental oral health behavior. The framework proposed that HL: (a) has a direct effect on parental oral health knowledge, beliefs (i.e. self-efficacy; perceived susceptibility, severity, benefits, barriers), and behavior; (b) influences beliefs indirectly through knowledge; and (c) influences behavior indirectly through knowledge and beliefs.

Methods We analyzed cross-sectional data from a randomized controlled trial designed to reduce dental decay in American Indian children ($N = 521$). Parents completed survey questions assessing sociodemographic characteristics, HL, and parental oral health knowledge, beliefs, and behavior. Path analysis was used to test the framework.

Results HL exerted significant direct effects on knowledge and beliefs but not behavior. HL had significant indirect effects on all beliefs through knowledge. Significant indirect effects of HL on behavior occurred through self-efficacy (estimate: 0.99, 95% CI: 0.42, 1.83, $p = .005$), perceived barriers (estimate: 0.73, 95% CI: 0.29, 1.43, $p = .010$), knowledge to self-efficacy (estimate: 0.57, 95% CI: .31, 0.98, $p = .001$), and knowledge to perceived barriers (estimate: 0.24, 95% CI: 0.09, 0.47, $p = .012$).

Conclusions HL exerted an indirect effect on parental oral health behavior, with knowledge, self-efficacy, and perceived barriers being the primary constructs linking HL to behavior.

Introduction

Health literacy (HL) is the "ability to find, understand, evaluate and put information to use to improve decision making and, ultimately, improve health and quality of life" [1]. Although definitions of HL often focus on the skills of the individual (e.g. reading and writing, understanding and using numbers, verbal communication), there is growing consensus that HL reflects an interaction of these personal capabilities with features of the environment that may facilitate or obstruct "access to information and active engagement" in the management of one's health [2]. Data from a large, nationally representative sample show that 36% of U.S. adults have limited HL and that such limitations are more common in individuals with lower levels of income and education [3].

The HL skills of parents may have implications for pediatric oral health. Parents with more limited HL have lower levels of knowledge regarding children's oral health and

recommended parental oral health behaviors (e.g. brushing children's teeth twice a day, taking children to the dentist for routine preventive care) [4–7]. Moreover, lower-literate parents hold oral health beliefs that are unlikely to encourage positive parental oral health behaviors. Compared with higher-literate parents, those with more limited HL have less confidence that they can care for their children's teeth, perceive fewer benefits and more barriers related to recommended parental oral health practices, and are more likely to believe that external forces—such as the dentist or mere chance— govern their children's oral health [5, 7]. Perhaps, as a result, parents with more limited HL are often less likely to engage in recommended parental oral health behaviors [4–6].

National guidelines established by the American Academy of Pediatric Dentistry (AAPD) highlight the importance of implementing preventive oral health measures early in a child's life [8, 9]. Dental decay, which is the most common chronic condition in U.S. children [10], can begin immediately once teeth begin to erupt and has been shown to advance quickly among children from low socioeconomic backgrounds [8]. Early prevention efforts are crucial for delaying and controlling the progression of the disease. As such, AAPD guidelines encourage parents to engage in positive oral health behaviors from the early days of a child's life [8, 9]. Specific recommendations include using appropriate bottle-feeding practices, limiting a child's sugar consumption, routinely examining and cleaning children's teeth and gums, brushing emerging teeth twice a day with fluoride toothpaste, and initiating routine dental exams before one year of age.

Early action to prevent dental decay is particularly important for American Indian children, who develop teeth earlier than children from other racial groups [11] and are at high risk for poor oral health outcomes [12–16]. By 11 months of age, Native children have an average of eight teeth, compared with four among their non-Native peers [11]. Early tooth eruption contributes to poor outcomes among American Indian children. Indeed, by 1 year of age, 16% of Native children have dental decay [16]. The prevalence of dental decay rises quickly thereafter, with 40% of 2-year-olds and 61% of 3-year-olds experiencing disease [16]. To combat the early development and swift progression of dental decay among Native children, early action is recommended [17].

Although the literature suggests an association of HL with parental oral health behavior, the mechanisms underlying this relationship are unclear. Theoretical models developed to clarify the pathways linking HL to health behavior or outcomes often propose that HL influences behavior through its relationship with health-related knowledge and beliefs [18]. Some empirical evidence supports this proposition. Results of simple mediation analyses suggest that health-related knowledge and self-efficacy (i.e. the belief that one is capable of engaging in specific health practices) may explain the relationship of HL with health behavior [19–21]. Investigators testing more complex models have shown significant direct effects of HL on knowledge, self-efficacy, and behavior [22–24]; of knowledge on self-efficacy and behavior [22, 24]; and of self-efficacy on behavior [23, 24]. Few studies have examined health beliefs other than self-efficacy [25].

The goal of the reported analysis was to clarify pathways through which HL is associated with parental oral health behavior. The theoretical framework that guided this analysis was based on established health behavior theory—specifically, the extended Health Belief Model [26, 27]—as well as theoretical models and research addressing the mechanisms linking HL with health behavior [18–20, 22–24]. The framework (Fig. 1) proposes that HL influences parental

oral health behavior directly and indirectly through its association with parental oral health knowledge and beliefs. The framework outlines the following key hypotheses:

1. HL is directly associated with knowledge, beliefs, and behavior, such that stronger HL is linked to higher levels of knowledge, greater endorsement of beliefs conducive to positive oral health behaviors, and greater adherence to those behaviors;
2. Stronger HL is linked to positive oral health beliefs indirectly, through improved knowledge;
3. Stronger HL is associated with positive oral health behavior indirectly, through enhanced knowledge and beliefs.

We tested the theoretical framework using data from a randomized controlled trial that evaluated a program to reduce early childhood caries in American Indian children. Early childhood caries is dental decay in children less than six years of age [28]. American Indian children experience caries at a higher rate and severity than do children in the general U.S. population [12–16]. Given limited educational opportunities and high rates of poverty in many American Indian communities, Native parents may be at risk for HL limitations [3, 29]. Such limitations may hinder adherence to recommended parental oral health behaviors, potentially putting Native children at risk for caries. Using path analysis, we tested the direct and indirect pathways proposed by the theoretical framework. As the only known test of a comprehensive model designed to clarify the link between HL and parental oral health behavior, this analysis provided important insight into the mechanisms through which HL may influence behavioral adherence, and ultimately, oral health outcomes among Native children.

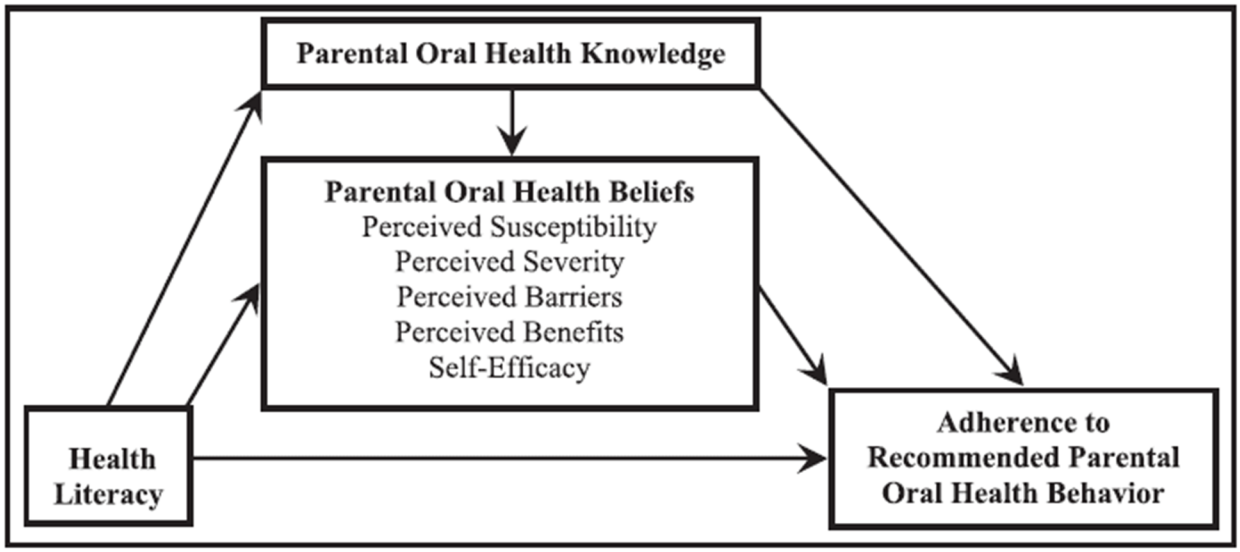

Fig. 1. Theoretical framework.

Methods

Participants and Procedures

Analyses used data collected as part of the clinical trial entitled "Promoting Behavioral Change for Oral Health in American Indian Mothers and Children" (PBC) [30, 31]. The PBC study tested the effectiveness of an intervention to reduce caries in young American Indian children residing on or near a specific Indian reservation in the Northern Plains. The reservation is home to approximately 20,000 people, most of whom are members of a single Northern Plains tribe [32]. Recent oral health assessments conducted in the Northern Plains have shown caries experience in the majority of 3-year-old Native children, with an average of 10 decayed, missing, or filled tooth surfaces [31, 33].

The protocol for the PBC study has been described in detail in prior papers [30, 31]. In brief, 579 parent–child dyads were enrolled in the trial, randomized, and followed for 36 months. At enrollment, pediatric participants were required to be American Indian, 0–3 months of age, residing on or near the participating reservation, and free of medical conditions that could impair tooth development. Participating adults were required to be the child's mother or primary caregiver (hereafter referred to as the "parent"), 15–65 years of age, willing and able to follow the study protocol, and able to understand and provide consent.

Parent–child dyads were randomized to an intervention group or a control group [30, 31]. Parents in the intervention group participated in an oral health intervention using motivational interviewing, a technique designed to help participants identify and resolve barriers to engaging in recommended health behaviors [34, 35]. Parents in the control group received "enhanced community services," which included oral health educational materials and messages that were made available throughout the reservation (e.g. public service announcements disseminated via billboards and tribal radio; culturally targeted educational brochures distributed at community events). Although parents in the intervention group had better parental oral health knowledge at the 12- and 24-month time points, compared to the control group, knowledge did not differ by the group at 36 months. Likewise, the intervention did not result in improved parental oral health behavior or pediatric oral health outcomes, compared to the control group [31].

We used data collected at the 12-month follow-up visit, at which time participating children were approximately one year of age. Given that 11-month-old Native children have an average of eight teeth [11], using data collected at the 12-month time point ensured that most or all children in the sample would have multiple teeth and, thus, that parents should be actively engaged in the management of their children's oral health. Because of slight study attrition from baseline to 12 months, the sample for the reported analysis included 521 parent–child dyads.

Approval for this secondary analysis and the original PBC study was obtained from the participating tribe's research review board and the institutional review board of the University of Colorado Anschutz Medical Campus, where the research team was located. Parents provided written informed consent and HIPAA authorization prior to participation. Parents under 18 years of age were required to obtain consent from their parents/legal guardians, in addition to providing their own assent.

Measures

Participating parents completed the Basic Research Factors Questionnaire (BRFQ) at baseline and annually for 3 years [36]. The BRFQ was administered by computer with questions presented on the screen and narrated by a member of the participating tribe. Questions included in the BRFQ assessed constructs such as HL; parental oral health knowledge, beliefs, and behavior; and sociodemographic characteristics of parents and children. All BRFQ items used in this report have been validated in Native populations [35–38].

Health Literacy

As previously reported [7], HL was measured as the mean of three BRFQ items examining participants' confidence in reading and completing medical forms (α = .49). The questions were adapted from existing items known to accurately identify patients with inadequate HL [37–42]. The HL score had a range of 1–5, with larger numbers indicating stronger HL skills (M = 4.0, SD = 0.8).

Parental Oral Health Knowledge

Parental oral health knowledge was measured using 17 items that assessed parents' knowledge of pediatric oral health and recommended parental oral health behaviors. Responses were coded as correct or incorrect. Because responses of "don't know" indicated that a respondent was not able to identify the correct answer, these responses were classified as incorrect. The overall knowledge score was computed as the percentage of questions answered correctly (M = 79.1, SD = 12.6).

Parental Oral Health Beliefs

Parental oral health beliefs were assessed using data from the BRFQ, which included items assessing five constructs from the extended Health Belief Model (HBM): perceived susceptibility, perceived severity, perceived barriers, perceived benefits, and self-efficacy [26, 27]. The HBM suggests that parents are more likely to engage in recommended parental oral health behaviors if they believe their children are susceptible to caries, that caries is a severe outcome, that there are few barriers to and many benefits of recommended behaviors, and that they are capable of engaging in those behaviors (i.e. self-efficacy).

The BRFQ included two to five items assessing each of four constructs: perceived susceptibility (M = 2.8, SD = 1.1; α = .54), severity (M = 4.4, SD = 0.8; α = .48), barriers (M = 2.1, SD = 0.9; α = .53), and benefits (M = 4.4, SD = 0.8; α = .82). All constructs used a 1–5 scale with larger numbers reflecting greater endorsement of the construct. The average of items associated with each construct was computed.

Self-efficacy was assessed using 14 items, each of which evaluated parents' confidence that they could engage in a specific parental oral health behavior (e.g. checking their children's teeth and gums for spots or problems). Because many participants selected the highest score for most items (5 on the 1–5 scale), the overall self-efficacy score was computed as the number of items for which the highest score was chosen. The overall score had a possible range of 0–14 (M = 8.8, SD = 4.0; α = .88).

Adherence to Recommended Parental Oral Health Behaviors

The BRFQ contained 13 items assessing adherence to oral health behaviors recommended for parents of young children (e.g. "How often are your child's teeth and gums brushed or wiped?"). Electronic Supplementary Material 1 provides the complete text of all items. Responses were coded as adherent or non-adherent with the recommended behavior [8, 9]. The behavioral adherence score was computed as the percentage of behaviors for which a parent was adherent (M = 52.0, SD = 17.9).

Sociodemographic Characteristics

The BRFQ solicited information about the sociodemographic characteristics of participating parents and children. For parents, items captured age, sex, race, tribal affiliation, ethnicity, highest grade completed, household income for the prior year, and employment status. For children, sociodemographic questions assessed age, sex, race, and ethnicity.

Data Analysis

Descriptive and Exploratory Analyses

All variables were summarized using means (standard deviations) for continuous variables and frequencies (percentages) for categorical variables. Spearman's correlations were computed to examine the bivariate relationships among constructs included in the theoretical framework (see Electronic Supplementary Material 2).

Path Analysis

Path analysis was used to test the theoretical framework (Fig. 1), with analyses performed in R (version 3.5.3) [43], using the lavaan package (version 0–6.3) [44]. As intervention differences were not expected, we planned to combine the intervention and control groups in the analysis. To determine whether this approach would be appropriate, we first estimated the theoretical model using a multiple-group analysis, in which we fit the model simultaneously in both the intervention and control groups, allowing for group differences. A second model was also fit that estimated parameters with no allowance for group differences. A chi-square difference test ($\Delta\chi^2$) indicated that there was not a significant difference between the two models ($\Delta\chi^2(58) = 45.50$, $p = .88$). Hence, we present the more parsimonious model, which constrained parameter estimates to be the same in both treatment arms.

This model was estimated using full information maximum likelihood. We evaluated the goodness of fit of the model to the data as well as the magnitude and significance of all proposed direct and indirect effects. Indirect effects were calculated using the product of coefficients method and bias-corrected bootstrapped standard errors (5,000 bootstrap draws). Parent age, education (high school degree or less vs. college degree or more), and household income (<$10K, $10–$20K, >$20K, or missing) were included as predictors of HL. Residual correlations were estimated among the five HBM constructs.

Model fit was assessed using the model chi-square, comparative fit index (CFI), the root mean square error of approximation (RMSEA), and standardized root mean square residual

(SRMR) [45–47]. In evaluating the goodness of fit, we used the following criteria as indicators of a close or good fit: non-significant chi-square value, CFI values ≥.90 for close fit (≥.95 for a good fit), and RMSEA and SRMR values ≤.08 for close fit (≤.05 for a good fit) [45].

Results

Sample Characteristics

Table 1 summarizes characteristics of the sample at the 12-month time point. On average, parents were 26.2 years old, ranging from 16 to 65 years of age. Most participants were women (96.7%) and were the mothers of the enrolled children (94.4%). Almost all adult participants were American Indian (92.9%) and most identified as members of the Northern Plains tribe that participated in the PBC trial (76.6%). Few parents (5.2%) self-identified as Hispanic.

Adult participants reported having limited educational attainment and income (Table 1). More than one-third of parents (36.7%) reported not having finished high school, with only 8.8% having completed a college or more advanced degree. More than 40% of parents were unemployed (40.9%) and nearly half had a household income under $10,000 in the prior year (48.9%).

Table 1 also summarizes the characteristics of participating children. At the 12-month time point, children were 11.7 months old, on average, and were evenly divided between males and females. All children were American Indian (100%), with a small percentage being of Hispanic descent (7.3%).

Model Fit

The final path model demonstrated a close fit to the data based on the SRMR (.045), RMSEA (.058), and the CFI (.920). Although the chi-square test was significant (χ^2 (35, N = 521) = 97.32, $p < .001$), this indicator is known to be sensitive to sample size [48]. Given adequate fit, we proceeded with interpreting direct and indirect effects rather than exploring data-driven approaches aimed at improving the overall fit.

Evaluation of Direct & Indirect Pathways

Direct Effects Tested in the Path Model

According to key hypothesis 1, HL has a significant direct effect on parental oral health knowledge, beliefs, and behavior. As expected, HL was significantly associated with knowledge and beliefs proposed to support positive health behaviors (Fig. 2). Compared with lower-literate participants, parents with stronger HL had significantly higher levels of knowledge and self-efficacy, perceived oral health problems to be more severe, and perceived more benefits of and fewer barriers to recommended parental oral health behaviors. Unexpectedly, parents with stronger HL perceived their children to be less susceptible to cavities than did those with more limited HL skills. Also contrary to key hypothesis 1, HL did not have a significant direct effect on behavior.

In addition to pathways highlighted by key hypothesis 1, Fig. 2 presents all other direct effects outlined in the theoretical framework. As expected, knowledge was a key predictor of

parental oral health beliefs. Parents with greater knowledge had significantly stronger self-efficacy, perceived more benefits of and fewer barriers to recommended parental oral health behaviors, and believed caries to be a more severe outcome than did parents with less knowledge of pediatric oral health. Contrary to expectations, knowledge was significantly, but negatively, associated with perceived susceptibility and was not significantly associated with behavior.

Only two of the parental oral health beliefs were related to behavior. Parents with greater confidence in their ability to care for their children's teeth adhered to a significantly higher percentage of recommended behaviors than did parents with lower levels of self-efficacy. Likewise, parents who perceived a higher level of barriers to recommended oral health behaviors engaged in a significantly lower percentage of those behaviors, compared with parents who perceived a lower level of barriers. No other health beliefs were significantly associated with behavior.

Table 1. Sample characteristics ($N = 521$)

Mean (*SD*) or *N* (%)	
Parent characteristics	
Age	26.2 (6.1)
Gender: female	504 (96.7%)
Race and ethnicity	
American Indian	484 (92.9%)
Member of the participating tribe	399 (76.6%)
Hispanic	27 (5.2%)
Highest grade completed	
< High school graduate	191 (36.7%)
High school grad or GED	123 (23.6%)
Some college or vocational	155 (29.8%)
College degree or more	46 (8.8%)
Income	
<$10K	255 (48.9%)
$10 to <$20K	60 (11.5%)
$20 to <$30K	38 (7.3%)
$30 to <$40K	23 (4.4%)
≥$40K	27 (5.2%)
Income missing	118 (22.6%)
Employment status	
Full- or part-time employment	147 (28.2%)
Full- or part-time student	47 (9.0%)
Homemaker	67 (12.9%)
Unemployed	213 (40.9%)
Other (retired, disabled, medical leave)	13 (2.5%)
Relationship to child	
Mother	492 (94.4%)
Father	14 (2.7%)
Other	11 (2.1%)
Child characteristics	
Age (months)	11.7 (1.4)
Gender: female	267 (51.2%)
Race and ethnicity	
American Indian	521 (100.0%)
Hispanic	38 (7.3%)

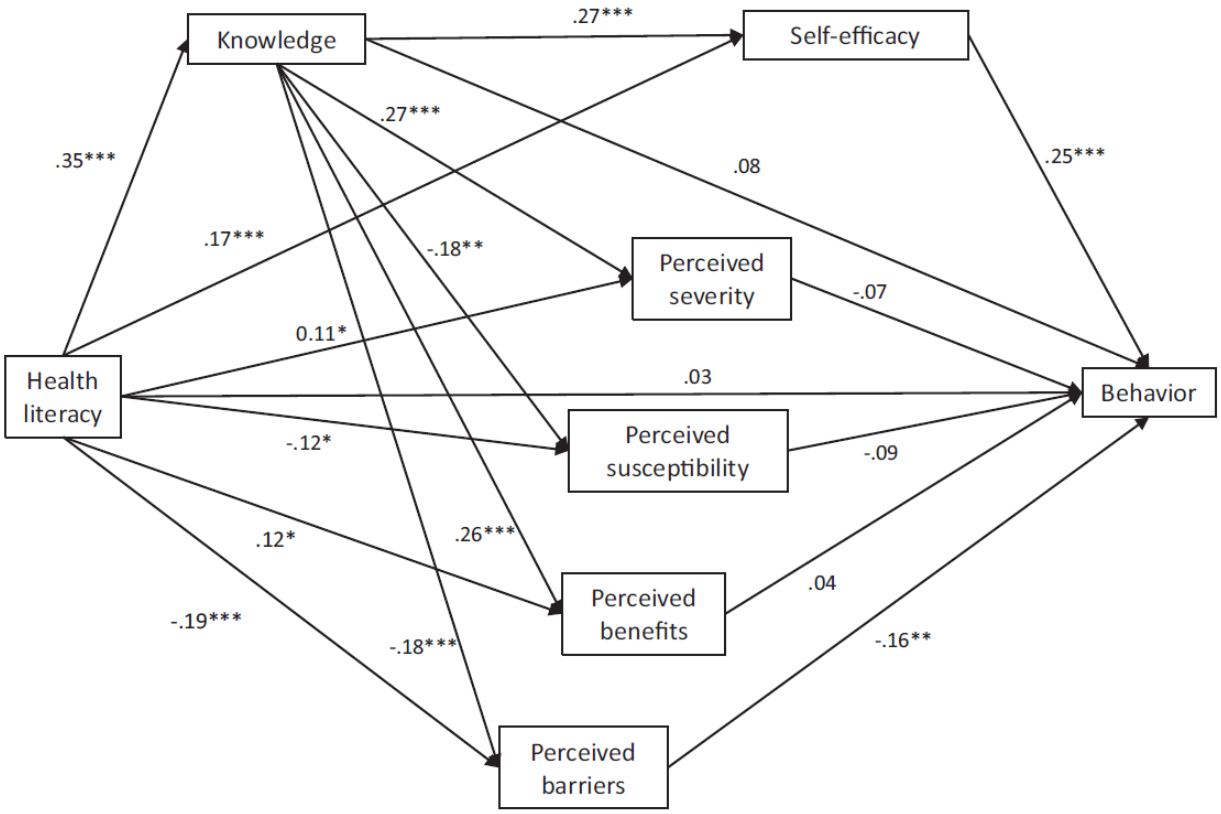

Fig. 2. Direct effects tested in the path model[a]. [a]Standardized coefficients for all direct paths are shown. *P* values are represented by asterisk(s): **p* < .05, ***p* < .01, ****p* < .001.

Table 2. Indirect effects of health literacy (HL) on parental oral health beliefs through knowledge[a]

	Indirect effect of HL on health belief through knowledge		
Parental oral health belief	**Estimate**	**95% CI**	***P* value**
Self-efficacy	0.50	0.31, 0.73	<.001
Perceived susceptibility	−0.09	−0.15, −0.04	.001
Perceived severity	0.10	0.06, 0.15	<.001
Perceived barriers	−0.07	−0.11, −0.04	<.001
Perceived benefits	0.09	0.05, 0.14	<.001

[a]The estimates provided reflect the product of the unstandardized coefficients from the path model.

Indirect Effects Tested in the Path Model

Results supported key hypothesis 2, which proposes that HL is associated indirectly with parental oral health beliefs through its relationship with knowledge (Table 2). Indeed, stronger HL was related to better parental oral health knowledge, which then predicted more positive oral

health beliefs (i.e. stronger self-efficacy, perceived severity and benefits, and lower perceived barriers). All indirect effects of HL to beliefs, through knowledge, were significant. All indirect effects were in the hypothesized direction, with the exception of perceived susceptibility (stronger HL led to increased knowledge, which was associated with reduced perceptions of susceptibility).

Key hypothesis 3 proposes that HL is associated indirectly with parental oral health behavior through its relationship with knowledge and beliefs. Results showed that HL had a significant indirect relationship with behavior through pathways involving knowledge, self-efficacy, and perceived barriers (Table 3). First, HL was associated with behavior through self-efficacy (column 1). Higher levels of HL were associated with stronger self-efficacy, which was then associated with better behavioral adherence (estimate: 0.99, 95% CI: 0.42, 1.83, p = .005). Second, HL had a significant indirect effect on behavior through perceived barriers (column 1). Stronger HL was associated with lower perceived barriers, which was associated with greater engagement in recommended parental oral health behaviors (estimate: 0.73, 95% CI: 0.29, 1.43, p = .010). Third, stronger HL was linked to greater parental oral health knowledge, which was associated with stronger self-efficacy, which was then associated with better behavioral adherence (column 2; estimate: 0.57, 95% CI: 0.31, 0.98, p = .001). Fourth, stronger HL was associated with better knowledge, which was associated with better behavioral adherence through lower perceived barriers (column 2; estimate: 0.24, 95% CI: 0.09, 0.47, p = .012). Although HL did not have a direct effect on behavior, as a result of these indirect pathways, it had a significant total effect on behavior (estimate: 4.17; 95% CI = 2.17, 6.20; p < .001).

Table 3. Indirect effects of health literacy (HL) on behavioral adherence through oral health knowledge and beliefs[a]

	Column 1: indirect effect of HL on behavioral adherence through construct			Column 2: indirect effect of HL on behavioral adherence through knowledge to construct		
Construct	Estimate	95% CI	*P* value	Estimate	95% CI	*P* value
Knowledge	0.66	−0.06, 1.51	.098	-	-	-
Self-efficacy	0.99	0.42, 1.83	.005	0.57	0.31, 0.98	.001
Perceived susceptibility	0.25	0.01, 0.77	.162	0.13	0.01, 0.35	.119
Perceived severity	−0.19	−0.72, 0.04	.297	−0.16	−0.44, 0.05	.187
Perceived barriers	0.73	0.29, 1.43	.010	0.24	0.09, 0.47	.012
Perceived benefits	0.12	−0.07, 0.49	.391	0.09	−0.07, 0.33	.348

[a]The estimates provided reflect the product of the unstandardized coefficients from the path model.

Conclusions

The reported analysis represents the first known test of a comprehensive theoretical framework designed to clarify how parents' HL may influence their adherence to recommended parental oral health behaviors. Consistent with key hypothesis 1, parents with better HL skills had more extensive knowledge of pediatric oral health and more strongly endorsed oral health beliefs expected to encourage engagement in recommended behaviors. Results also provided some support for hypotheses related to the indirect effects of HL. Consistent with key hypothesis 2, parents with stronger HL skills had better knowledge of pediatric oral health, which then predicted more optimal oral health beliefs. (The direction of the relationship with perceived susceptibility was contrary to expectations.) Consistent with key hypothesis 3, HL demonstrated

an indirect effect on behavior, through parental oral health knowledge, self-efficacy, and perceived barriers. However, indirect effects on behavior via other HBM constructs were not observed.

A key finding of this study was that HL was not directly related to parental oral health behavior. We hypothesize that there are two primary reasons for the lack of a direct association between these variables. First, as depicted in our theoretical framework (Fig. 1), the pathways linking HL to behavior are proposed to be more distal and indirect than the pathways linking HL with knowledge and beliefs. This thesis was based on the results of prior research showing that knowledge and self-efficacy often mediate the relationship of HL with health behavior [20–23]. As such, it would be reasonable to expect HL to be more weakly associated with behavior than with knowledge and beliefs.

Second, we believe that the social conditions experienced by families participating in the PBC study may have resulted in a limiting effect on the association of HL with parental behavior. Participants in the trial experienced substantial socioeconomic challenges. More than one-third of parents had less than high school education, more than 40% were unemployed, and nearly half reported living on a household income of less than $10,000 in the prior year. Previous research has shown that the socioeconomic challenges of this sort are associated with suboptimal oral health behavior and negative pediatric oral health outcomes [49]. Further, access to dental care was limited for PBC families. Although the participating reservation covers 11,000 square miles and is home to nearly 20,000 people [32], it has only three dental clinics and a dentist-to-patient ratio much worse than that seen nationally (1:4,000 vs. 1:1,600) [15, 31]. As a result, dental care is not easily accessed on the reservation.

Under conditions of severe economic hardship and limited access to dental care, it may not be surprising that the personal HL skills measured in the PBC study did not have a significant direct effect on parental oral health behavior. As noted earlier, HL represents an interaction between personal capabilities and features of the environment in which health-related actions and behaviors take place. In the PBC study, the severe demands and restrictions of the social context may have overshadowed any benefit provided by the personal HL skills of individual participants. Even parents with strong HL, adequate knowledge, and optimal beliefs may not have been able to fully engage in recommended behaviors under these circumstances. Indeed, the social context in which the project took place may have limited the impact of the PBC intervention itself. Although the intervention had a positive impact on participant knowledge (at two of the three follow-up time points), it did not result in improved parental oral health behavior or pediatric oral health outcomes [31]. Just as the impact of HL may have been overshadowed by economic hardship and poor access to care, the limitations of the social environment may have made it difficult for parents assigned to the intervention group to translate their knowledge into optimal parental oral health behavior [50, 51].

Our findings corroborate prior research suggesting that knowledge and self-efficacy may be key constructs linking limited HL with poor adherence to recommended health behaviors and, ultimately, suboptimal health outcomes [19–24, 52–56]. A key finding of this analysis was that HL may influence behavior only indirectly. This result could explain an important inconsistency that has been seen in HL research. Although many studies show a significant association between HL and health behavior, others do not. In fact, investigators conducting a systematic review of HL research concluded that evidence linking HL with behavior was “insufficient because of inconsistent results” (p. 102) [57]. The findings of the current analysis suggest that HL may exert an effect on behavior, even when a direct association is not apparent. An

additional implication is that analytic models exploring the association of HL with behavior, while controlling for knowledge, self-efficacy, and/or perceived barriers may over-adjust the model and attenuate the estimated effect of HL on behavior. Theoretically, including variables that mediate the association of HL with health behavior should reduce the size and significance of the HL-behavior relationship. Researchers should carefully consider the inclusion of knowledge, self-efficacy, and perceived barriers as covariates and should explicitly examine both the direct and indirect effects of HL on health behaviors of interest.

The reported analysis provided important insight into the association of HL with parental oral health beliefs. To our knowledge, few HL studies have explored beliefs other than self-efficacy [5, 7, 25]. In contrast, this analysis examined all of the primary health beliefs outlined in the extended HBM. A key finding of this work was that parents with stronger HL skills endorsed oral health beliefs expected to be conducive to positive parental oral health behaviors. Specifically, higher-literate parents had better self-efficacy, perceived oral health problems to be more severe, and perceived more benefits of and fewer barriers to recommended parental oral health behaviors. These findings are corroborated by research conducted with parents of children from the Navajo Nation [5], a tribe in the Southwestern United States.

Inconsistent with the theoretical framework, and with prior research with Navajo parents [5], higher-literate parents participating in the PBC study perceived their children to be less susceptible to caries than did those with more limited HL. As a heightened sense of susceptibility is proposed to encourage positive health behavior, this negative association contradicted the theoretical framework and the otherwise consistent link between HL and beliefs expected to support positive behavior. It is possible that parents with stronger HL anticipated fewer oral health problems for their children specifically because they felt more capable of managing their children's teeth. Because the data used in the reported analysis were cross-sectional, it is impossible to determine with certainty the direction of this relationship. Although perceived susceptibility did not behave as expected, the overall pattern of results related to HL and beliefs was consistent with the theoretical framework and the results of prior work with American Indian parents [5].

Although our analysis showed a significant association between HL and parental oral health beliefs, it also called into question the importance of health beliefs more generally in influencing parental oral health behavior. Specifically, the HBM constructs of perceived susceptibility, severity, and benefits were not significantly associated with adherence to recommended parental oral health behavior. Indeed, of the health beliefs examined, only self-efficacy and perceived barriers were important predictors of behavior. Thus, although the study provided evidence for many of the hypotheses outlined in the theoretical framework, the expectation that the full set of HBM constructs would influence behavior was not supported.

The research reported here has several strengths. First, the theoretical framework tested was based on accepted health behavior theory [26, 27] as well as prior research and theoretical perspectives on HL [18]. Unlike many earlier studies seeking to understand the mechanisms linking HL to health behavior or outcomes [19–21, 52–56], the theoretical framework that guided this analysis was comprehensive. In addition to incorporating knowledge and self-efficacy, we tested the complete set of constructs typically identified with the HBM [26, 27]. Second, our analysis utilized a large sample, which provided adequate power to fully test our theoretical framework. Third, we utilized path analysis to enable a comprehensive test of our theoretical model. This method allowed us to examine both direct and indirect pathways, providing important insight into the mechanisms underlying the relationship between HL and

behavior. Finally, this work allowed us to better understand the manner in which HL may influence oral health in Native populations, which are at risk for limited HL and poor oral health [3, 12–16].

Like all research, this work also has limitations. Importantly, the reported analysis was conducted with data from a single time point of the PBC trial. Use of data from a single time point and the observational nature of the health belief data made it impossible to assess whether HL might play a causal role with regard to the other constructs examined in the theoretical framework. As a result, although HL was associated with knowledge and beliefs, we cannot say whether HL limitations may serve as a barrier to the development of strong oral health knowledge and optimal oral health beliefs. Nor can we draw clear conclusions about the directionality of other pathways tested in the model (e.g. the relationships between knowledge, beliefs, and behavior). Although the use of cross-sectional data contributed to limitations, the reported analysis provided a crucial initial test of our theoretical framework and analysis approach. Our findings will be used to inform future testing of the theoretical framework using longitudinal data from the PBC trial.

An additional limitation of this work was that some of the constructs under investigation had Cronbach alphas that were below the typical threshold used to establish good internal consistency (i.e. HL; perceived susceptibility, severity, and barriers). Notably, each of these measures was computed based on a small number of items (i.e. two to four). The small number of component items for these scales may have negatively affected alpha, which is known to increase with the number of scale items [58]. To address the potential impact of this limitation on study conclusions, we conducted a series of sensitivity analyses in which the computed scale scores were replaced with representative items for each construct. The primary study conclusion of indirect effects on behavior occurring through knowledge, self-efficacy, and perceived barriers were unchanged, with one exception: An item assessing barriers to "making sure my child's teeth are brushed the last thing before bed" was associated with behavioral adherence, whereas an item assessing barriers to "taking my child to the dentist for regular check-ups" was not associated with behavioral adherence. Therefore, the indirect effects of HL on behavioral adherence through perceived barriers appear to be driven by specific barriers, rather than by an overarching theoretical "barrier" construct. The finding of greater HL being associated with behavioral adherence through decreased perceptions of barriers should therefore be interpreted with caution, and future research should identify the specific types of barriers that may be most impactful in influencing oral health behaviors.

This work has important implications for interventions aimed at improving pediatric oral health. As parental oral health knowledge, self-efficacy, and to some extent, perceived barriers were the primary constructs linking limited HL with poor adherence to recommended parental oral health behaviors, these constructs should likely be the main focus of health promotion efforts. Prior HL research suggests that interventions aimed at improving knowledge should incorporate some specific features. First, several studies have shown that health care providers are not able to accurately identify which of their patients have HL limitations [59–64]. Presuming that health educators may also struggle to identify parents with limited HL, educational interventions should be designed assuming that all parents may experience some level of HL limitations. By incorporating principles of clear communication [65–67], intervention designers can ensure that written materials are easy to understand and act upon for all parents. Intervention developers also should consider the value of communication strategies that do not involve reading [68, 69]. In a recent study, for instance, women with limited HL

learned more than their higher-literate counterparts when oral health information was communicated verbally, rather than in writing [70]. Finally, some research suggests that lower-literate participants show similar degrees of improvement in knowledge as their higher-literate counterparts [68, 69, 71]. However, as participants with limited HL have lower levels of knowledge at the outset, they tend to have lower levels of knowledge at the end of educational interventions, in comparison with participants having stronger HL skills [68, 69, 71]. These results suggest that additional educational strategies or extended interventions may be needed to help parents with HL limitations achieve the best possible knowledge levels [68].

Educational interventions designed to be sensitive to the needs of adults with HL limitations also should seek to enhance self-efficacy for and reduce perceived barriers to recommended health behaviors. The literature suggests a variety of strategies through which self-efficacy can be enhanced [72]. Goal setting, behavioral practice, and regular feedback are important strategies for achieving mastery of recommended health practices and enhancing associated behavioral confidence. Likewise, individuals can develop stronger self-efficacy through observation of or interaction with peers (e.g. other Native parents) who can model successful mastery of behaviors and problem-solving strategies. Persuasive messages from knowledgeable others (e.g. health promotion interventionists) or peers also can promote the development of confidence for specific health behaviors. Finally, explicit identification of and problem-solving around social barriers that may interfere with behavioral adherence (e.g. financial constraints, limited access to dental care) are crucial for ensuring that parents can successfully engage in recommended health behaviors. Investigators and clinicians seeking to improve parental oral health behavior should consider incorporating these strategies in their interventions.

In conclusion, the reported analysis makes an important and novel contribution to the literature. As the first known test of a comprehensive theoretical framework examining the link between HL and parental oral health behavior, this work provides valuable insight into the mechanisms through which HL might impact pediatric oral health outcomes. Our findings suggest that HL may influence parents' efforts to care for their children's teeth through its effect on knowledge and specific health beliefs. This work also highlights the possibility that the effect of HL may be only indirect, a finding that has potential to explain substantial inconsistencies in the HL literature and that can inform analytic approaches used in the field. Finally, this work represents the first attempt to understand the mechanisms driving oral health behavior among parents of young Native children, a population that has received little attention in the literature and that is at high risk for poor oral health outcomes. Our work highlights the potential value of interventions targeting improved knowledge, self-efficacy, and perceived barriers, while also acknowledging the important role the social environment may play in the oral health of Native children.

Acknowledgments The research reported here was supported by the National Institute of Dental and Craniofacial Research (NIDCR) of the National Institutes of Health under Award Number R01DE027077 (AGB). The data used for this secondary analysis were collected as part of a randomized controlled trial funded by NIDCR (U54DE019259). The Basic Research Factors Questionnaire (BRFQ) was developed with support from NIDCR (U54DE019285, U54DE019275, and U54DE019259). The content of this report is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

We are grateful to the families who took part in the clinical trial that was the source of the data and to Sierra Quintana for her assistance with the literature review summarized in this report.

Compliance with Ethical Standards

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards
The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed Consent Informed consent was obtained from all individual participants included in the study.

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