

Bridging the gap between efficacy and scale: A RE-AIM evaluation of a child drowning prevention program in Vietnam

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Abstract

Background

Drowning is a leading cause of death for children in Vietnam and other low- and middle-income countries (LMICs). While survival swimming interventions have demonstrated efficacy, systematic evaluations addressing scalability and sustainability remain scarce. This study applies the RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) framework to evaluate a large-scale national drowning prevention program in Vietnam across its pilot and expansion phases (2018–2022).

Methods

A mixed-methods design was employed across 11 provinces in Vietnam. Data were triangulated from three primary sources: (1) secondary analysis of commune-level mortality registers (Form A6) for drowning deaths in 29 intervention districts (115 communes) and 15 matched control districts (56 communes); (2) longitudinal program monitoring logs tracking enrollment, attendance, and instructor certification; and (3) a cross-sectional household survey of 2,225 parents conducted at baseline (2017) and follow-up (2022). RE-AIM indicators were calculated to assess program scalability and sustainability. Linear regression and Spearman's rank correlation were used to quantify temporal trends in drowning mortality.

Results

The program reached 373,400 children (3.9% of the target population aged 0–15 years), with 78.1% of households in intervention areas reporting program awareness. Cumulative drowning incidence was significantly lower in intervention areas (67.02 per 100,000) compared to controls (98.64 per 100,000), corresponding to an estimated 31.62 deaths averted per 100,000 children. Intervention areas showed a robust downward mortality trend ($R^2 = 0.78$, $p = 0.019$; Spearman $\rho = -0.94$, $p = 0.005$), while control areas exhibited no significant trend. The program expanded to 11 provinces via a Training of Trainers model certifying 841 instructors, with high fidelity (2:1 student-to-instructor ratio) and zero safety incidents. Following a 94% enrollment decline during COVID-19 restrictions (2021), the program rebounded to peak enrollment in 2022. At follow-up in 2022, 24.1% of parents were willing to pay more than 750,000 VND (~ USD 30) for future courses, supporting a public-private co-funding model.

Conclusions

This intervention demonstrates that high-intensity drowning prevention can be scaled effectively in an LMIC context using lay providers and decentralized delivery. Future efforts must address equity gaps in

reach for younger children (aged 6–8) and formalize co-funding mechanisms to transition from donor dependency to sustainable local ownership.

Background

Drowning remains a critically neglected public health issue, particularly in low- and middle-income countries (LMICs), where the burden is disproportionately high [1]. Global estimates suggest drowning causes hundreds of thousands of deaths annually, with more than 90% of these fatalities occurring in LMICs [2]. In Vietnam, drowning is a leading cause of death for children, with historical data indicating over 5,700 annual deaths, predominantly among those aged 2–15 [3]. This burden is exacerbated by environmental risks—such as open water sources near homes—and a distinct lack of water competency; surveys indicate that over 90% of children aged 6–15 lack functional swimming skills [4].

While effective and low-cost interventions exist—such as survival swimming, barrier installation, and community supervision—the translation of these interventions from efficacy trials to real-world, scalable programs remains a critical gap. This challenge is often described as the "voltage drop" in public health, where interventions proven effective in controlled settings fail to achieve the same impact when deployed in complex, resource-constrained environments.

To bridge the gap between efficacy (does it work in a controlled setting?) and effectiveness (does it work in the real world?), implementation science frameworks are essential. The RE-AIM framework is a planning and evaluation model that enhances research translation and assesses the public health impact of interventions, initially for individual-level interventions but now also for multi-sector partnerships and community programs [5, 6]. Its five dimensions determining overall impact are: Reach (number, proportion, and representativeness of participants); Effectiveness (impact on key outcomes, including negative effects, quality of life, and economic outcomes); Adoption (number, proportion, and representativeness of settings and staff initiating the program); Implementation (fidelity to the protocol, consistency of delivery, time, and costs); and Maintenance (extent of program institutionalization or becoming routine practice over time). The framework is often operationalized using mixed methods, combining quantitative and qualitative data to explain outcomes [7–12].

A primary advantage of RE-AIM is its ability to bridge the "evidence-to-practice gap" by expanding the focus beyond efficacy to include factors essential for scalability. By systematically assessing adoption and implementation, the framework helps researchers identify specific barriers and facilitators to practice change, such as competing organizational priorities or staff turnover [13, 14]. The framework is versatile and has been successfully applied across diverse settings, including sports organizations [15], emergency departments [16], and community centers [17]. It allows for the evaluation of complex, real-world interventions where strict control is impossible.

The application of RE-AIM is often hindered by incomplete reporting. A systematic review of injury prevention in youth sports found that reporting is skewed toward effectiveness (60%) and implementation (48%), while adoption (26%) and maintenance (7%) are frequently neglected [8].

Collecting data on organizational adoption and long-term maintenance is resource-intensive, and researchers often lack the access to track these outcomes [6]. Additionally, high adoption or reach does not guarantee fidelity. Studies in sports injury prevention have shown that while reach may be high, implementation fidelity can be low due to lack of supervision or coach adherence [11]. Finally, detecting long-term maintenance effects remains difficult [18].

In high-income settings, RE-AIM is widely applied to evaluate injury prevention resources, including online platforms, fall prevention initiatives, and athletic training programs, with examples from Canada, the United States, and Sweden. These evaluations consistently highlight that while interventions often prove effective, translating them into routine, sustainable practice—specifically the Adoption and Maintenance dimensions—remains the primary hurdle to achieving widespread public health impact.

While the majority of RE-AIM research originates from high-income nations, its application is expanding in LMICs, focusing on crucial elements like feasibility, cultural adaptation, and systems-based approaches to address resource constraints [19–21]. However, the application of RE-AIM to drowning prevention, particularly in LMICs, remains scarce. Most drowning studies focus narrowly on behavioral outcomes (e.g., swimming skills) without quantifying Reach or documenting the policy-level factors driving Adoption. This study addresses this gap by applying the full RE-AIM framework to a large-scale, multi-province drowning prevention program, contributing rare data on implementation determinants in a resource-constrained context.

Methods

Study design and framework

We employed a mixed-methods design guided by the RE-AIM framework [22]. This approach allows for a robust assessment of both the impact of the intervention (Effectiveness) and the processes (Reach, Adoption, Implementation, Maintenance) that facilitated or hindered its delivery in a real-world setting.

Setting and participants

The intervention was implemented in 11 provinces representing Vietnam's diverse geographical regions (Northern mountainous, Central coastal, and Mekong Delta). The intervention group comprised 29 districts (115 communes) selected for implementation based on high baseline drowning burdens, and the control group comprised 15 districts (56 communes) matched on socio-demographic characteristics and drowning risk profiles. The target population was children aged 0–15 years residing across the study provinces.

Intervention description

The program, implemented by the Ministry of Labor, Invalids and Social Affairs (MOLISA) in partnership with the international non-governmental organizations Hue Help and Swim for Life, consisted of three core components:

(1) Survival Swimming: Free courses for children aged 6–15, consisting of 15 lessons. The curriculum required students to swim 25 meters and float for 90 seconds to achieve certification—a standard defined as "survival swimming" rather than recreational swimming.

(2) Water Safety Education: Classroom-based instruction on hazard recognition, rescue skills, and safe water practices for primary and secondary students.

(3) Community Supervision: Awareness campaigns and training for parents and caregivers of children under 5 years to improve supervision and eliminate home-based hazards (e.g., covering water jars, fencing ponds).

Data collection and measures

Data were triangulated from three primary sources:

Program monitoring data (Reach and Adoption): Longitudinal administrative logs were used to track the number of children enrolled, attendance rates, and certification results. Adoption was measured by the number of provinces and districts initiating the program and the number of instructors trained via a Training of Trainers (TOT) model.

Mortality registers (Effectiveness): Drowning mortality data (2017–2022) were extracted from the commune-level death recording system (Form A6) managed by local health stations. This provided objective data on drowning incidence in both intervention and control areas.

Household survey (Implementation and Maintenance): Cross-sectional surveys were conducted in 2017 and 2022 with 2,225 households (1,500 intervention, 775 control) selected via multi-stage random sampling. The survey assessed parental Knowledge, Attitudes, and Practices (KAP) and Willingness to Pay (WTP) for future courses to gauge financial sustainability.

Statistical analysis

Mortality trends were analyzed pre-intervention (2017) and post-intervention (2018–2022). Cumulative incidence rates were calculated per 100,000 children. Linear regression analysis was employed to quantify the magnitude and statistical significance of temporal trends in drowning mortality rates from 2017 to 2022 for both study groups. Spearman's rank correlation was utilized to assess the strength and direction of monotonic associations, ensuring robustness against data volatility and outliers. Statistical significance was set at $p < 0.05$.

Estimation of deaths averted

The number of deaths averted was calculated as the absolute difference in cumulative drowning incidence between control and intervention areas (98.64 vs. 67.02 per 100,000 children, 2017–2022), expressed as a rate difference per 100,000 children. This approach assumes comparability between intervention and control areas beyond the matched socio-demographic and risk-profile characteristics described above; it does not adjust for underlying population trends unrelated to the intervention, and no confidence interval is presented around this point estimate. This assumption is addressed further in the Limitations.

Results

Reach

The program successfully reached approximately 373,400 cumulative child contacts across the 11 pilot provinces over 2018–2022, representing 3.9% of the total child population aged 0–15 years. This total reflects cumulative enrollment across program components and years rather than a count of unique children, as some children participated in more than one component (e.g., both survival swimming and classroom-based water safety education) or attended in more than one program year; single-year enrollment in the two primary streams comprised survival swimming courses (n = 28,819) and classroom-based water safety education (n = 52,250). Awareness was high in intervention areas, with 78.1% of households reporting knowledge of the program, primarily through local loudspeakers (62.7%) and school channels (68.4%).

Distribution of reach across participating provinces is shown in Table 1. Reach was uneven across age groups: participation was robust among children aged 9–11 but significantly lower among younger children aged 6–8. Program staff reported that the physical demands of the survival curriculum (swimming 25 m and floating 90 seconds) were difficult for younger children to meet, leading to lower recruitment in this demographic.

Table 1. Program reach and coverage by province (2018–2022)

Province	Child population (0–15)	Children reached	Coverage (%)
Dak Lak	348,192	44,630	12.8
Dong Thap	253,917	63,598	25.0
Hanoi	1,402,917	43,650	3.1
Lao Cai	155,550	9,124	5.9
Long An	253,762	20,308	8.0
Nam Dinh	301,887	17,841	5.9
Nghe An	581,271	42,446	7.3
Ninh Binh	162,687	8,907	5.5
Quang Binh	159,161	35,194	22.1
Soc Trang	206,888	42,792	20.7
Thanh Hoa	595,074	44,910	7.5
Total	9,578,264	373,400	3.9

Effectiveness

Mortality reduction

Analysis of drowning mortality rates from 2017 to 2022 reveals a distinct divergence in trend stability and significance between study groups. The intervention group demonstrated a consistently lower mean mortality rate (9.95 ± 3.60 per 100,000) compared to the control group (14.82 ± 7.10 per 100,000), with markedly reduced volatility. Statistical evaluation confirmed a robust and significant downward trend for the intervention group across both linear ($R^2 = 0.78$, $p = 0.019$) and monotonic ($\rho = -0.94$, $p = 0.005$) measures, indicating a systematic reduction in mortality over time. In contrast, the control group exhibited high variability and failed to achieve statistical significance in either linear ($p = 0.338$) or rank-based ($p = 0.156$) analyses, suggesting that observed fluctuations in non-intervention communes were attributable to stochastic environmental factors rather than structural improvements. Trend analysis results are presented in Table 2 and Figure 1.

Table 2. Trend analysis of drowning mortality rates (per 100,000 children aged 6–15 years, 2017–2022)

Study Group	Mean Rate (SD)	Linear Slope (β)	R ²	p-value (linear)	Spearman's ρ	p-value (Spearman)
Intervention	9.95 $\pm$ 3.60	-1.70	0.78	0.019*	-0.94	0.005**
Control	14.82 $\pm$ 7.10	-1.81	0.23	0.338	-0.66	0.156

* Statistically significant at $p < 0.05$; ** Statistically significant at $p < 0.01$

Skill acquisition

Among participants in the swimming courses, 75.6% passed the final assessment (swimming 25 m and floating 90 seconds) on first attempt. Following remedial training for those who initially failed, the pass rate increased to 93.7%. Province-level certification outcomes are presented in Table 3.

Table 3. Survival swimming certification outcomes by province

Province	Swim pass rate (%)	Float pass rate (%)	Both skills (%)
Dak Lak	76.3	73.3	65.2
Dong Thap	73.3	80.4	64.4
Hanoi	86.5	75.4	72.7
Lao Cai	64.7	57.5	55.0
Long An	82.4	78.4	74.8
Nam Dinh	78.6	65.7	65.0
Nghe An	80.1	76.3	72.7
Ninh Binh	100.0	100.0	100.0
Quang Binh	83.3	83.8	82.7
Soc Trang	90.0	79.2	74.5
Thanh Hoa	77.1	70.4	69.5
Total Average	81.1	76.4	72.4

Adoption

The program successfully expanded from 8 provinces in Phase 1 to 11 provinces by 2022. Institutional adoption was robust, facilitated by inter-sectoral coordination committees involving the Department of Labor, Invalids and Social Affairs (DOLISA), Education, and Sports sectors. A total of 841 swim instructors and 720 water safety education instructors were trained via the Training of Trainers model. Summary RE-AIM indicators across all five dimensions are presented in Table 4.

Table 4. Summary of RE-AIM indicators

Dimension	Indicator	Result	Data source
Reach	% of target population participating	3.9% (373,400 children)	Monitoring logs
	Program awareness in intervention areas	78.1% of households	Household survey
Effectiveness	Deaths averted (estimated)	31.62 per 100,000	Mortality register (A6)
	Swim certification pass rate	93.7% (post-remedial)	Monitoring logs
Adoption	Number of provinces implementing	11 provinces (29 districts)	Monitoring logs
	Instructors trained (TOT model)	841 swim / 720 water safety	Training records
Implementation	Fidelity (student:instructor ratio)	2:1	Fidelity checklists
	Safety incidents	0 reported	Incident logs
Maintenance	Parental willingness to pay (>500,000 VND)	40.6%	Household survey
	Policy integration	Decision 1248/QĐ-TTg	Policy documents

Implementation

Fidelity

The program strictly adhered to safety protocols, requiring consent forms for 100% of participants and maintaining a ratio of two instructors and one supervisor per class. Consequently, no safety incidents were recorded during training across the entire 2018–2022 period.

Resilience during the COVID-19 pandemic

Figure 2 illustrates a distinct "V-shaped" recovery trajectory, capturing the severe impact of COVID-19 followed by significant programmatic resilience. After a strong baseline in 2019, enrollment declined sharply during 2020 and 2021 due to social distancing measures, with practical survival swimming reaching a critical low of just 544 participants in 2021. However, the program rebounded robustly in 2022, with swimming enrollment surging to 14,380—surpassing pre-pandemic levels—and water safety education returning to near-baseline figures (17,400). This demonstrates the decentralized model's capacity to reactivate quickly once restrictions were lifted.

Maintenance

Financial sustainability

Figure 3 illustrates a significant shift in parental valuation of survival swimming courses from 2017 to 2022. At baseline in 2017, only 4% of parents were willing to pay more than 750,000 VND (~USD 30). However, following the intervention, the proportion of parents willing to pay this highest tier rose dramatically to 38.3% in 2019 and stabilized at 24.1% in 2022. At the lower threshold of 500,000 VND (~USD 20), willingness to pay reached 40.6% by 2022, according to the CIPPR/HUPH household survey report (2022). This sevenfold increase at the higher tier, combined with willingness to pay moderate fees among over 40% of the population, supports the feasibility of a "socialization" model where community contributions can replace donor funding for long-term maintenance.

Discussion

This study confirms that survival swimming and water safety education are not only efficacious but can be effectively implemented at scale in an LMIC setting. The intervention averted approximately 31 deaths per 100,000 children, a substantial public health impact. Beyond the primary outcomes, the deep application of RE-AIM offers several critical insights into the mechanisms of scaling injury prevention programs.

Effectiveness and the role of lay providers

A key finding of this evaluation is the high effectiveness achieved by lay providers—specifically physical education teachers trained via the TOT model. With pass rates exceeding 93% after remedial training, this study validates that technical interventions do not require specialized external experts if the local workforce is adequately supported. This parallels findings from the integrated Community Case Management evaluation in Kenya, where community health workers successfully delivered complex interventions when provided with structured training [23]. In the context of drowning prevention, where a lack of trained instructors is often cited as a barrier to adoption, the success of the 841 locally trained instructors demonstrates a scalable workforce solution.

The Reach-Equity Paradox

While the overall Reach (3.9% of the population) is significant for a high-intensity pilot, the RE-AIM analysis revealed a concerning "Reach-Equity Paradox." The program was highly successful in recruiting children aged 9–11 but struggled to engage the 6–8 age group. Qualitative data suggest this was due to the physical rigor of the survival curriculum (swimming 25 m and floating 90 seconds), which younger children found difficult to achieve.

This finding aligns with broader public health literature where standardized interventions often fail to reach the most vulnerable subpopulations—in this case, younger children who are at high risk of drowning but less physically capable. To improve equity, future iterations of the program must adapt the curriculum. Introducing a "water familiarization" tier for younger children, rather than a rigid survival

certification, could broaden reach and ensure that the most vulnerable demographics are not excluded from the safety net.

Implementation resilience in crisis

The Implementation domain highlighted remarkable resilience. Despite the COVID-19 pandemic causing a 94% drop in participation in 2021, the program rebounded to peak levels in 2022. This V-shaped recovery suggests that the decentralized Adoption model—where local provinces and districts took ownership of logistics—created a system capable of hibernating and restarting quickly. Unlike centralized interventions that may collapse when supply chains or external staff are removed, the Vietnam program's reliance on local teachers and local infrastructure allowed for rapid restart once social distancing policies were lifted. This resilience is a critical indicator of long-term program viability.

However, infrastructure remains a tension point. The reliance on fixed assets (pools) creates a bottleneck compared to more portable health interventions. While mobile pools were deployed to increase reach, they often lacked roofing, making them unusable during midday heat. This highlights that Implementation fidelity is not just about human compliance but also about environmental suitability.

Financial maintenance and the "socialization" model

Perhaps the most significant contribution of this study to the injury prevention literature is the data on Maintenance. Maintenance is historically the least reported RE-AIM dimension, often due to a lack of long-term follow-up [8]. This study provides a concrete pathway for financial sustainability through "socialization" (public-private partnership).

The finding that over 40% of parents are willing to pay approximately USD 20 for the course challenges the assumption that injury prevention in LMICs must be entirely donor-funded. This high Willingness to Pay suggests a tiered implementation model is viable: government funding can target the poorest, rural districts (equity), while urban and wealthier districts utilize co-funding mechanisms. The successful transition of Yen Bai and Ninh Binh provinces to self-funding serves as a proof-of-concept that drowning prevention can transition from a project-based initiative to a sustainable public service.

Limitations

Intervention districts were purposively selected on the basis of high baseline drowning burden, while control districts were matched on socio-demographic and risk characteristics rather than assigned randomly; this raises the possibility that some of the observed convergence in mortality trends reflects regression to the mean rather than the intervention effect alone, and effectiveness estimates should be interpreted with this design limitation in mind. Additionally, the study utilized secondary mortality data (Form A6 registers), which in some communes were incomplete or delayed due to the pandemic. While the trends are robust, the precise number of averted deaths is an estimate. Additionally, the lack of pre-course swimming ability assessments limits the granularity of skill-gain analysis, although teacher reports indicated 100% of participants were non-swimmers. Finally, the reporting of Adoption was

limited to successful provinces; more data on districts that declined to participate would provide valuable insights into barriers.

Conclusions

The Child Drowning Prevention Intervention (2018–2022) serves as a proof-of-concept for scaling technical injury prevention interventions in LMICs. By achieving high Effectiveness and Adoption, the program has saved lives and built a capable local workforce. However, the evaluation reveals that scaling is not linear; challenges in Reach equity and infrastructure remain.

Crucially, the study illuminates a path for Maintenance that relies on shifting from a donor-dependent model to a "socialized" co-funding mechanism, supported by high parental value for the service. Future scaling efforts should prioritize curriculum adaptation for younger children to address equity gaps and formalize public-private partnerships to ensure that drowning prevention remains a sustainable priority in Vietnam and beyond.

Abbreviations

DOLISA: Department of Labor, Invalids and Social Affairs

KAP: Knowledge, Attitudes, and Practices

LMIC: Low- and Middle-Income Country

MOLISA: Ministry of Labor, Invalids and Social Affairs

RE-AIM: Reach, Effectiveness, Adoption, Implementation, Maintenance

TOT: Training of Trainers

WTP: Willingness to Pay

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki. It involved secondary analysis of existing program monitoring data, mortality register data, and household survey data collected as part of the national drowning prevention program. Ethical approval was obtained from the Institutional Review Board / Ethics Council of Hanoi University of Public Health, which holds international registration numbers IORG0003239 and FWA0009326 with the U.S. National Institutes of Health (NIH) / Department of Health and Human Services (HHS). For the household survey, informed consent was obtained from all participants prior to data collection. Access to and use of the program monitoring and mortality register data were officially granted by the respective authorities, with all data fully de-identified prior to analysis.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available due to participant privacy protections and institutional agreements with the program governing authorities. De-identified data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to compliance with ethical approvals and necessary authorization from the relevant governing bodies.

Competing interests

The authors declare no competing interests.

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Authors' contributions

CP: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing. **HD:** Validation, Investigation, Resources, Writing - Review & Editing, Supervision. **DD:** Investigation, Data Curation, Validation, Writing - Review & Editing, Visualization, Project administration, Funding acquisition. **NT:** Investigation, Data Curation, Validation, Writing - Review & Editing, Project administration, Funding acquisition. **TD:** Methodology, Validation, Writing - Review & Editing, Supervision.

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Figures

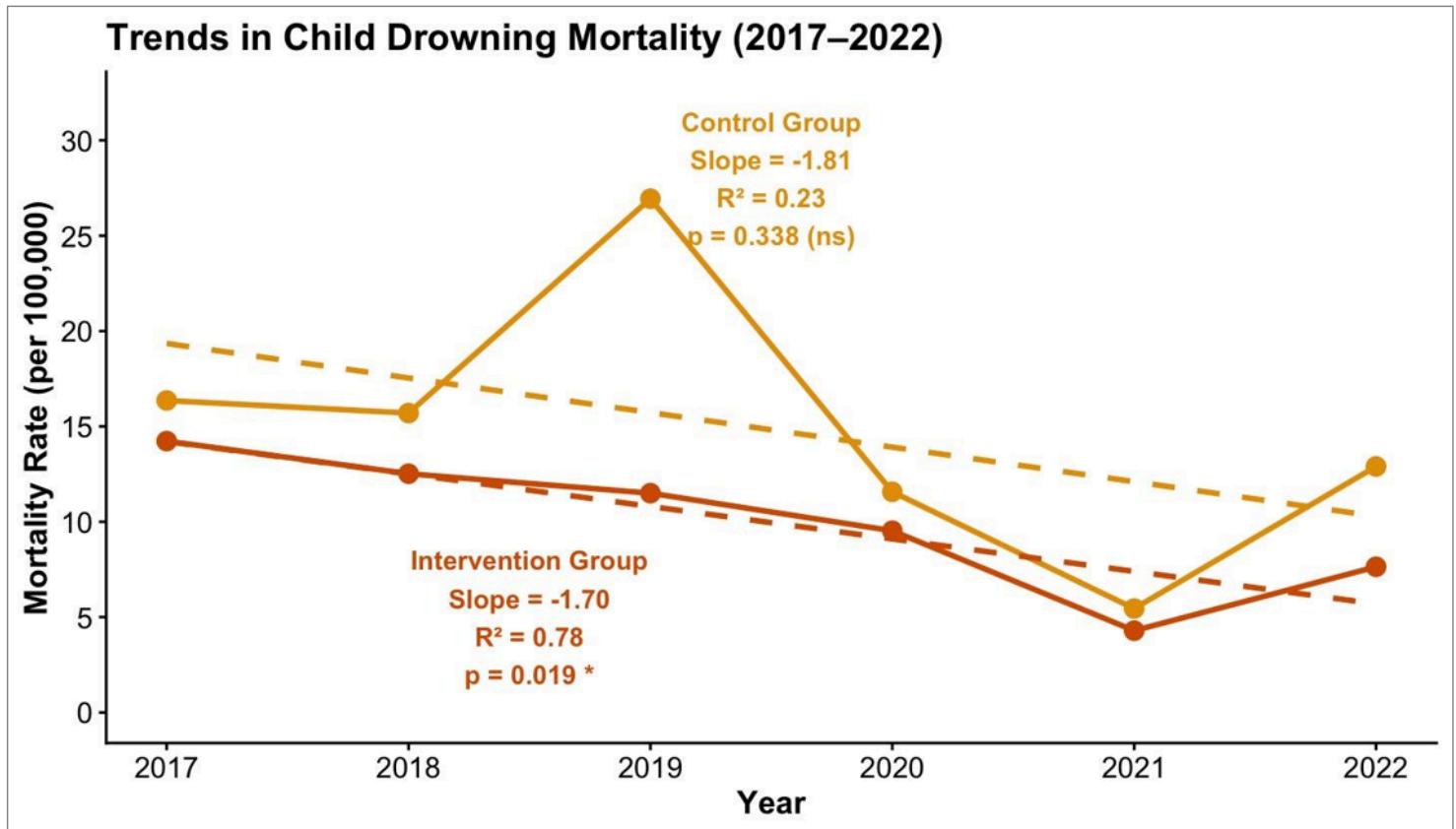


Figure 1

Trend analysis of drowning mortality rates (per 100,000) among children aged 6–15 years (2017–2022)

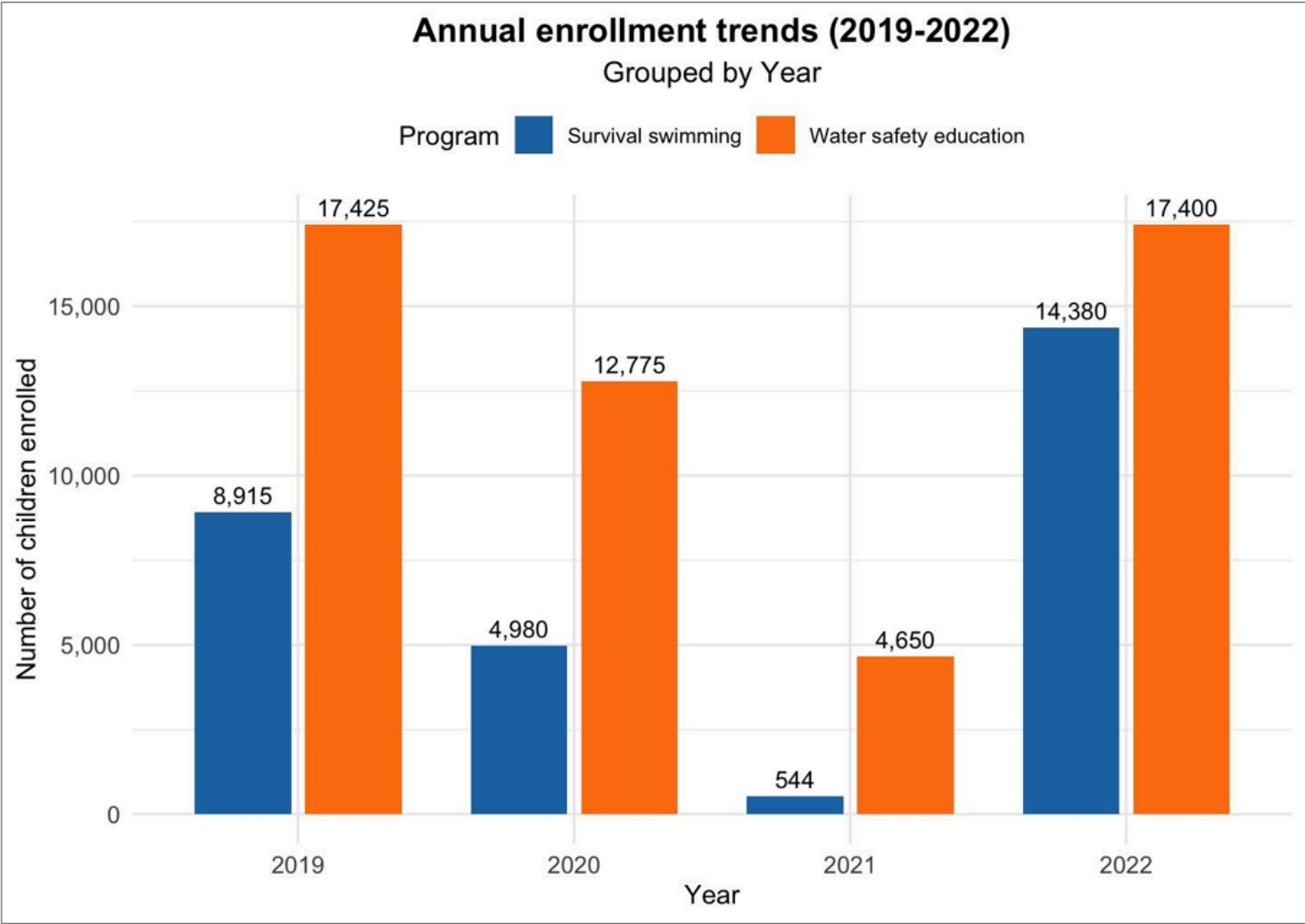


Figure 2

Annual enrollment in survival swimming and water safety education interventions (2019–2022)

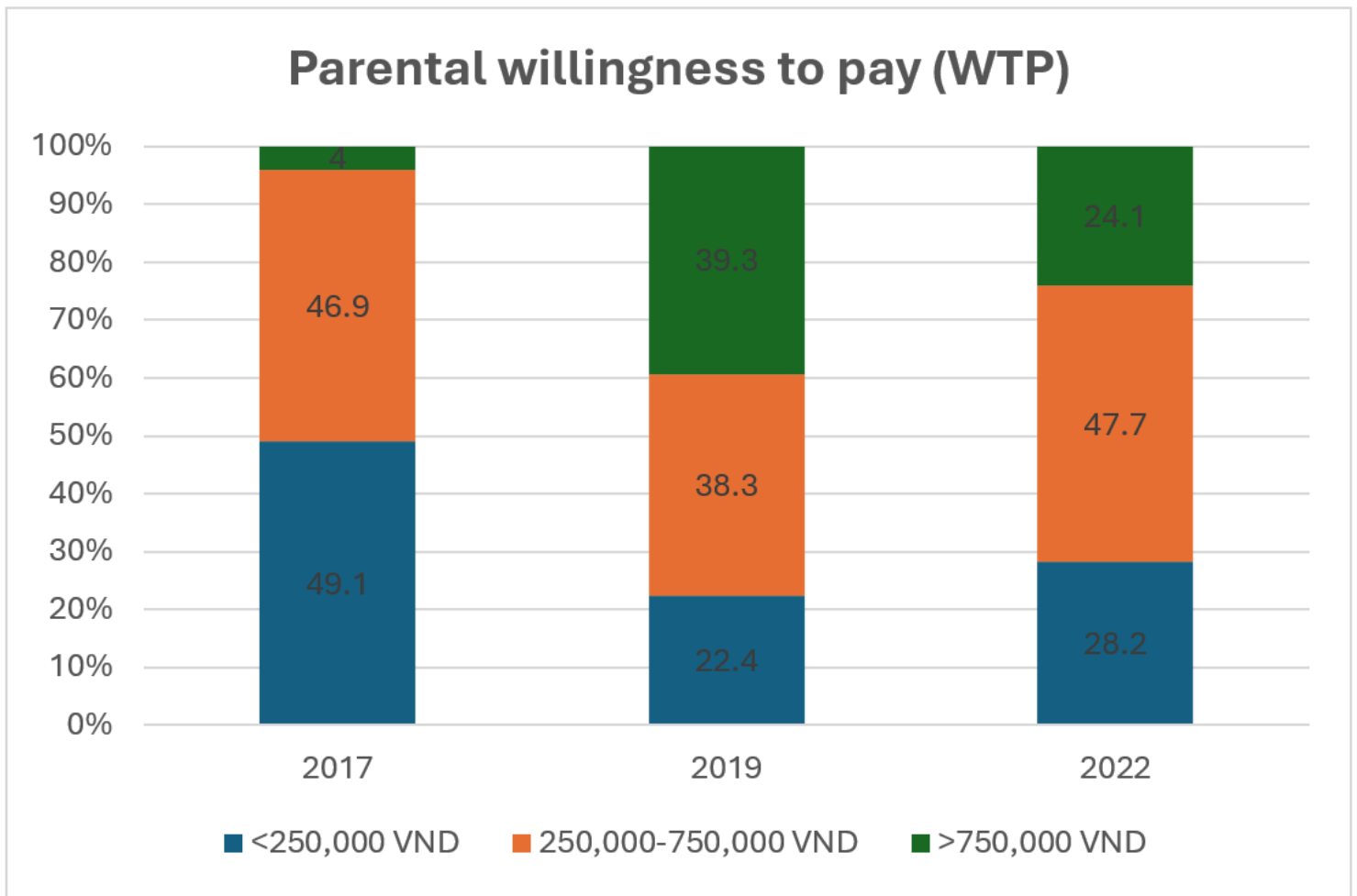


Figure 3

Parental willingness to pay (WTP) for future survival swimming courses