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The Potential Benefit of Improving Health Literacy to Reduce Socioeconomic Inequities in Adolescent Health and Educational Outcomes.

Shuaijun Guo[1,2,3,*], Xiaoming Yu[4,*], Fan He[5], Elise Davis[2], Rebecca Armstrong[2], Lucio Naccarella[2]

[1] Centre for Community Child Health, Murdoch Children's Research Institute, Royal Children's Hospital, Melbourne, Australia. Email: jun.guo@mcri.edu.au.

[2] Melbourne School of Population and Global Health, University of Melbourne, Australia. Email: elise.davis@summerfoundation.org.au(ED);Rebecca.rmstrng@gmail.com(RA);l.naccarella@unimelb.edu.au(LN).

[3] Department of Paediatrics, University of Melbourne, Australia.

[4] Institute of Child and Adolescent Health, School of Public Health, Peking University, China. Email: yxm@bjmu.edu.cn.

[5] The John Richards Centre for Rural Ageing Research, La Trobe Rural Health School, La Trobe University, Australia. Email: F.He@latrobe.edu.au.

Research Article

***Corresponding author**

Shuaijun Guo,
Centre for Community Child Health, Murdoch Children's Research Institute, Royal Children's Hospital, Level 2 East Building, 50 Flemington Road, Parkville, Victoria, Australia, 3052.
Email: jun.guo@mcri.edu.au;

Xiaoming Yu,
Institute of Child and Adolescent Health, School of Public Health, Peking University, Beijing, China, 100191.
Email: yxm@bjmu.edu.cn

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Abstract

Background: Exposure to early socioeconomic disadvantage is associated with a range of adverse health and educational outcomes in later life, leading to substantial social and economic costs. Health literacy, as a personal asset to maintain and protect good health, has the potential to reduce socioeconomic inequities in these adverse outcomes. This study aimed to estimate the extent to which improving health literacy could reduce socioeconomic inequities in adolescents' health and educational outcomes.

Methods: A cross-sectional study was conducted with 650 students (54.9% male and 45.1% female) in Years 7 to 9 from four secondary schools in Beijing. Socioeconomic disadvantage was assessed by the Family Affluence Scale. Health literacy was measured by the 8-item skills-based Health Literacy Assessment Tool overall and by three domains: functional, interactive and critical. Outcomes included self-report global health status, health behaviours (breakfast eating, teeth brushing, cigarette smoking, alcohol drinking, physical activity, two or more health-compromising behaviours), patient-provider communication, and academic achievement. An interventional effects approach to causal mediation analysis was conducted.

Results: Improving disadvantaged adolescents' health literacy to the level of their non-disadvantaged peers could reduce 15.3%, 12.0%, 15.2% and 11.4% of socioeconomic differences in global health status, two or more health-compromising behaviours, patient-provider communication, and academic achievement, respectively. There were varying benefits of improving health literacy in each domain, depending on the outcome measured.

Conclusion: Improving health literacy could contribute to reducing socioeconomic inequities in adolescents' health and educational outcomes. Health literacy interventions should be considered within a broader, multifaceted and sustained strategy via collaborations between schools, families and communities.

Keywords: Health Inequities, Educational Outcome, Socioeconomic Disadvantage, Health Literacy, Adolescents, Transition to Adulthood, Mediation, Cross-Sectional

Abbreviations:

COVID-19: Coronavirus Disease of 2019.

FAS: Family Affluence Scale.

HLAT-8: The 8-item Health Literacy Assessment Tool.

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Introduction

Inequities in health and development are unjust and preventable inequalities between different population groups [1]. They often emerge from birth, persist across childhood and adolescence, and continue into adulthood, contributing to unequal rates of poor physical and mental health, low educational attainment and low income in later life [2,3]. Inequities in health and development bring about substantial social and economic costs [1]. Addressing inequities in early life has gained global attention, particularly in the context of the coronavirus disease of 2019 (COVID-19) pandemic, where these inequities have been amplified [4,5]. The World Health Organisation Commission on Social Determinants of Health has called for eliminating inequitable health and developmental outcomes within a generation since 2008 [6].

While there is a strong commitment to ensuring that no one child should be left behind [7], inequities exist in all countries and remain a global public health challenge [3]. The social determinants of health framework suggests that multiple nested factors and contexts shape a child's health and development [7,8]. As one of the most vital influencing factors, early exposure to socioeconomic disadvantage has lasting and adverse consequences on children's physical, mental and educational outcomes [9,10]. For instance, across 79 Organisation for Economic Co-operation and Development countries, the average academic performance of socioeconomically disadvantaged 15-year-olds was three years behind that of their most advantaged peers in 2018 [11]. Developmental trajectories are difficult to shift as children grow [12]. Therefore, closing socioeconomic gaps in early life is crucial to reducing future disease burdens and improving population health.

While adolescents are relatively healthy, they are facing unprecedented health challenges nowadays with a high disease burden arising from mental disorders, injury and violence [13]. Adolescence is a critical developmental life stage of preparing and transitioning to adulthood. During this period, adolescents develop their own self-identities and become more independent about everyday health-related decisions [14]. In the increasingly complex health care environment [15], adolescents are required to equip adequate health skills to maintain good health, that is, health literacy. While there is a wide range of definitions, health literacy is commonly understood as an individual's ability to find, understand, and use health information to promote and maintain good health [16,17]. The importance of health literacy to adolescent health has been well-documented in the literature [18,19]. Adolescents with low health literacy are at higher risk of having poor health status, health-compromising behaviours, underutilization of health services, and low academic performance [18,19,20,21,22]. As a personal asset, health literacy empowers adolescents to take the right health-related actions, resulting in better health and educational outcomes [23].

Health literacy is a multidimensional concept [16]. According to Nutbeam's health promotion outcome model [17], health literacy consists of functional, interactive, and critical domains. The functional domain refers to basic skills in reading and understanding health information. The interactive domain denotes advanced skills that allow individuals to extract health information from various forms of communication. The critical domain represents more advanced skills that can be used to critically evaluate health information and take control over health determinants. While previous research suggested that health literacy was associated with a range of health and developmental outcomes [18,19], most studies focused on the functional domain, neglecting the interactive and critical domains. Suppose theory-driven interventions are to be developed to promote adolescent health and development [24], for instance, based on Nutbeam's three-domain health literacy model [17]. In this case, it is important to obtain insights into the relationship between each domain of health literacy and adolescent health and development, particularly for those from socioeconomically disadvantaged backgrounds. Such evidence will help inform intervention opportunities from more precise perspectives, including whom to target, which domain of health literacy should focus on, and which outcome would have the most considerable benefit.

The social ecological model highlights that adolescent health literacy is not only an individual's capability to protect and maintain health, but also an interactive outcome with the broader environment [24]. Except for socioeconomic disadvantage, empirical studies have shown that other intrapersonal, interpersonal and environmental factors are associated with adolescent health literacy [25,26,27]. Examples of these factors are personal self-efficacy, peer relationships, social support, school environment, and community environment, which also influence adolescents' physical, mental and educational outcomes. For instance, findings from recent systematic reviews suggest that school climate and psychosocial factors such as self-esteem and peer relationships have the potential to mitigate the negative impact of socioeconomic disadvantage on educational outcomes among adolescents [28,29]. Currently, there is increasing policy and practice attention on health literacy as an intervention target to reduce health and developmental inequities. The World Health Organization's Shanghai Declaration on Promoting Health in the 2030 Agenda for Sustainable Development recognises health literacy as a critical driver of achieving an equitable world [30]. One potential pathway by which socioeconomic disadvantage leads to poor health and educational outcomes in adolescents is through low health literacy [31]. Adolescents from socioeconomically disadvantaged families are more likely to have low health literacy due to low basic reading skills, institutional bias, and limited opportunities for education and health services [32,33]. As shown in a recent literature review [34], health literacy was suggested to mediate the relationship between socioeconomic status and a range of health outcomes (e.g., health status, health behaviours, use of preventive services) based on 16 included studies. However, due to the heterogeneity of measurement tools and a limited number of studies focusing on adolescents in the 16 included studies, it remains unclear about the extent to which adolescent health literacy explains socioeconomic inequities in these outcomes. Moreover, most included studies focused on functional health literacy, rather than interactive and critical health literacy [17].

Current Study:

To further inform policy frameworks and program implementation, we aimed to investigate the extent to which improving health literacy amongst disadvantaged adolescents could potentially reduce socioeconomic inequities in health and educational outcomes. Based on previous theoretical and

empirical research studies [31,34], we hypothesized that health literacy would mediate the relationship between socioeconomic disadvantage and a range of health and educational outcomes among adolescents (Hypothesis 1). Given that the concept of health literacy has its specific nature in each domain (i.e., functional, interactive, and critical), we also hypothesized that different health literacy domains would play varying mediation roles in the relationship between socioeconomic disadvantage and developmental outcomes (Hypothesis 2).

Materials and Methods

Participants and settings:

A cross-sectional study was designed to recruit adolescents from four secondary schools in Beijing, China, using convenience and clustering sampling. In brief, a three-stage cluster sample design was used based on the Chinese Youth Risk Behaviour Survey in Beijing [35,36]. First, two districts were selected according to their socioeconomic levels, one representing high and the other representing low. Second, two schools in each district were selected based on previous research partnerships and appropriate survey timing (class time, class break time or lunchtime). Third, two intact classes (ranging from 20 to 35 students) from each year level (Year 7, 8 or 9) at each chosen school were invited to participate in the survey. Passive, opt-out consent was obtained from both parents and students. Data collection was undertaken in November 2015.

Measures:

Our conceptual model (Fig 1) shows the hypothesized pathway from socioeconomic disadvantage to adolescent health and educational outcomes, informed by current knowledge (see Appendix 1 for full details in Supplementary File). This model was used to guide the selection of measure and inform the analytic approach.

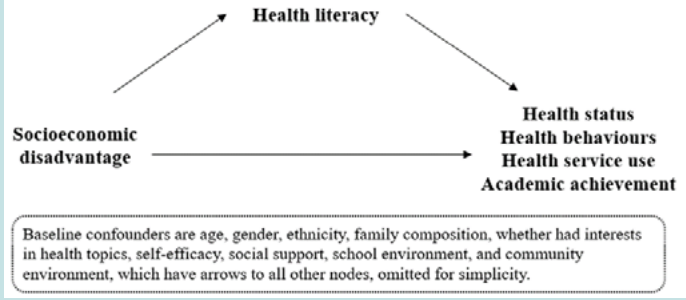

Figure 1: Conceptual model depicting the pathway from socioeconomic disadvantage to health and educational outcomes, via health literacy as a mediator of interest.

Exposure:

Socioeconomic disadvantage was assessed by the Chinese version of the Family Affluence Scale (FAS II) [37], which is an objective measure of family wealth and has been used in the global health behaviour in school-aged children survey [38]. The FAS II scale is composed of four items that ask adolescents about things they are likely to know about in their family (e.g., "Does your family own a car/van/truck?" 0=No, 1=Yes, one, 2=Yes, two or more). This scale has shown satisfactory reliability and validity in Beijing adolescents [37]. A composite FAS score (0-7) was summed and categorized into two groups based on the established cut-off [37]: adolescents from disadvantaged (score=0-3) families and those from non-disadvantaged (score=4-7) families.

Mediator:

Health literacy was assessed using the Chinese version of the 8-item Health Literacy Assessment Tool (HLAT-8) [16]. Students self-reported their abilities to access, understand, evaluate, and communicate health information in everyday life (e.g., "When I have questions on diseases or health problems (e.g. headache, back pain, sport injury), I know where I can find information on these issues." 1=Strongly disagree, 4=Strongly agree). The HLAT-8 consists of eight items within three domains: functional (four items, score range 1-18), interactive (two items, score range 1-10), and critical (two items, score range 1-9). The total score range is 1-37, with higher scores indicating higher levels of health literacy. The HLAT-8 has strong construct validity and reliability (Cronbach's α = 0.79) in our sample [16]. Due to the lack of standardized cut-off values, we dichotomized health literacy overall and by each domain using the bottom 25th percentile for interpretation. Students who scored below the bottom quartile were categorized as having low health literacy. We also considered using the bottom tertile as another cut-off to define low health literacy in Appendix 2 in Supplementary File.

Outcomes:

Global health status was assessed using a widely-used general self-report health question ('In general, would you say your health is?' 1=poor, 5=excellent) [39]. This single question has demonstrated strong predictive validity with objective indicators of health and mortality [40]. We recoded health status into a binary response ("poor/fair" versus "good/very good/excellent").

Health behaviours were measured by five items derived from the global school-based student health survey [41]. They included: the frequency of breakfast eating ("During the past 7 days, how often did you have breakfast?"; 1=0 days; 8=7 days), teeth brushing ("How often do you brush your teeth?"; 1=never; 5=more than once a day), cigarette smoking ("On how many occasions have you smoked cigarettes in the last 30 days?"; 1=never; 7=40 times or more), alcohol drinking ("On how many occasions have you drunk alcohol in the last 30 days?"; 1=never; 7=40 times or more) and physical activity ("During the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?"; 1=0 days; 8=7 days). For interpretation, we recoded each item to a binary response: regular breakfast eating (yes=breakfast eating 7 days/week versus no=breakfast eating ≤ 6 days/week) [42]; teeth brushing (at least twice a day versus less than twice a day) [43]; cigarette smoking (no smoking versus ever smoking) [41]; alcohol drinking (no drinking versus ever drinking) [41]; and physical activity (physically active ≤ 4 days/week versus physically inactive ≥ 5 days/week) [44]. In order to investigate the impact of health literacy on the overall health behaviour, we also created a composite measure of health behaviours if students had two or more aforementioned health-compromising behaviours (yes versus no).

Health service use was assessed using a single item that asked students' frequency of patient-provider communication over the last 12 months ('how many times have you raised a question during your doctor's appointment in the last 12 months?'; 1=0 times, 2=1-2 times, 3=3-5 times, 4=6 times or more). This single question was selected from the Health Literacy Survey-Asia Questionnaire [45]. Patient-provider communication was coded as "yes (at least one time)" if students had raised a question during the doctor's appointment.

Academic achievement was self-reported by students using a single item that asked them "think of your marks at school, if putting them all together, where were your marks like last year?" This single item was derived from the Chinese Youth Risk Behaviour Surveillance survey [46]. Students answered this item on a 5-point scale (1=very poor, 2=poor, 3=average, 4=good, 5=very good). A binary response was created for those scored below average versus those scored average and above.

Covariates:

Based on substantive knowledge, we posited nine covariates (see Appendix 1 for rationale in Supplementary File): students' age (continuous), gender (female/male), ethnicity (Han/ethnic minority) family composition (two parents/lone parent), whether had interests in health topics (not interested/not sure/interested), personal self-efficacy measured by the General Self-Efficacy Scale (continuous, with higher scores indicating higher levels of self-efficacy), social support measured by the Multidimensional Scale of Perceived Social and Support (continuous, with higher scores indicating higher levels of social support), perceptions of school environment measured by the School Environment Scale (continuous, with higher scores indicating more positive school environment), and perceptions of community environment measured by the Community Environment Scale (continuous, with higher scores indicating more supportive community environment).

Statistical Analysis:

Participant descriptive characteristics were summarized overall and by socioeconomic disadvantage. Correlation analysis was conducted to examine the relationships between socioeconomic disadvantage, health literacy and each outcome. To provide a preliminary examination of the strength of the pathways depicted in Fig 1, we also used a series of logistic regression analyses to examine the associations between socioeconomic disadvantage, health literacy, and each outcome. We obtained unadjusted estimates and those adjusting for covariates.

Next, we conducted an interventional effects approach [47] to causal mediation analysis as outlined by Moreno-Betancur et al. [48] to estimate the potential for interventions on health literacy to reduce socioeconomic disparities in each outcome (see Appendix 3 for technical details in Supplementary File). Interventional effects approaches have been increasingly used in the health disparities literature [49,50]. This approach to mediation analysis decomposes the total association between socioeconomic disadvantage and each outcome into direct (i.e. effect of socioeconomic disadvantage on each outcome not via low health literacy) and indirect (i.e., effect of socioeconomic disadvantage on each outcome via low health literacy) effects [51]. The estimate of the proportion mediated quantifies the extent to which socioeconomic disparities in each outcome would be eliminated by a hypothetical intervention that would make the level of health literacy of disadvantaged students more like that of non-disadvantaged peers. This approach was developed for contexts like the present one where data on actual, well-defined interventions already rolled out in the community are not available. We examined the reduction in socioeconomic disparities in four intervention scenarios (i.e., overall health literacy and by each domain: functional, interactive and critical). This allows us to compare the impact of hypothetical interventions across three domains of health literacy. All analyses were conducted using Stata 17.0 [52].

The proportion of students with complete data was 94.5% in our sample. The percentage of missing data ranged from 0.2% to 4.0% across all study variables. Due to a small percentage of missing data, we used the complete case dataset for all analyses.

Results

Sample Characteristics:

In total, 661 students were invited to participate, with 11 students declined, resulting in a response rate of 98.3% (650/661). Participant characteristics are summarized in Table 1. The mean age of participants was 13.42 ± 1.01 (range: 11-17 years). Around one-fourth (27.7%) of students were from socioeconomically disadvantaged families. Table 1 shows that a larger proportion of disadvantaged students had low health literacy than their non-disadvantaged peers (overall: 34.4% versus 22.6%; functional: 37.2% versus 28.4%, interactive: 38.9% versus 28.1%; critical: 56.1% versus 43.3%). At least one-third of students had poor health and educational outcomes: poor or fair health status (34.5%), two or more health-compromising behaviours (53.9%), no patient-provider communication (53.2%), and below average academic achievement (32.1%).

Table-1: Sample characteristics (N=650).

Participants' characteristics	Frequency (%) / Mean(SD)	Socioeconomic disadvantage	
		Non-disadvantaged	Disadvantaged
Exposure			
Socioeconomic disadvantage			
Non-disadvantaged	470 (72.3)	-	-
Disadvantaged	180 (27.7)	-	-
Mediator			
Overall health literacy			
High	481 (74.1)	363 (77.4)	118 (65.6)
Low	168 (25.9)	106 (22.6)	62 (34.4)
Functional health literacy			
High	449 (69.2)	336 (71.6)	113 (62.8)
Low	200 (30.8)	133 (28.4)	67 (37.2)
Interactive health literacy			
High	447 (68.9)	337 (71.9)	110 (61.1)
Low	202 (31.1)	132 (28.1)	70 (38.9)
Critical health literacy			
High	345 (53.2)	266 (56.7)	79 (43.9)
Low	304 (46.8)	203 (43.3)	101 (56.1)
Outcome			
Global health status			
Good/very good/ excellent	426 (65.5)	321 (68.3)	105 (58.3)
Poor/fair	224 (34.5)	149 (31.7)	75 (41.7)
Regular breakfast eating			
Yes	327 (50.5)	239 (51.1)	88 (48.9)
No	321 (49.5)	229 (48.9)	92 (51.1)
Teeth brushing			
At least twice a day	302 (46.5)	242 (51.6)	60 (33.3)
Less than twice a day	347 (53.5)	227 (48.4)	120 (66.7)
Cigarette smoking			
No smoking	630 (97.2)	458 (97.7)	172 (96.1)
Ever smoking	18 (2.8)	11 (2.3)	7 (3.9)

Alcohol drinking			
No drinking	552 (85.1)	401 (85.5)	151 (83.9)
Ever drinking	97 (14.9)	68 (14.5)	29 (16.1)
Physical activity			
Physically active	369 (57.0)	278 (59.4)	91 (50.8)
Physically inactive	278 (43.0)	190 (40.6)	88 (49.2)
Two or more health-compromising behaviours			
No	299 (46.1)	231 (49.3)	68 (37.8)
Yes	350 (53.9)	238 (50.7)	112 (62.2)
Patient-provider communication			
Yes	292 (46.8)	228 (50.4)	64 (37.2)
No	332 (53.2)	224 (49.6)	108 (62.8)
Academic achievement			
Average and above	440 (67.9)	335 (71.6)	105 (58.3)
Below average	208 (32.1)	133 (28.4)	75 (41.7)
Confounder			
Child age	13.42 (1.01)	13.39 (0.99)	13.48 (1.08)
Gender			
Male	357 (54.9)	258 (54.9)	99 (55.0)
Female	293 (45.1)	212 (45.1)	81 (45.0)
Ethnicity			
Han	617 (94.9)	446 (94.9)	171 (95.0)
Ethnic minority	33 (5.1)	24 (5.1)	9 (5.0)
Lone parent			
No	572 (88.1)	416 (88.7)	156 (86.7)
Yes	77 (11.9)	53 (11.3)	24 (13.3)
Interested in health topics			
Not interested	88 (13.5)	58 (12.3)	30 (16.7)
Not sure	85 (13.1)	56 (11.9)	29 (16.1)
Interested	477 (73.4)	356 (75.7)	121 (67.2)
Self-efficacy	26.85 (6.37)	27.49 (6.30)	25.18 (6.26)
Social support	62.79 (15.26)	64.60 (14.63)	58.05 (15.88)
School environment	30.48 (5.59)	30.92 (5.49)	29.36 (5.71)
Community environment	25.89 (6.09)	26.57 (6.11)	24.12 (5.68)
SD: standard deviation			

Associations between socioeconomic disadvantage, health literacy, and each outcome:

Correlation analysis showed socioeconomic disadvantage, health literacy and each outcome were correlated with each other (Appendix 4 in Supplementary File). Preliminary analyses confirmed the association between socioeconomic disadvantage, health literacy and most outcomes (Table 2). The odds of having poor or fair health status (odds ratio [OR]=1.54; 95% CI=1.08, 2.19), two or more health-compromising behaviours (OR=1.60; 95%CI=1.12, 2.27), no patient-provider communication (OR=1.72; 95%CI=1.20, 2.46) and below average academic achievement (OR=1.80; 95%CI=1.26, 2.57) were elevated 1.5 to 1.8 times among children from socioeconomically disadvantaged families in the unadjusted model, compared with their non-disadvantaged peers. When adjusting for all covariates, we found that the magnitude of effect sizes was smaller but still in the expected direction, except for breakfast eating and alcohol drinking. The odds of experiencing poor health and educational outcomes (except for cigarette smoking and alcohol drinking) were elevated to 1.07 to 1.90 times among children with low health literacy compared with those with high health literacy, after adjusting for socioeconomic disadvantage and all covariates. Children from socioeconomically disadvantaged families had 36% higher odds of having low health literacy compared with their non-disadvantaged peers, after adjusting for all covariates. Despite small effect sizes observed, most of our preliminary results support next-step causal mediation analysis, except for the outcome of breakfast eating, cigarette smoking and alcohol drinking.

Table-2: Regression results showing the associations between socioeconomic disadvantage, overall health literacy, and each outcome.

	Model 1: Unadjusted		Model 2: Adjusted for covariates		Model 3: Adjusted for covariates and socioeconomic disadvantage	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Association with poor or fair health status						
Socioeconomic disadvantage	1.54 (1.08, 2.19)	0.017	1.25 (0.86, 1.83)	0.247	1.23 (0.84, 1.81)	0.281
Low health literacy	2.01 (1.40, 2.88)	<0.001	1.33 (0.89, 1.99)	0.158	1.32 (0.88, 1.97)	0.178
Association with no regular breakfast eating						
Socioeconomic disadvantage	1.09 (0.77, 1.54)	0.619	0.83 (0.57, 1.21)	0.335	0.83 (0.57, 1.20)	0.327
Low health literacy	1.42 (0.99, 2.02)	0.054	1.06 (0.71, 1.57)	0.785	1.07 (0.72, 1.59)	0.745
Association with less frequent teeth brushing						
Socioeconomic disadvantage	2.13 (1.49, 3.05)	<0.001	1.79 (1.21, 2.64)	0.003	1.77 (1.20, 2.61)	0.004
Low health literacy	1.82 (1.27, 2.62)	0.001	1.32 (0.88, 1.98)	0.184	1.28 (0.85, 1.93)	0.241
Association with cigarette smoking						
Socioeconomic disadvantage	1.69 (0.65, 4.44)	0.283	1.28 (0.42, 3.86)	0.661	1.33 (0.44, 4.05)	0.613
Low health literacy	1.11 (0.39, 3.16)	0.844	0.46 (0.13, 1.58)	0.214	0.45 (0.13, 1.55)	0.206
Association with alcohol drinking						
Socioeconomic disadvantage	1.13 (0.71, 1.82)	0.606	0.88 (0.53, 1.47)	0.619	0.89 (0.53, 1.49)	0.662
Low health literacy	1.19 (0.74, 1.93)	0.468	0.79 (0.46, 1.34)	0.377	0.79 (0.46, 1.35)	0.395
Association with physically inactivity						
Socioeconomic disadvantage	1.41 (1.00, 2.00)	0.049	1.28 (0.88, 1.86)	0.204	1.26 (0.86, 1.83)	0.238
Low health literacy	1.82 (1.27, 2.59)	0.001	1.40 (0.94, 2.09)	0.097	1.38 (0.93, 2.06)	0.111
Association with two or more health-compromising behaviours						
Socioeconomic disadvantage	1.60 (1.12, 2.27)	0.009	1.23 (0.84, 1.80)	0.299	1.21 (0.83, 1.78)	0.321
Low health literacy	1.97 (1.37, 2.84)	<0.001	1.22 (0.81, 1.84)	0.342	1.21 (0.80, 1.82)	0.368
Association with no patient-provider communication						
Socioeconomic disadvantage	1.72 (1.20, 2.46)	0.003	1.59 (1.09, 2.33)	0.016	1.54 (1.05, 2.26)	0.026
Low health literacy	2.26 (1.55, 3.29)	<0.001	1.95 (1.29, 2.94)	0.001	1.90 (1.26, 2.87)	0.002
Association with below average academic achievement						
Socioeconomic disadvantage	1.80 (1.26, 2.57)	0.001	1.42 (0.97, 2.09)	0.074	1.39 (0.95, 2.05)	0.093
Low health literacy	1.98 (1.37, 2.85)	<0.001	1.46 (0.97, 2.19)	0.066	1.43 (0.95, 2.15)	0.083
Association with low health literacy						
Socioeconomic disadvantage	1.80 (1.24, 2.62)	0.002	1.36 (0.89, 2.08)	0.149	-	-

CI: Confidence Interval; **OR**: Odds Ratio. Covariates include students' age, gender, ethnicity, family composition, whether had interests in health topics, personal self-efficacy, social support, perceptions of school environment, and perceptions of community environment.

The extent to which improving health literacy reduces socioeconomic inequities in adolescent health and educational outcomes:

Results from the interventional effects approach show that (Table 3) low health literacy explained 11.4%~15.3% of the effect of socioeconomic disadvantage on poor health and developmental outcomes. That means, if we could offer effective interventions to improve the levels of high health literacy among disadvantaged adolescents to be the same as their non-disadvantaged peers, we could potentially reduce 15.3%, 12.0%, 15.2% and 11.4% of socioeconomic differences in poor outcomes for global health status, two or more health-compromising behaviours, patient-provider communication and academic achievement, respectively. The potential reduction appears to be more prominent within the domain of critical health literacy (17.0%) for the outcome of global health status. In terms of two or more health-compromising behaviours, improving interactive health literacy seems to have the largest benefit (13.5%). Intervening on functional health literacy would have the largest effect on patient-provider communication (10.1%) and academic achievement (13.3%).

Our sensitivity analyses showed similar results when using the bottom tertile as cut-offs to define low health literacy (see Appendix 5 for details in Supplementary File). Improving disadvantaged adolescents' health literacy to the level of their non-disadvantaged peers could reduce 17.6%, 14.8%, 15.1% and 16.4% socioeconomic differences in health status, two or more health-compromising behaviours, patient-provider communication, and academic achievement, respectively.

Table-3: Results of evaluation of mediator interventions to reduce socioeconomic disparities using the interventional effects approach.

	Global health status		Teeth brushing		Physical activity		Two or more health-compromising behaviours		Patient-provider communication		Academic achievement	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Overall health literacy												
Total effect	1.27 (0.87, 1.88)	0.218	1.80 (1.18, 2.74)	0.006	1.31 (0.88, 1.94)	0.182	1.24 (0.79, 1.94)	0.343	1.67 (1.21, 2.30)	0.002	1.46 (0.91, 2.33)	0.016
Indirect effect	1.04 (0.97, 1.11)	0.260	1.04 (0.97, 1.11)	0.304	1.04 (0.97, 1.12)	0.267	1.03 (0.96, 1.09)	0.418	1.08 (0.99, 1.18)	0.072	1.04 (0.99, 1.10)	0.085
Direct effect	1.23 (0.84, 1.80)	0.291	1.74 (1.14, 2.64)	0.010	1.26 (0.85, 1.85)	0.245	1.21 (0.77, 1.89)	0.407	1.54 (1.12, 2.12)	0.007	1.40 (0.86, 2.27)	0.176
% mediated	15.3	0.899	6.0	0.688	14.7	0.823	12.0	0.895	15.2	0.067	11.4	0.820
Functional health literacy												
Total effect	1.27 (0.86, 1.86)	0.225	1.78 (1.18, 2.71)	0.006	1.30 (0.87, 1.94)	0.195	1.24 (0.79, 1.94)	0.346	1.65 (1.19, 2.28)	0.003	1.47 (0.92, 2.35)	0.106
Indirect effect	1.02 (0.98, 1.07)	0.350	1.02 (0.97, 1.06)	0.436	1.03 (0.97, 1.09)	0.344	1.03 (0.99, 1.07)	0.189	1.05 (0.98, 1.13)	0.169	1.05 (0.98, 1.13)	0.133
Direct effect	1.24 (0.85, 1.81)	0.269	1.75 (1.15, 2.66)	0.008	1.27 (0.86, 1.87)	0.238	1.21 (0.78, 1.88)	0.401	1.57 (1.14, 2.15)	0.006	1.40 (0.88, 2.23)	0.159
% mediated	9.5	0.886	3.0	0.615	10.6	0.406	12.2	0.399	10.1	0.135	13.3	0.728
Interactive health literacy												
Total effect	1.26 (0.86, 1.83)	0.230	1.78 (1.18, 2.71)	0.007	1.32 (0.89, 1.96)	0.162	1.24 (0.80, 1.92)	0.334	1.64 (1.20, 2.25)	0.002	1.45 (0.90, 2.32)	0.124
Indirect effect	1.02 (0.96, 1.07)	0.547	1.02 (0.97, 1.07)	0.478	1.08 (0.99, 1.17)	0.076	1.03 (0.98, 1.08)	0.220	1.05 (0.99, 1.10)	0.090	1.03 (0.98, 1.09)	0.218
Direct effect	1.24 (0.84, 1.83)	0.280	1.75 (1.15, 2.68)	0.009	1.23 (0.84, 1.80)	0.285	1.20 (0.77, 1.89)	0.420	1.57 (1.13, 2.16)	0.006	1.40 (0.86, 2.27)	0.174
% mediated	7.0	0.917	3.1	0.831	25.9	0.720	13.5	0.779	9.1	0.146	9.1	0.858
Critical health literacy												
Total effect	1.29 (0.88, 1.89)	0.188	1.79 (1.18, 2.70)	0.006	1.29 (0.86, 1.92)	0.217	1.22 (0.78, 1.91)	0.372	1.65 (1.20, 2.27)	0.002	1.44 (0.89, 2.30)	0.135
Indirect effect	1.04 (0.98, 1.11)	0.169	1.01 (0.97, 1.06)	0.564	1.01 (0.94, 1.08)	0.798	1.00 (0.95, 1.06)	0.888	1.04 (0.98, 1.10)	0.196	1.01 (0.96, 1.06)	0.701
Direct effect	1.24 (0.85, 1.80)	0.262	1.76 (1.16, 2.67)	0.008	1.28 (0.86, 1.89)	0.225	1.22 (0.78, 1.90)	0.379	1.58 (1.15, 2.18)	0.005	1.42 (0.88, 2.30)	0.152
% mediated	17.0	0.884	2.5	0.723	3.5	0.938	2.0	0.979	7.8	0.172	2.8	0.969

CI: Confidence Interval; OR: Odds Ratio

Covariates were adjusted, including students' age, gender, ethnicity, family composition, whether had interests in health topics, personal self-efficacy, social support, perceptions of school environment, and perceptions of community environment.

Discussion

Summary of Key Findings:

Confirming previous findings [9,10], we found that socioeconomic disadvantage was associated with a range of poor health and educational outcomes amongst adolescents. Using a novel causal mediation analytic approach, we estimated the potential benefit of hypothetical interventions on adolescent health literacy (overall and by each domain: functional, interactive and critical) to reduce socioeconomic inequities in poor health and educational outcomes. Overall, we found that the potential benefit of intervening on health literacy to reduce socioeconomic inequities varied, depending on the health literacy domain and the outcome measured.

Consistent with our Hypothesis 1, health literacy was found to mediate the relationship between socioeconomic disadvantage and a range of health and educational outcomes in adolescents. Improving health literacy amongst disadvantaged adolescents could reduce 11.4%~15.3% socioeconomic differences in their health and educational outcomes. While previous studies showed the mediating role of health literacy in health outcomes [34,53,54,55,56], they mainly targeted adults and focused on measuring functional health literacy. In a recent study examining the mediation role of adolescent health literacy [21], the authors measured health literacy comprehensively with multiple domains and found that health literacy and other upstream factors (e.g., family affluence, school achievement, gender) together explained 7%~20% of the variance of health behaviours. However, it remains unknown about the indirect effect of adolescent health literacy on health behaviours and its effect on other outcomes such as global health status and health service use. The present study extends the current understanding of the mediating role of adolescent health literacy in the relationship between socioeconomic disadvantage and a range of developmental outcomes. Consistent with previous findings [54,57], we found varying mediating effects of health literacy in the relationship between socioeconomic disadvantage and outcomes, depending on the types of outcome measured. For example, the mediating effect of the overall health literacy was most prominent on global health status, followed by patient-provider communication and two or more health-compromising behaviours. One possible reason for this finding is that overall health literacy was measured as a subjective construct indicating one's self-perceived competence at performing various health-related tasks in everyday life [21)], which was more pertinent to self-rated global health status (a subjective construct as well). These varying benefits of hypothetical interventions on adolescent health literacy to reduce socioeconomic inequities in these outcomes suggest that future school-based intervention programs may consider including health literacy education as a key component to improve adolescents' global health status, patient-provider communication, health behaviours and academic achievement, aligning with the 2030 Agenda for Sustainable Development [30].

We also found varying benefits of improving health literacy in each domain to reduce health and educational inequities, corresponding to our Hypothesis 2. Health literacy is a

multidimensional construct including functional, interactive and critical domains [17]. While previous studies found that overall health literacy mediated the relationship between socioeconomic disadvantage and global health status in adults [54], little is known about the specific role of each domain particularly in adolescents. We found critical health literacy played a more prominent role in determining adolescents' global health status. Compared with functional and interactive health literacy, critical health literacy is more relevant to an individual's ability to exert control over health situations [58]. Adolescents' self-reported health status was more linked with the presence of chronic health conditions [59]. In the present study, our samples consisted of a relatively healthy population from secondary schools and therefore were likely to report higher capability to take control of their health. In a study with 29473 adults in Denmark, Friis et al. [57] investigated whether different domains of health literacy mediated the relationship between educational attainment and health behaviour (smoking, physical inactivity, poor diet) and obesity. They found that functional health literacy contributed to 6.6%~20.1% of the total effect and interactive health literacy contributed to 0.5%~5.4%. In the present study, we observed a greater effect of interactive health literacy (13.5%) than functional health literacy (12.2%) on two or more health-compromising behaviours. The possible explanation for our findings is that, compared with adults, adolescents are more likely to be influenced by dynamic interactions between personal and environmental factors [60]. Particularly, adolescents' perceptions of health information are more likely to be influenced by their peer groups when observing and communicating with peers [61]. In terms of health service use, Jansen et al. [62] investigated 1811 adults with chronic health conditions in the Netherlands and found that functional health literacy explained 19.9%~21.0% of educational differences in out-of-hours primary care service use, whereas interactive health literacy accounted for 14.9% and critical health literacy accounted for 9.8%~11.8%. In our case here, we found that functional health literacy (10.1%) also had the greatest effect than interactive (9.1%) and critical (7.8%) health literacy for adolescents' patient-provider communication. The underlying explanation might be that functional health literacy requires basic skills in reading and understanding health concepts, which are more related to one's advanced skills such as communication. Similarly, we found that functional health literacy appeared to have the largest effect on academic achievement, given this domain focused on more about adolescents' cognitive ability and basic reading and numeracy skills [17].

Findings from the hypothetical interventions on health literacy suggest that the potential benefit to reduce socioeconomic differences in poor health and educational outcomes is modest, ranging from 11.4%~15.3%. Detecting any persisting effect over the life course is nevertheless worthy. In the 'real world,' these small reductions in health and developmental inequities could have larger impacts at the population level that we were unable to simulate [63]. Achieving these simulated improvements in health literacy would also likely have long-term and intergenerational benefits beyond adolescence. Early life disadvantage can impact adolescent health and development through a range of complex pathways, such as via health literacy we examined, as well as other features of children's environments (e.g., home reading, preschool attendance, social support) [49]. Future studies may explore other important mediators of interest and investigate the potential benefit of reducing socioeconomic inequities. However, socioeconomic disadvantage itself remains a major social determinant of health that drives adolescent health inequities.

Limitations:

There are several limitations that should be noted. First, this study used cross-sectional data to examine the causal pathways linking socioeconomic disadvantage to a range of health and educational outcomes via health literacy at a single time point. Cohort studies are suggested in future to confirm the mediation effect of health literacy on these outcomes. Second, while we used a three-stage sample design to obtain students with different socioeconomic conditions, convenience sampling may limit the generalizability of our findings. We recruited students from four secondary schools in a metropolitan city where the ability of subjects to access good education might be much higher than the general school population in China. Future studies are recommended to recruit adolescents from a wider range of socio-demographic backgrounds. Third, socioeconomic position is a broad concept regarding one's social standing or class that includes educational level, income, occupation status and perceived social status. In the present study, we used family affluence level as a simple measure of socioeconomic position. Future studies may consider using other alternative indicators to replicate our results. Fourth, self-report bias may exist for health literacy and outcome measures. We selected these measures based on their validity and reliability in previous empirical research. Finally, the possibility of residual confounding can never be fully eliminated in an observational study. For example, we did not include students' disease characteristics and long-term health conditions, which may result in biases in our analyses. In the causal mediation analysis, we assumed no unmeasured exposure-mediator, exposure-outcome or mediator-outcome confounding, including no mediator-outcome confounding affected by the exposure. All findings should be interpreted considering these assumptions.

Implications and Future Directions:

While we explored the potential benefit of improving health literacy (overall and by each domain) on a range of health and educational outcomes, there remains a lack of specificity to inform precise health literacy policy decisions. The hypothetical intervention of health literacy is not well-defined in the present study. For example, it remains unknown at which time point, at what dosage, and which delivery approach is likely to have the most significant impact on improving health literacy and reducing subsequent health inequities. Future research could consider using both longitudinal and experimental data to examine the specific nature and impact of health literacy interventions (e.g., maternal or child health literacy, eHealth literacy, at school) [64].

Our findings suggest that while health literacy represents a promising intervention opportunity, it can never fully address adolescent health and developmental inequities alone. Future intervention programs may consider focusing on different domains of health literacy when targeting a specific health or learning outcome. For example, all domains of health literacy (functional, interactive, and critical) can be improved through different platforms of health educational such as school health education programs and health clinic education [17,65]. In addition, health literacy interventions should be considered within a broader,

multifaceted and sustained strategy by collaborations between schools, families and communities. There has been increasing evidence that the benefits of stacking multiple complementary interventions may exceed that of single intervention approaches [2]. This includes intervening on socioeconomic disadvantage itself through upstream strategies such as unconditional cash transfers [66], as well as health literacy interventions through downstream strategies such as health education and health systems change. As suggested from a recent systematic review [67], health literacy interventions are more likely to be successful if they are theory-based and use person-cantered operational components such as cultural appropriateness, tailoring, skills building, goal setting and active discussions.

Conclusions

This study found that improving adolescent health literacy might help reduce socioeconomic inequities in a range of health and educational outcomes. The potential benefit of improving health literacy varied by the outcome defined (health status, health behaviours, academic achievement) and by the measurement domain of health literacy (functional, interactive, critical). Interventions aiming to improve health literacy and reduce health and developmental inequities should be considered within a broader, sustained, and multipronged approach, which includes addressing socioeconomic disadvantage itself. Continued efforts are needed to identify the precise intervention policy opportunity to reduce adolescent health and developmental inequities.

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Informed consent:

Informed consent was obtained from each individual participant and parent involved in this study.

Statement of human rights:

This study was conducted in accordance with the 1964 Declaration of Helsinki and its subsequent amendments.

Statement of animal welfare: Not applicable.

Data availability:

The datasets used and/or analyzed in the current study are available from the corresponding author on reasonable request.

Author contributions:

SG and XY oversaw the planning, conduct, and reporting of the work described in this article. SG, XY, and FH wrote the first draft of the manuscript and participated in the interpretation of the data. SG conducted the data analysis. SG, XY, FH, ED, RA, and LN contributed to the planning and reporting of the work described in this article. All authors read and approved the final manuscript.

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