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ORIGINAL RESEARCH ARTICLE

Effectiveness of a Novel School-Based Diabetes Prevention Program: A Post-Implementation Analysis of Arogya World Healthy Schools Program, India, 2015–2022

Nitya Rajeshuni[1], Michael P. Huynh[2], Sonia Mahajan[3], Adrian M. Bacong[1], Aishee Mukherji[1], Nidhi Jaswal[4], Sandhya Ramalingam[4], Nandini Ganesh[5], Smriti Pahwa[5], Nalini Saligram[4] and Latha Palaniappan[1]

Introduction: Non-communicable diseases pose significant health challenges worldwide, particularly in low- and middle-income countries like India, where diabetes mellitus is on an alarming rise, especially among youth. The global health non-profit Arogya World created the Healthy Schools program (HSP), a 2-year, school-based initiative for Grades 6–8 targeting diabetes prevention through peer-led health literacy and lifestyle modification. The program was implemented across 18 states and over 7,500 schools, reaching nearly 450,000 students across rural and urban India.

Methods: This study evaluated the intervention's effectiveness in enhancing diabetes-related knowledge, attitudes, and practices among students participating in Arogya World's HSP across 18 states and over 7,500 schools. Previous sampling of 6,616 students aged 11–15 years using Knowledge, Attitude, and Practice questionnaires provided pre- and post-2-year data for each year of the intervention. The present study expanded on the prior study with a post-implementation, quasi-experimental analysis of the data that had been collected during 2015–2022. Changes in knowledge, dietary patterns, and physical activity levels were evaluated using descriptive statistics and mixed-effects regression.

Results: Overall knowledge scores improved by 15.9% with gains in nutrition (14.6%), physical activity (13.1%), and diabetes awareness (24.5%) [$P < 0.01$]. With respect to behavior change, healthy food consumption improved by 7.4% and physical activity increased by 10.1% ($P < 0.01$).

Conclusion: Analysis of program data during 2015–2022 indicated that the implementation of a low-cost, scalable health education program using a school-based, peer-led model for diabetes prevention affected knowledge and behavior change among a group of adolescent students participating in the HSP. Study limitations included the absence of a control group. These results could inform similar school-based programs in their efforts to curb the diabetes crisis among youth worldwide.

Key Words: Diabetes ▪ adolescent health ▪ non-communicable disease ▪ nutrition ▪ physical activity ▪ knowledge ▪ attitude ▪ practice ▪ prevention ▪ school-based intervention ▪ peer-led health activism ▪ digital health

Non-communicable diseases (NCDs) are among the leading causes of morbidity and mortality worldwide,[1,2] with disproportionately worse outcomes occurring among populations living in low- and middle-income countries (LMICs).[3] Diabetes mellitus, in particular, is a growing international health crisis, with approximately 589 million adults aged 20–79 years living with diabetes around the world as of 2024, three-quarters of whom are in LMICs.[4] Over 136 million people in India live with prediabetes, and the current population of those with diabetes is expected to grow from the current estimates of 100 million to 124 million by 2045.[5] The onset of

Correspondence to: Nitya Rajeshuni, MD, MS, 3180 Porter Drive, Palo Alto, CA 94304, USA. Email: nityar@stanford.edu

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POPULAR SCIENTIFIC SUMMARY

- Non-communicable diseases like diabetes are among the leading causes of chronic disease and death worldwide. In India alone, the number of individuals with type 2 diabetes mellitus (T2DM) is expected to grow by 80% by 2045. T2DM among children and adolescents in India has doubled within the last 20 years, hastening the need for preventive health education programs starting at an early age. Global health non-profit Arogya World has created one such program–Healthy Schools. This two-year school-based initiative for Grades 6–8 is focused on diabetes prevention through peer-led health literacy and lifestyle modification. Since 2011, the program has been implemented across 18 states, reaching nearly 450,000 students across rural and urban India.
- This study used program data from 2015–2022 to assess the program's effect on students' knowledge levels and behavior change related to diabetes. Overall gains were seen in improved knowledge on diabetes, nutrition, and physical activity among 6,616 student participants. Peer-led instruction also seemed to help students choose and eat healthier meals and become more active. These findings could help other schools start similar programs to take on the challenge of TDM2 affecting youth worldwide.

diabetes-related complications often occurs early in the course of the disease, requiring lifelong treatment which poses a significant economic burden to both patients and the health system.[6,7]

While type 2 diabetes mellitus (T2DM) is traditionally considered a disease of adulthood, global prevalence among children and adolescents is on the rise.[6] One-fifth of India's population are adolescents, and childhood diabetes rates have doubled in the last 20 years.[8,9] These trends are linked to worsening malnutrition and declining physical activity in this age group – key risk factors that warrant intervention to prevent and manage diabetes. Establishing healthy habits early in life is critical to improving health outcomes in adulthood and thereby combating the diabetes crisis. Adolescents are an effective target group for preventive public health and policy interventions due to their high adaptability and motivation.[10–12] Many NCD risk factors also take root in adolescence. [3,13,14]

As outlined in India's National NCD Monitoring Framework, requisite aspects of school-based programs include good dietary and exercise practices that are integrated into students' daily routines.[15] School-based interventions can reach young people across various socioeconomic strata in rural and urban geographies,[11,16–18] particularly those that use student leadership to address both health literacy (knowledge) and lifestyle modification (practice). While peer-led models in which students function as teachers are not yet well-documented, studies to date show promising outcomes.[12,19–22]

INTERVENTION DESIGN AND IMPLEMENTATION

Arogya World, a non-profit based in the United States and India that partners with other non-governmental organizations (NGO) across India, developed the Healthy Schools program (HSP), a 2-year, school-based, peer-led intervention targeting diabetes prevention. Arogya World works to prevent NCDs in India through health education, adopting a doorstep health model by implementing programs in the communities in which participants live, learn, and work. The initial design of HSP was piloted in 2011 in partnership with the organization Health-Related Information Dissemination Amongst Youth (HRIDAY), an NGO affiliated with the Public Health Foundation of India. Frontline workers, volunteers, teachers, and student leaders are trained to deliver education on diabetes prevention through interactive and age-appropriate curricula (e.g. games and interactive workshops). The HSP targets middle-school students aged 11–15 years in Grades 6–8 in both government and private schools. Notably, HSP aligns with the Government of India's Ayushman Bharat National School Health Curriculum.

Arogya World also partnered with five NGOs to rollout HSP across North, South, East, West, and Central India. These program partners selected candidate schools in their assigned geographies. While both government and private schools were considered, implementation focused on government, semi-government, and aided schools, which are often under-resourced compared with private schools. Implementation partners coordinated with local district education officers to select a representative sample of schools within geographic blocks and districts. Average sociodemographic and socioeconomic characteristics of local communities were considered during the selection process. Schools from areas with climatic or political challenges were not selected to ensure uninterrupted implementation and data collection. Approval by school authorities was required prior to implementation.

Students completed 10 activities over the course of the HSP's 2-year program, five completed each year. During the first year (Year One) of the program, material on diabetes knowledge, awareness, and behavior change is covered, with an emphasis on modifiable risk factors like nutrition and physical activity. These 40-min sessions fit within each school's regular curricula. During the second year (Year Two), students design and implement community outreach projects, reinforcing Year One material and honing leadership and advocacy skills. Arogya World modeled its curriculum on Mobilizing Youth for Tobacco-Related Initiatives in India (MYTRI), a 2-year,

school-based tobacco control initiative conducted in the cities of New Delhi and Chennai.[12]

All interventions were conducted in person in schools or community settings such as health centers until 2021, when Arogya World incorporated digital versions due to the COVID-19 pandemic. The fully digital curricula included 10 videos that students could view on their parents' smartphones, as most students did not have their own. However, smartphone access varied significantly across families and geographies, with additional challenges like poor internet connectivity, limited data, and recharge costs. Some schools implemented hybrid curricula, in which teachers played curricular videos in class and students completed worksheet-guided activities afterward.

A previous study of the program's initial implementation in six schools in New Delhi, India, with data from 2011 to 2013 showed significant improvement in knowledge and behavior change,[17] indicating that such school-based interventions could help curb the global diabetes crisis. Sustaining and mainstreaming such efforts, however, would require evidence of their effectiveness through program evaluation – information that would be crucial in helping to secure funding and resources to scale. This study is one such analysis of the HSP, a school-based, peer-led intervention targeting diabetes prevention developed by Arogya World. This analysis expands on the previous analysis (2011–2013) with a pretest-posttest, quasi-experimental design that evaluated 7 years of program data (2015–2022) from more than 7,500 schools across 18 states in India.

METHODS

Data collection – knowledge, attitude, and practice assessment

A sample of students from each school (3–5% per school; total $N = 6{,}616$) was selected using convenience sampling to complete a self-reported Knowledge, Attitude, and Practice (KAP) survey pre- and post- each year of intervention. Response rates ranged from 80 to 85%. Surveys with incomplete data (20.8%) were excluded; only one 2-year campaign was not completed due to limited resources and constraints during the COVID-19 pandemic. Among the four campaigns that started in 2021 and 2022, only Year One data were available at the time of the present analysis. Students who completed the full program had two sets of pre- and post-data, while those who completed only Year One had one set. The KAP questionnaire was divided into three sections: (1) 'What do you know?' (knowledge); (2) 'What do you do?' (nutrition and physical activity practices); (3) 'What do you prefer?' (attitudes). Similar questionnaires were used pre- and post-intervention. Trained project staff administered surveys via standardized protocols in local languages. Surveys were administered on paper and online. Data from paper surveys were entered into a digital database. No incentives were provided for survey completion. Responses were confidential, and students were assigned unique, anonymous identification numbers. All work was conducted in adherence to the ethical standards regarding human subjects research, as outlined in the Declaration of Helsinki.

Study design

This study was a retrospective post-implementation pretest-posttest, quasi-experimental analysis of data retrieved during 2015–2022 from 450,000 students, which included survey results from 5 partners, 18 states, over 100 districts, and more than 7,500 schools across India. No institutional review board (IRB) or informed consent was required, as all data were deidentified.

Study population

This analysis examined data retrieved from student surveys conducted during 2015–2022. Each program partner selected schools representing various socioeconomic and geographical strata; all students in Grades 6–8 were enrolled. A subset was surveyed pre- and post- each year of the intervention. Students with incomplete pretest and posttest data were excluded from the study cohort. Subjects with reported ages less than 11 years ($n = 657$, 8.5%) were excluded and subjects with pre- and post-intervention age differences less than zero or greater than one year ($n = 450$, 5.8%) were dropped, since interventions were divided into 1-year installments. The final analytic sample included a total of 6,616 individuals.

Covariates

Subject demographics included age pre- and post- each year of intervention. Survey data on sex, socioeconomic status, and geographic region were not collected consistently and therefore were not included in this analysis. Intervention modality was defined as in-person or hybrid if some students in the intervention cycle participated in a digital version of HSP. Student-level data on curricular versions (digital versus hybrid versus in-person) were not collected. Implementing program partners were anonymized to preclude bias during interpretation of results. Baseline age, modality, and partner were all included as covariates in regression analyses. Less than 10% of data were missing for each variable. For descriptive statistics, a complete case analysis was performed.

Outcome measures

The original KAP questionnaire included 33 questions, which were consolidated into six domains (Supplemental Table 2). Individual outcomes were condensed into composite scores for knowledge and behavior change. Sub-scores were generated for overall knowledge and knowledge about nutrition, physical activity, and diabetes, respectively. Knowledge was measured using true or false questions with three possible choices: 'Yes', 'No', or 'Don't Know'; 'Don't Know' responses were counted as incorrect. Both overall scores and sub-scores were calculated as the percentage of correct answers.

Behavior change was evaluated by asking students to report how often (e.g. daily, alternate days, once or twice a month, or never) they engaged in healthy nutrition and physical activity practices. Healthy nutrition choices included consumption of breakfast and items like whole fruits, vegetables, and milk products. Unhealthy foods included items like carbonated drinks, fried snacks, and sweets. For healthy foods, 'daily' and 'alternate days' were counted as healthier or correct answers ('eating healthier foods more often'), while 'once or twice a month' and 'never' were counted as correct answers for unhealthy foods ('eating unhealthier foods less often'). Food consumption scores for healthy food, unhealthy food, and overall dietary appropriateness were calculated as the percentage of questions answered correctly. Physical activity data included only one survey question and therefore did not require sub-scoring. Students were asked how they spent games period in school. The choices 'play games in the playground' and 'play a little bit/walk with friends' indicated physical activity, while the choices 'sit and talk with friends' and 'finish my homework/read' indicated no physical activity.

Statistical analysis

Frequency counts and means with standard deviation and range were generated for baseline characteristics. Pre-post differences in knowledge and food consumption scores were evaluated as continuous outcome variables using paired *t*-tests. Pre-post differences in physical activity were evaluated as binary outcomes using McNemar's chi-square tests. Differences across program partners were examined using one-way ANOVA (analysis of variance) and chi-square tests. Mixed-effects linear regression was used to determine the impact of intervention years on knowledge and appropriate food consumption, while mixed-effects logistic regression was used for physical activity. These regression models also accounted for differences in age, partner, and intervention modality. Significance was assessed at an alpha level of 0.05. All analyses were completed using Stata statistical software (StataCorp version 16.1).

RESULTS

Study population characteristics

The Arogya World HSP is a 2-year, school-based, peer-led intervention targeting diabetes prevention (Table 1). This analysis examined data retrieved during 2015–2022 from a total of 6,616 students across India. Students were aged 11–5 years at the start of the intervention. Mean age was 11.88 years at baseline. The number of students in each school site ranged from 597 to 1,981; the in-person intervention had 3,463 student participants, and the hybrid intervention had 3,153 student participants (Supplemental Table 1).

Knowledge

Among all students (N = 6,616), 58.5% correctly answered knowledge questions on nutrition, physical activity, and diabetes at pre-intervention (Table 2). Post-intervention, students correctly answered 74.4%, yielding a 15.9% increase ($p < 0.01$). By sub-category, pre-post increases in knowledge on nutrition (14.6%, $p < 0.01$), physical activity (13.1%, $p < 0.01$), and diabetes (24.5%, $p < 0.01$) were observed. Across partners, pre-post differences ranged from 1.0 to 34.6% (Figure 1A). Regarding intervention modality, pre-post differences for overall knowledge were 24.4% ($p < 0.01$) for hybrid cycles versus 8.2% ($p < 0.01$) for fully in-person cycles (Table 2; Figure 2A). Non-composite individual outcomes were also assessed (Supplemental Table 2).

Behavior change: Food consumption and physical activity

Pre-intervention, students reported 64.2% appropriate food consumption, which included eating healthier foods more often and unhealthier foods less often. Post-intervention, students reported 71.6% appropriate food consumption, indicating a 7.4% increase pre- to post-intervention ($p < 0.01$). On average, there was a 10.9% pre-post increase in eating healthier foods more often ($p < 0.01$) and 4.1% pre-post improvement in eating unhealthier foods less often ($p < 0.01$) (Table 3). Across partners, pre-post differences in appropriate food consumption ranged from -1.6 to 11.8% (Figure 1B). Regarding intervention modality, the pre-post difference for appropriate food consumption was 11.0% ($p < 0.01$) for hybrid cycles and 4.2% ($p < 0.01$) for in-person cycles (Table 3; Figure 2B).

As for changes in physical activity, 48.6% indicated some level of physical activity at baseline. Post-intervention, 58.7% indicated that they engaged in physical activity, yielding a 10.1% increase pre- to post-intervention ($p < 0.01$) (Table 3). Across partners, pre-post differences

Table 1. Outline of Arogya Healthy Schools Program

Step	Module	Objectives	Activities/Tasks
0	Pre-intervention evaluation		Knowledge, Attitude, and Practice survey pre intervention
1	Way to Health (general health)	(1) Recognize healthy lifestyle practices and how they prevent NCDs	(1) Small-group, peer-led discussion on how healthy and unhealthy lifestyle habits can prevent disease
		(2) Initiate healthy practices in student's lives and classrooms	(2) 'Identify the Actions' worksheet in which students identify healthy habits (e.g. playing in playground) and unhealthy habits (e.g. sitting and eating chips) in a colored cartoon illustration of students at school during lunchtime
			(3) Reflect on three healthy and unhealthy habits in students' lives
2	Climb the Health Ladder (diabetes)	(1) Learn about types of diabetes, their risk factors, symptoms, and long-term consequences	(1) Teacher-led classroom discussion on risk factors, consequences, prevention, and management of T2DM
		(2) Learn how to prevent and manage diabetes	(2) Snakes & Ladders, where 'snakes' (penalties) are risk factors of T2DM (e.g. junk food, obesity) and 'ladders' (rewards) are healthy lifestyle habits (e.g. avoiding sweets or fats, exercising)
			(3) Discuss prevention of T2DM through healthy living
3	Pass it On: The Traffic Signal (healthy nutrition)	(1) Understand importance of a balanced diet and breakfast	(1) Teacher-led discussion of healthy/unhealthy foods
		(2) Investigate the food pyramid, and learn the recommended portions of each food group	(2) Study food pyramid and different color-coded food groups: red zone (foods high in fat and refined carbohydrates/sugars), yellow zone (foods to eat in moderation), and green zone (healthy, low-fat foods rich in fiber)
		(3) Learn to prepare healthier meals at home	(3) Three food group-colored cards (red, green, yellow) passed around a circle until teacher says 'stop'. Students holding cards must quickly identify the food group color and food examples
			(4) Create and rate the healthiness of their own recipes
4	Jump Forward and Race with Pace (physical activity)	(1) Learn how physical activity and maintaining a healthy weight helps prevent T2DM	(1) Discuss the benefits of physical activity, do activities that are considered physical activity, and allow students to brainstorm ways to increase their frequency of physical activity and outdoor playtime
		(2) Incorporate more physical activity into their daily routine	(2) Learn about the body mass index and the negative health consequences of obesity
			(3) Students compete in outdoor sack race both with and without their backpacks to feel the importance of maintaining a healthy body weight through physical activity
5	Doctor says, 'Be Fit, Eat Right' (healthy behaviors in real life)	(1) Apply intervention knowledge to a case study	(1) Read case study about a student who experiences challenges with tiredness and appetite
		(2) Demonstrate understanding about how even small lifestyle modifications help prevent diabetes	(2) Categorize students' lifestyle practices as ones that should be (a) avoided (e.g. hating physical activity, eating junk food), (b) practiced less (e.g. driving to school instead of walking, long hours of video games, eating ice cream daily), or (c) practiced regularly (e.g. daily breakfast, early bedtime, walking, limited TV use, and eating homemade tiffin lunch)
			(3) Suggest lifestyle modifications students should implement
6	Post-intervention evaluation		(1) Knowledge, Attitude, and Practice survey following school Year One of intervention

Abbreviations: NCD, non-communicable disease; T2DM, type 2 diabetes mellitus.

in physical activity ranged between -0.7 and 15.3% (Figure 1C). On average, the pre-post difference for physical activity was 19.2% ($p < 0.01$) for hybrid cycles, while there was no significant pre-post difference for in-person cycles (Table 3; Figure 2C). Non-composite individual outcomes are reported in Supplemental Table 2.

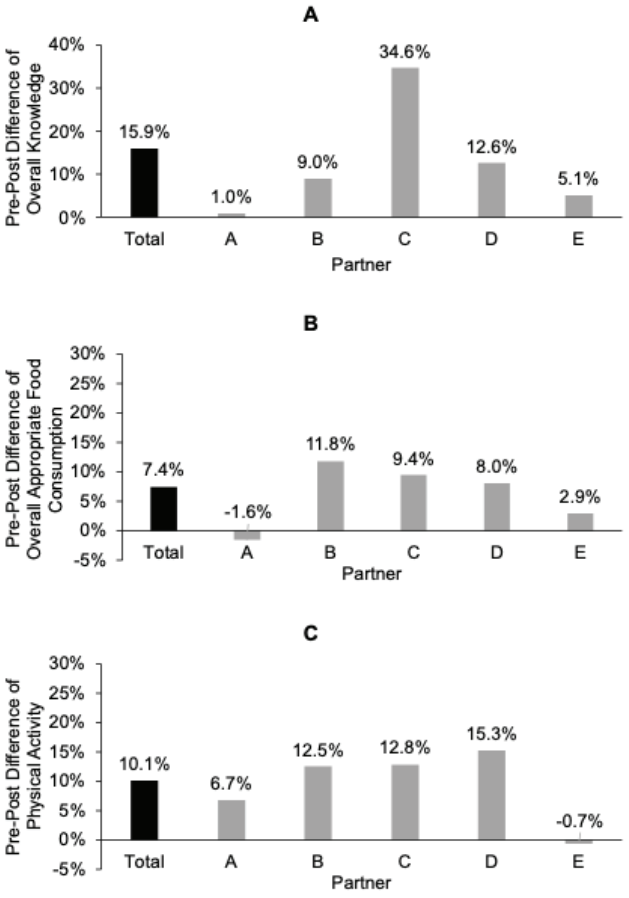
Trends over time

Most in-person cycles from all school partners except for one were structured as 2-year interventions during 2015–2022. The percentage of students with correct knowledge on nutrition, physical activity, and diabetes ranged from 50.4 to 88.5% at baseline for the in-person cycles. Post-Year One, the percentage ranged from 63.9 to 88.5% (Figure 3A). Post-Year Two, the percentage ranged from 60.6 to 88.6%. The percentage of students' appropriate food consumption ranged from 58.7 to 69.2% at baseline for the in-person interventions. Post-Year One, the percentage for appropriate food consumption ranged from 58.6 to 76.8% (Figure 3B). Post-Year Two, the percentage ranged from 58.8 to 74.1%. The percentage of students' physical activity during games period ranged from 1.8 to 77.2%. Post-Year Two, the percentage for physical activity

Table 2. **Pre- and post-intervention differences in knowledge: Arogya Healthy Schools, 2015–2022**

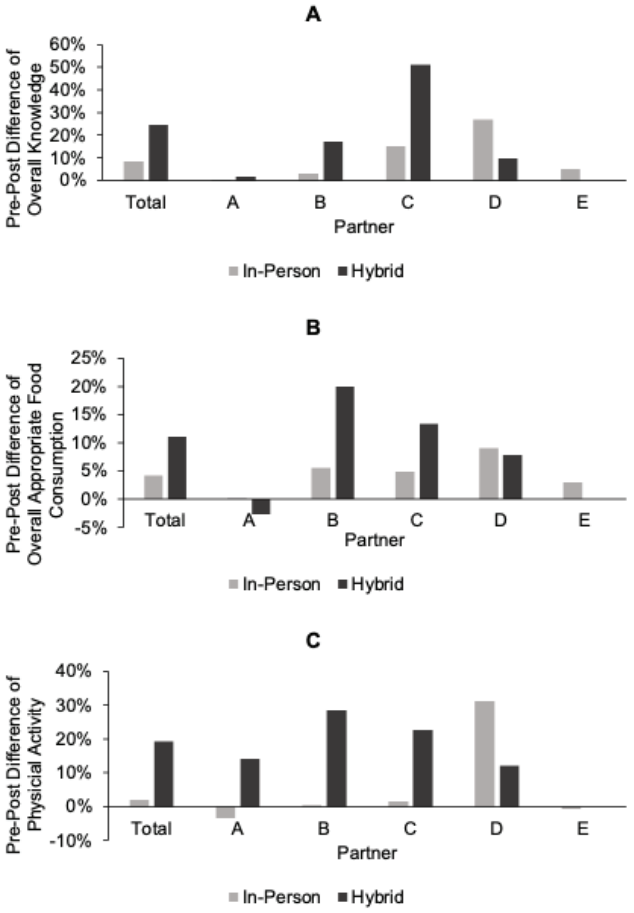
Knowledge	Total					Hybrid					In-person				
	N	Pre (%)	Post (%)	Difference	*p*-value	N	Pre (%)	Post (%)	Difference	*p*-value	N	Pre (%)	Post (%)	Difference	*p*-value
Total	**6,616**					**3,153**					**3,463**				
Nutrition		75.0	89.6	14.6	<0.01		62.7	87.2	24.5	<0.01		86.2	91.7	5.5	<0.01
Physical activity		56.2	69.3	13.1	<0.01		51.5	73.0	21.5	<0.01		60.5	65.9	5.4	<0.01
Diabetes		44.8	69.3	24.5	<0.01		42.6	73.0	30.4	<0.01		46.7	65.9	19.2	<0.01
Overall		58.5	74.4	15.9	<0.01		54.9	79.3	24.4	<0.01		61.8	70.0	8.2	<0.01
A	597					346					251				
Nutrition		93.8	91.7	-2.1	0.02		89.3	85.7	-3.6	0.02		100.0	100.0	0.0	
Physical activity		68.2	71.7	3.5	<0.01		48.4	54.5	6.1	<0.01		95.5	95.4	-0.1	0.32
Diabetes		66.8	71.7	4.9	<0.01		61.7	54.5	-7.2	<0.01		74.0	95.4	21.4	<0.01
Overall		79.0	80.0	1.0	0.25		72.1	73.8	1.7	0.26		88.5	88.6	0.1	0.57
B	1,476					641					835				
Nutrition		80.6	92.5	11.9	<0.01		71.8	88.0	16.2	<0.01		87.4	95.9	8.5	<0.01
Physical activity		54.7	61.0	6.3	<0.01		61.8	78.0	16.2	<0.01		49.3	47.9	-1.4	0.15
Diabetes		51.0	61.0	10.0	<0.01		56.5	78.0	21.5	<0.01		46.7	47.9	1.2	0.48
Overall		61.2	70.2	9.0	<0.01		65.5	82.7	17.2	<0.01		57.8	60.6	2.8	<0.01
C	1,981					1,070					911				
Nutrition		59.6	89.9	30.3	<0.01		38.9	87.4	48.5	<0.01		84.0	92.7	8.7	<0.01
Physical activity		40.4	71.8	31.4	<0.01		32.1	81.7	49.6	<0.01		50.1	60.1	10.0	<0.01
Diabetes		21.7	71.8	50.1	<0.01		16.0	81.7	65.7	<0.01		28.4	60.1	31.7	<0.01
Overall		40.2	74.8	34.6	<0.01		31.5	82.6	51.1	<0.01		50.4	65.5	15.1	<0.01
D	1,318					1,096					222				
Nutrition		72.0	87.4	15.4	<0.01		72.2	87.0	14.8	<0.01		70.9	89.6	18.7	<0.01
Physical activity		64.1	69.9	5.8	<0.01		65.3	67.5	2.2	0.07		58.3	81.5	23.2	<0.01
Diabetes		53.2	69.9	16.7	<0.01		54.3	67.5	13.2	<0.01		47.3	81.5	34.2	<0.01
Overall		64.5	77.1	12.6	<0.01		66.0	75.7	9.7	<0.01		57.3	84.2	26.9	<0.01
E	1,244										1,244				
Nutrition		87.0	86.9	-0.1	0.97							87.0	86.9	-0.1	0.97
Physical activity		69.0	73.4	4.4	<0.01							69.0	73.4	4.4	<0.01
Diabetes		54.6	73.4	18.8	<0.01							54.6	73.4	18.8	<0.01
Overall		68.1	73.2	5.1	<0.01							68.1	73.2	5.1	<0.01

Figure 1. Pre-post differences in knowledge and behavior change by implementing partner in Arogya Healthy Schools Program, 2015–2022.[a]



[a]Panel A plots the pre-post differences for overall knowledge. Panel B plots pre-post differences for overall appropriate food consumption. Panel C plots pre-post differences for physical activity.

Figure 2. Pre-post differences in knowledge and behavior change by implementing partner and intervention cycle modality in Arogya Healthy Schools Program, 2015–2022.[a]



[a]Panel A plots pre-post differences for overall knowledge. Panel B plots pre-post differences for overall appropriate food consumption. Panel C plots pre-post differences for physical activity.

ranged from 1.8 to 76.4%. Post-Year Two, the percentage ranged from 2.0 to 76.1% (Figure 3C). Overall, both Year One and Year Two showed important gains in knowledge and healthy food consumption, with particularly notable trends in Year One.

Mixed-effects regression analyses

Mixed-effects linear regression models for knowledge and appropriate food consumption and a mixed-effects logistic regression model for physical activity were conducted to determine the association between intervention years over time and the outcomes of interest. After accounting for differences in age, partner, and intervention modality, time spent in HSP was significantly associated with increases in correctly answering knowledge questions, appropriate food consumption, and physical activity ($p < 0.01$). Age at the start of intervention was significantly associated with increases in knowledge and appropriate food consumption ($p < 0.01$). All implementing partners showed independent increases in all outcomes except for Partner B for physical activity. Hybrid intervention cycles were independently associated with increases in knowledge and physical activity ($p < 0.01$) (Table 4).

Socioeconomic associations

Each implementing partner covered diverse geographies with varying poverty levels.[23] Regions covered by Partner C had the highest poverty rates across regions, ranging from 25 to 35% followed by Partner B (15–20%); rates for Partner A (1–35%) and Partner D (1–25%) spanned broader ranges. Partner E's region had the lowest poverty rate (<10% population). Implementing partners covering regions with higher poverty levels generally observed greater improvement pre-post intervention. Pre-post differences were greatest for Partner C, followed by

Table 3. **Pre- and post-intervention differences in behavior change (food consumption, physical activity): Arogya Healthy Schools Program, 2015–2022**

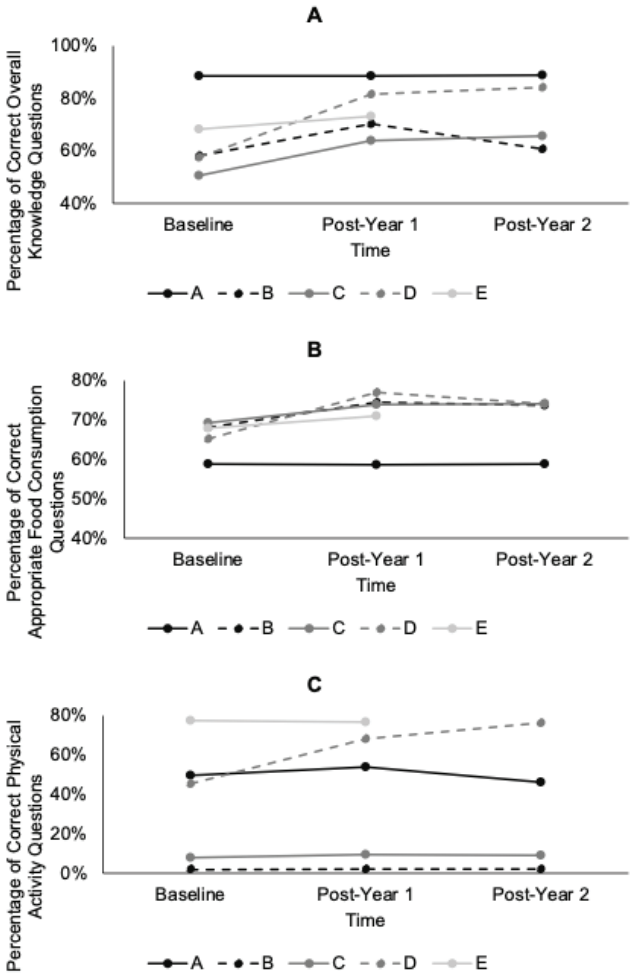
Activities/tasks	Total					Hybrid					In-Person				
In-person	N	Pre (%)	Post (%)	Difference	*p*-value	N	Pre (%)	Post (%)	Difference	*p*-value	N	Pre (%)	Post (%)	Difference	*p*-value
Total	**6,616**					**3,153**					**3,463**				
Eating healthier foods more often		69.2	80.1	10.9	<0.01		52.4	71.7	19.3	<0.01		84.4	87.8	3.4	<0.01
Eating unhealthier foods less often		56.2	60.3	4.1	<0.01		68.8	71.4	2.6	<0.01		44.8	50.2	5.4	<0.01
Overall appropriate food consumption		64.2	71.6	7.4	<0.01		60.6	71.6	11.0	<0.01		67.5	71.7	4.2	<0.01
Physical activity during games period		48.6	58.7	10.1	<0.01		61.8	80.9	19.2	<0.01		36.6	38.5	1.9	0.11
A	597					346					251				
Eating healthier foods more often		86.4	84.4	-2.0	0.09		77.3	74.4	-2.9	0.14		98.9	98.2	-0.7	0.05
Eating unhealthier foods less often		51.9	50.8	-1.1	0.36		85.8	83.1	-2.7	0.19		5.2	6.2	1.0	0.10
Overall appropriate food consumption		72.0	70.4	-1.6	0.08		81.5	78.8	-2.7	0.08		58.7	58.8	0.1	0.85
Physical activity during games period		62.3	69.0	6.7	0.02		71.7	85.8	14.2	<0.01		49.4	45.8	-3.6	0.42
B	1,476					641					835				
Eating healthier foods more often		67.0	77.7	10.7	<0.01		49.5	71.7	22.2	<0.01		80.4	82.2	1.8	0.04
Eating unhealthier foods less often		59.5	73.1	13.6	<0.01		69.7	87.4	17.7	<0.01		51.6	62.0	10.4	<0.01
Overall appropriate food consumption		64.4	76.2	11.8	<0.01		59.6	79.6	20.0	<0.01		68.1	73.6	5.5	<0.01
Physical activity during games period		27.1	39.6	12.5	<0.01		60.1	88.5	28.4	<0.01		1.8	2.0	0.2	0.72
C	1,981					1,070					911				
Eating healthier foods more often		57.6	79.6	22.0	<0.01		39.7	75.0	35.3	<0.01		78.6	85.1	6.5	<0.01
Eating unhealthier foods less often		60.7	57.2	-3.5	<0.01		64.0	55.4	-8.6	<0.01		56.8	59.4	2.6	0.02
Overall appropriate food consumption		59.9	69.3	9.4	<0.01		51.9	65.2	13.3	<0.01		69.2	74.1	4.9	<0.01
Physical activity during games period		34.4	47.2	12.8	<0.01		57.2	79.7	22.5	<0.01		7.6	9.0	1.4	0.27
D	1,318					1,096					222				
Eating healthier foods more often		63.5	72.4	8.9	<0.01		58.7	67.7	9.0	<0.01		87.4	95.5	8.1	<0.01
Eating unhealthier foods less often		62.1	69.2	7.1	<0.01		67.5	74.0	6.5	<0.01		35.3	45.5	10.2	<0.01
Overall appropriate food consumption		63.4	71.4	8.0	<0.01		63.1	70.9	7.8	<0.01		65.1	74.1	9.0	<0.01
Physical activity during games period		60.9	76.2	15.3	<0.01		64.1	76.2	12.0	<0.01		45.0	76.1	31.1	<0.01
E	1,244										1,244				
Eating healthier foods more often		87.9	90.1	2.2	<0.01							87.9	90.1	2.2	<0.01
Eating unhealthier foods less often		41.2	45.2	4.0	<0.01							41.2	45.2	4.0	<0.01
Overall appropriate food consumption		67.9	70.8	2.9	<0.01							67.9	70.8	2.9	<0.01
Physical activity during games period		77.2	76.4	-0.7	0.67							77.2	76.4	-0.7	0.67

Table 4. Mixed-effects regression for knowledge and behavior change in Arogya Healthy Schools, 2015–2021.[a]

	Overall knowledge				Overall appropriate food consumption				Physical activity			
	Coefficient	*p*-value	95% CI		Coefficient	*p*-value	95% CI		Coefficient	*p*-value	95% CI	
Time	0.092	<0.01	0.087	0.098	0.039	<0.01	0.035	0.044	0.560	<0.01	0.477	0.644
Age	0.015	<0.01	0.011	0.019	0.018	<0.01	0.014	0.022	-0.093	<0.01	-0.161	-0.025
Partner												
A	0.228	<0.01	0.215	0.241	0.071	<0.01	0.058	0.084	1.890	<0.01	1.667	2.113
B	0.080	<0.01	0.071	0.089	0.052	<0.01	0.043	0.062	-0.318	<0.01	-0.483	-0.152
D	0.131	<0.01	0.120	0.141	0.045	<0.01	0.034	0.055	1.072	<0.01	0.907	1.237
E	0.176	<0.01	0.164	0.187	0.049	<0.01	0.038	0.061	4.500	<0.01	4.252	4.749
Intervention modality												
Hybrid	0.042	<0.01	0.033	0.050	-0.037	<0.01	-0.045	-0.029	3.724	<0.01	3.537	3.911

[a]Mixed-effects linear regression was conducted for overall knowledge and overall appropriate food consumption. Mixed-effects logistic regression was conducted for physical activity.

Figure 3. Trends in knowledge and behavior change scores from in-person intervention cycles by implementing partner in Arogya Healthy Schools Program, 2015–2022.[a]



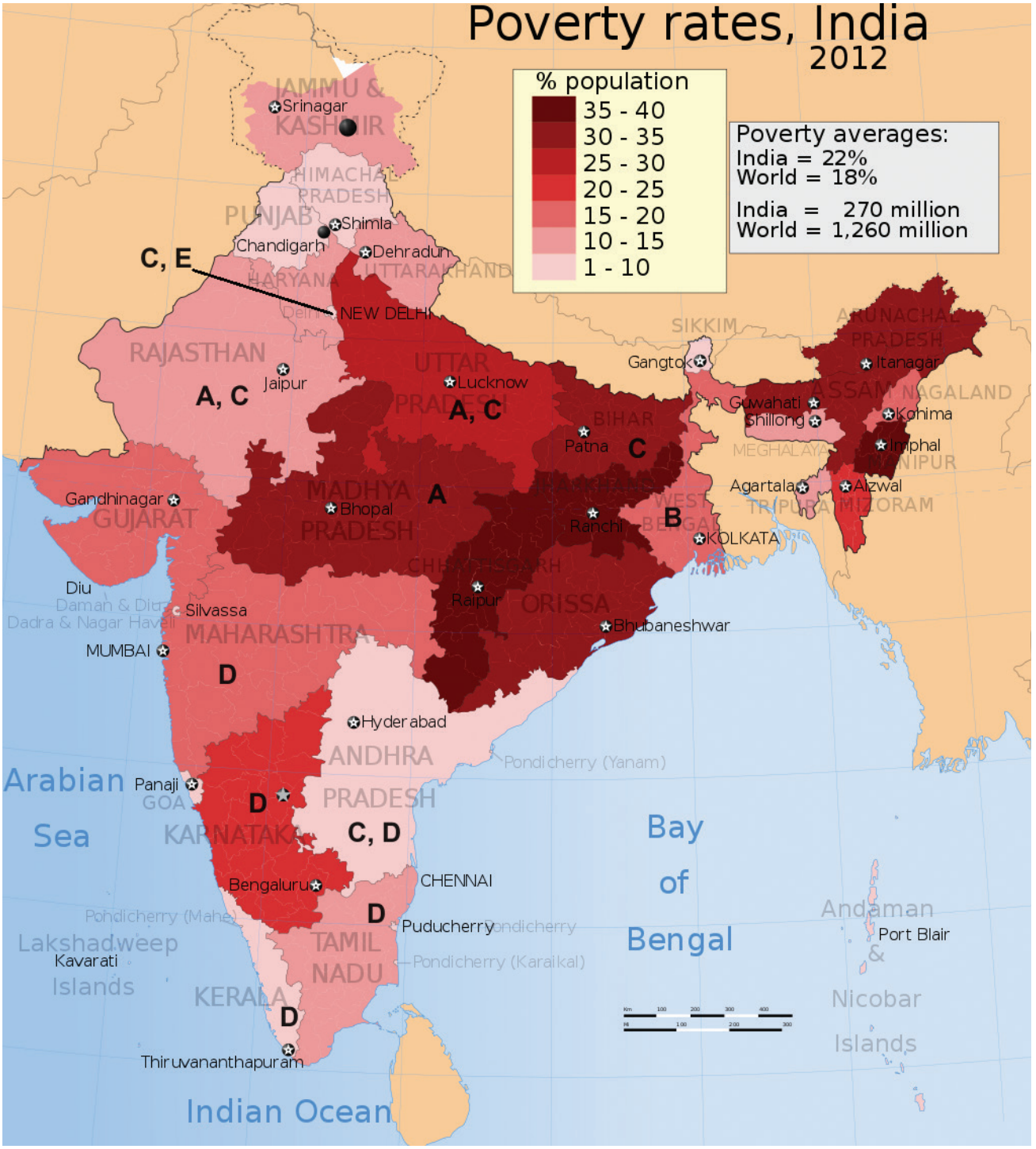
[a]Panel A plots the percentage of correct overall knowledge questions. Panel B plots the percentage of correct overall appropriate food consumption questions. Panel C plots the percentage of correct physical activity questions.

Partners D and B. Partner E, whose region had the lowest poverty rates, saw lower gains (Figures 3b, 4).

DISCUSSION

This post-implementation analysis of Arogya HSP during 2015–2022 indicated the potential for school-based interventions in improving knowledge about diabetes and its risk factors as well as the ability for such programs to affect behavior change among school-aged children across government and private schools in India. Knowledge about nutrition, physical activity, and diabetes increased pre/post-intervention, as did healthy food consumption and physical activity. Improvement in outcomes was particularly noteworthy within the first year of intervention. While the magnitude of improvement varied by partner and intervention cycle

Figure 4. Geographic reach of Arogya World Healthy Schools Program by implementing partner and corresponding poverty levels.[a]



[a]Reserve Bank of India using mixed reference period consumption data. Data Source: Table 162, Number and percentage of population below poverty line, Reserve Bank of India (2013). https://www.rbi.org.in/scripts/PublicationsView.aspx?id=15283

modality (in-person versus hybrid), the intervention proved to be effective across all environments. Implementing partners covering regions with greater poverty saw larger improvements in health knowledge and behaviors.

Students who participated in HSP showed improvement across all knowledge and behavior change domains. Overall knowledge scores improved in the total cohort by 15.9%, with comparable gains in nutrition (14.6%), physical activity (13.1%), and diabetes awareness

(24.5%). Baseline scores for diabetes-specific knowledge were often lower than those for nutrition and physical activity, but HSP was able to close this gap, leading to larger differences on average in pre/post knowledge on diabetes. With respect to behavior change, appropriate food consumption improved by 7.4% and physical activity by 10.1%. Students were generally more apt to better their intake of healthier items like fruits and vegetables (10.9%) than to reduce their consumption of unhealthy items like fried snacks and sweets (4.1%). This difference may be explained by socioeconomic barriers in accessing and affording healthier items. Research also shows that eliminating unhealthy habits is more challenging than building new positive habits.[24] Improvements in knowledge were consistently greater than in dietary patterns and physical activity. However, studies have shown that knowledge is often more easily improved than behavior change.[25] Behavior change also requires a longer timeframe to see meaningful effects. Regardless, health literacy is the first step to building sustainable healthy lifestyle habits.[26]

Students who completed the full 2-year intervention showed greater improvements in knowledge and appropriate food consumption during Year One than in Year Two. These patterns were consistent across all partners. While Year One curricula involved in-class lectures and small-group activities, Year Two reinforced this material through advocacy projects. This may explain why Year One yielded greater gains than Year Two, as students had likely built a solid baseline level of knowledge by the end of Year One. Year Two also focused on delivering Year One material through different methods instead of introducing new concepts. Students likely experienced the novelty effect of a fresh approach to diabetes education during Year One, inspiring notable improvements in knowledge and habits. Regardless, Year Two's focus on advocacy efforts led by students is critical to reinforcing lifelong behavior change in themselves and their fellow community members – creating a 'multiplier' effect.

While all implementing partners generally observed positive outcomes, the magnitude varied across knowledge (1.0 to 34.6%), food consumption (-1.6 to 11.8%), and physical activity (-0.7 to 15.3%). Organizational factors like type (non-profit versus for-profit versus government), size, and resources may have engendered these differences. Student and school factors like urban versus rural status and state might also play a role. While socioeconomic status could not be assessed at the student level, implementing partners that covered regions with higher poverty levels observed greater improvements in knowledge and health behaviors. This finding reinforced the notion that community-based public health programs could serve as important and effective means of delivering health information and affecting behavioral change in lower-resource settings.

Due to the COVID-19 pandemic, a digital version of the curriculum was created in 2021 and delivered to some students participating in hybrid intervention cycles. Students on average did better during hybrid cycles than during in-person cycles (knowledge: 24.4 vs. 8.2%; food consumption: 11 vs. 4.2%; physical activity: 19.2 vs. 1.9%, respectively). This pattern was consistent across most partners, suggesting digital health holds potential for both knowledge transfer and scale in an increasingly technology-adept generation. Mobile and digital health applications are powerful tools for increasing healthcare access and warrant further investment as highlighted in the WHO Global Strategy on Digital Health.[27]

Despite varied outcomes across implementing partners and intervention modality, findings from this study suggest that HSP was an effective intervention, as substantiated by our multivariate mixed-effects regression analyses. Effectiveness was sustained longitudinally and across implementing partners, 18 states, and over 7,500 rural and urban schools. This study, which analyzed data from young adolescents in several real-world school and community settings, demonstrated persistent results beyond the initial pilot conducted in 2011,[17] suggesting that HSP's approach through novel features including age-targeted design (e.g. interactive games, playground activities), school-based, peer-led model, and skillful technology adoption could be broadly applied.

Community-based prevention programs are important public health tools in combating NCDs, especially in resource-constrained or rural settings.[28,29] Prior interventions targeting diabetes in India have shown a reduction in fasting blood glucose from 11 to 25% in people with prediabetes and diabetes.[28] The landmark Indian Diabetes Prevention Programme notably showed a 28.5% risk reduction in the progression from impaired glucose tolerance to diabetes through lifestyle modification.[29] However, community-based programs targeting diabetes prevention in healthy individuals in India are limited, with few programs focused on youth – a gap HSP addresses. School-based and peer-led models are gaining acceptance as effective modes of healthcare delivery in both LMICs like India and high-income countries (HIC). These models have broad public health applications, including tobacco use, mental health, substance use, and diabetes prevention.[19–21,30]

While HSP was highly effective, future directions include implementing program features that support the maintenance of lifestyle modifications. This may be achieved through extended advocacy efforts like those developed by students in Year Two of HSP. Educating family members in the household, in addition to children, may also be critical to reinforcing sustainable behavior change. While Arogya covers 18 states in India, HSP could be scaled to the remaining 10 states through cost-effective non-profit, for-profit, and government partnerships leveraging digital tools. Both rural and urban

geographies as well as government and private schools could be targeted with curricular adaptation to meet local needs.

As with any programmatic implementation, limitations to this study exist. No control group was used to maximize the number of students reached. However, this quasi-experimental pretest-posttest design used baseline pre-intervention scores as 'controls'. This study could not account for confounding from certain demographic and social determinant variables due to limited data collection. Sex was not consistently collected and therefore excluded from the study, although the initial 2011 pilot noted no significant differences in outcomes by sex.[17] Socioeconomic and geographic data also were not consistently collected and therefore excluded from this analysis. Certain outcomes like physical activity could not be quantified due to non-continuous, multiple-choice reporting options. Clinical measurements like anthropometrics, blood pressure, and laboratory diagnostics were not collected. While self-reported metrics run the risk of social desirability bias, they still allow for meaningful evaluation of knowledge gain and behavior change – the first steps to long-term clinical improvement. Obtaining qualitative data through focus groups and student testimonials would also enhance monitoring, evaluation, and programmatic improvement of HSP. The true effect of digital interventions could not be assessed, as these data were not available at the student level but at the intervention cycle level. However, the observed trends still indicate that digital health information could increase access to public health interventions in resource-constrained settings and could improve outcomes in a generation increasingly reliant on technology. A limited sample was surveyed with no random sampling due to staffing constraints for data collection and appraisal. Sample representativeness was accordingly optimized through broad convenience sampling across all partners, schools, and geographies. Finally, further study is needed to evaluate long-term impact with longitudinal follow-up data post-implementation and to understand differences across partners, intervention modality, socioeconomic status, school type (government vs. private), and geography (urban vs. rural).

CONCLUSION

This study sought to assess the effects of a school-based, peer-led diabetes prevention initiative implemented across geographic regions that varied widely economically. The HSP by Arogya World is a low-cost, scalable intervention that, during an analysis of data from 2015 to 2022, indicated gains in student knowledge about diabetes and its risk factors alongside behavior changes in nutrition and physical activity. While some variation was noted across implementing partners and intervention modality cycles (in-person vs. hybrid), the intervention appeared to be effective despite these differences. Implementing partners working in regions with greater poverty observed larger improvements in health knowledge and behaviors. Digital interventions also indicated the potential for scaling this approach across geographies regardless of local resources. While knowledge gains ultimately exceeded improvements in behavior change, health literacy was critical to initiating and maintaining lifestyle modifications. School-based, peer-led public health interventions hold tremendous potential for combating NCDs by promoting healthy habits early in life. Arogya World's HSP, aligned with India's Ayushman Bharat National School health curriculum, is one noteworthy example – equipping young children with the tools to curb India's growing diabetes crisis.

ARTICLE INFORMATION

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Affiliations

[1]Department of Pediatrics, Stanford University School of Medicine, Palo Alto, CA; [2]Department of Public Health, College of Education, Health and Human Services, University California State University San Marcos, CA; [3]Department of Public Health, University of Rochester, Rochester, NY; [4]Arogya World, Spring House, PA; [5]Arogya World India, Dollars Colony, Bangalore, Karnataka, India

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Supplemental Table 1. Study Population Characteristics of Students in Arogya Healthy Schools Program, 2015–2022

		Baseline age (yrs)			
	N	Mean	SD	Minimum	Maximum
Total	6,616	11.88	0.79	11	15
Partner					
A	597	11.72	0.88	11	15
B	1,476	12.06	0.67	11	15
C	1,981	11.97	0.83	11	15
D	1,318	11.94	0.80	11	15
E	1,244	11.53	0.67	11	14
Intervention Type					
In-person	3,463	11.78	0.74	11	15
Hybrid	3,153	11.99	0.83	11	15

Abbreviations: SD = standard deviation; yrs = years.

Supplemental Table 2. **Non-Composite Knowledge, Food Consumption, and Physical Activity Pre-Post Differences in Arogya Healthy Schools, 2015-2022**

	Total (N=3,463)		A (n=251)		[a]B (n=835)		[b]C (n=911)		D (n=222)		[c]E (n=1,244)	
	Pre (%)	Post (%)	Pre (%)	Post (%)	Pre (%)	Post (%)	Pre (%)	Post (%)	Pre (%)	Post (%)	Pre (%)	Post (%)
Knowledge												
Nutrition knowledge												
Food items like noodles, chips, chocolate, samosa are bad for health	90.9%	93.1%	100.0%	100.0%	94.1%	95.7%	85.4%	93.2%	75.2%	91.4%	93.7%	90.3%
Whole grains and cereals are good sources of fibre	81.5%	90.4%	100.0%	100.0%	80.6%	96.2%	82.5%	92.2%	66.7%	87.8%	80.2%	83.6%
Physical activity knowledge												
Being active and doing regular exercise keeps a person fit and healthy	87.1%	89.6%	100.0%	100.0%	80.7%	81.4%	82.0%	92.1%	91.9%	85.1%	91.6%	92.0%
Lack of physical activity /exercise can put one at risk for NCDs like diabetes	40.9%	52.4%	100.0%	100.0%	58.0%	3.4%	4.6%	74.1%	41.9%	82.4%	44.1%	54.4%
It is false that only overweight people should exercise	53.5%	55.6%	86.5%	86.1%	9.2%	58.8%	63.7%	14.1%	41.0%	77.0%	71.3%	73.9%
Diabetes knowledge												
Unhealthy eating habits can put one at risk for NCDs like diabetes	44.7%	42.4%	98.4%	98.8%	44.4%	3.1%	4.6%	15.7%	50.9%	82.4%	62.2%	69.9%
Type 2 diabetes is preventable	34.3%	58.3%	23.5%	23.9%	35.3%	61.1%	31.1%	68.8%	36.9%	80.2%	37.8%	51.7%
People with diabetes are more likely to develop heart disease, stroke, kidney and eye problems	61.2%	78.0%	100.0%	100.0%	60.4%	85.5%	49.4%	74.0%	54.1%	86.9%	63.8%	69.9%
Food consumption												
Eating healthier foods more often (alternate days or once a week)												
Breakfast	91.1%	93.3%	100.0%	100.0%	98.1%	98.2%	96.5%	98.4%	84.7%	95.0%	81.8%	84.6%
Whole fruits	77.0%	80.0%	100.0%	100.0%	66.9%	61.7%	56.3%	67.3%	88.3%	94.6%	92.1%	94.9%
Vegetables	85.0%	90.2%	100.0%	100.0%	80.0%	86.7%	79.7%	89.1%	93.2%	98.2%	87.6%	90.0%
Milk and milk products	84.7%	87.7%	95.6%	92.8%	76.6%	82.3%	81.8%	85.7%	83.3%	94.1%	90.2%	90.7%
Eating unhealthier foods less often (never or once a month)												
Carbonated drinks	48.3%	54.8%	5.2%	6.8%	65.0%	68.5%	55.5%	64.0%	45.0%	59.9%	40.9%	47.7%
Fried snacks	38.9%	46.0%	4.0%	6.4%	40.6%	58.9%	49.4%	51.9%	23.4%	29.3%	39.9%	44.0%
Sweets	47.4%	49.8%	6.4%	5.6%	49.2%	58.7%	65.5%	62.3%	37.4%	47.3%	42.8%	44.1%
Packed chips	26.6%	33.2%	5.2%	5.2%	35.4%	56.3%	27.3%	31.0%	22.1%	16.2%	25.3%	27.9%
Physical Activity												
During the games period in school, I mostly:												
Sit and talk with friends or finish my homework/read	63.4%	61.5%	50.6%	54.2%	98.2%	98.0%	92.4%	91.0%	55.0%	23.9%	22.8%	23.6%
Play a little bit/walk with friends or play games in the playground	36.6%	38.5%	49.4%	45.8%	1.8%	2.0%	7.6%	9.0%	45.0%	76.1%	77.2%	76.4%

[a]For Partner B, chip consumption was measured using only the second year of pre-post intervention data.
[b]For Partner C, chip consumption was measured using only the first year of pre-post intervention data.
[c]For Partner E, all items were measured using only the first year of pre-post intervention data.