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Short Communication

Role of social ecological model level on young Pacific children's sugar-sweetened beverage and water intakes: Children's Healthy Living intervention

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Abstract

Objective: To examine children's sugar-sweetened beverage (SSB) and water intakes in relation to implemented intervention activities across the social ecological model (SEM) during a multilevel community trial.

Design: Children's Healthy Living was a multilevel, multicomponent community trial that reduced young child obesity (2013–2015). Baseline and 24-month cross-sectional data were analysed from nine intervention arm communities. Implemented intervention activities targeting reduced SSB and increased water consumption were coded by SEM level (child, caregiver, organisation, community and policy). Child SSB and water intakes were assessed by caregiver-completed 2-day dietary records. Multilevel linear regression models examined associations of changes in beverage intakes with activity frequencies at each SEM level.

Setting: US-Affiliated Pacific region.

Participants: Children aged 2–8 years (baseline: *n* 1343; 24 months: *n* 1158).

Results: On average (± SD), communities implemented 74 ± 39 SSB and 72 ± 40 water activities. More than 90 % of activities targeted both beverages together. Community-level activities (e.g. social marketing campaign) were most common (61 % of total activities), and child-level activities (e.g. sugar counting game) were least common (4 %). SSB activities across SEM levels were not associated with SSB intake changes. Additional community-level water activities were associated with increased water intake (0·62 ml/d/activity; 95 % CI: 0·09, 1·15) and water-for-SSB substitution (operationalised as SSB minus water: –0·88 ml/d/activity; 95 % CI: –1·72, –0·03). Activities implemented at the organization level (e.g. strengthening preschool wellness guidelines) and policy level (e.g. SSB tax advocacy) also suggested greater water-for-SSB substitution ($P < 0·10$).

Conclusions: Community-level intervention activities were associated with increased water intake, alone and relative to SSB intake, among young children in the Pacific region.

Keywords
Social ecological model
Multilevel trial
Sugar-sweetened beverages
Water
Young children
Pacific region

The heightened prevalence of obesity and type 2 diabetes among adults in the Pacific region requires early prevention efforts[1]. Reducing young children's sugar-sweetened beverage (SSB) intake, such as regular soft drinks, fruit drinks and sports and energy drinks – with corresponding increases in water intake – is common dietary targets to limit excess, nutrient-poor calories that may contribute to chronic disease risks[2–5]. Following a social ecological

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model (SEM) of health behaviour[6,7], there is consensus that beverage interventions are required at multiple levels of influence and scale – including children, their caregivers, the environments in which children spend their time and policies that influence dietary behaviours[2,3]. However, little is known about which strategies, and at what SEM level of implementation, are most effective in reducing SSB and increasing water consumption among young children, especially those in the Pacific region.

The Children's Healthy Living (CHL) Program was a multilevel, multicomponent community-randomised trial that took place between 2013 and 2015 in twenty-seven communities across five jurisdictions in the US-Affiliated Pacific (USAP) region: Alaska, American Samoa, Commonwealth of the Northern Mariana Islands, Guam and Hawaii. The trial resulted in a significant reduction in waist circumference, overweight/obesity prevalence and acanthosis nigricans prevalence (an indicator of insulin resistance) among young children aged 2–8 years[8]. Informed by a multilevel social ecological framework, CHL included a template of intervention activities that communities tailored and adapted to their local context[8–10]. Activities fit within four functional domains – policy change, environmental change, messaging and training – and targeted decreased SSB consumption by increasing water consumption, increased fruit/vegetable consumption, increased physical activity, decreased screen time and increased sleep time[8,9,11]. Despite having favourable intervention effects on anthropometric and acanthosis nigricans outcomes, significant differences in behavioural outcomes between children in the intervention and comparison communities were not observed[8]. Further process-oriented investigation is required to understand these findings, particularly towards the goals of replicating and scaling complex multilevel community interventions like CHL.

As one step in deconstructing CHL results and addressing these gaps, we examined whether changes in children's SSB and water intakes were associated with implemented intervention activities at different levels of the SEM. The focus on SSB and water intervention components, *v.* other behavioural targets, reflects the prevalence of beverage-targeted intervention activities across all SEM levels[8] and its potential in having measurable impact on energy balance[2,4,5].

Methods

This study involved secondary analysis of data from the CHL intervention arm in nine communities: Alaska (1 community), American Samoa (2), Commonwealth of the Northern Mariana Islands (2), Guam (2) and Hawaii (2). The comparison and temporal arms (nine communities each) were excluded given the focus on intervention implementation (implementation data were not collected in comparison and temporal communities). Further detail about CHL is provided elsewhere (ClinicalTrials.gov identifier: NCT01881373)[8–10,12]. The current analysis includes two cross-sectional samples of children aged 2–8 years in the intervention arm at baseline (T1; *n* 1517) and 24-month follow-up (T2; *n* 1342).

Intervention activities

Each jurisdiction had a CHL project team composed of five to seven members representing local academic institutions and community-based organisations. These CHL jurisdiction project teams led the selection of intervention activities from a template of nineteen activities, of which fourteen addressed SSB and water consumption[9]. Due to the diverse settings and the community-driven intervention, the template provided the teams 'what' to implement but not 'how' to implement. For example, one required activity was to 'work with existing organisations and coalitions and/or form new coalitions to advocate for better access to parks that are safe and inviting'. However, it was up to the team to decide how parks could be improved and which resources to leverage.

CHL jurisdiction project teams completed monthly standardised reports detailing the implementation of activities in each of the nine intervention communities. The research team counted the number of implemented activities targeting SSB and/or water consumption and coded each activity by the SEM level it addressed (child, caregiver, organisation, community and policy). Example activities at each level are as follows: *child-level* sugar counting games and creating 'fruity water' with chopped whole fruit; *caregiver-level* training for educators and home care providers about children's beverage consumption; *organisation-level* strengthening or implementing wellness policies in preschool settings and providing water dispensers at churches; *community-level* social marketing campaign and securing funding for placement of water fountains at parks and *policy-level* advocacy for SSB taxation and other legislation.

Beverage intakes

Child SSB and water intakes at T1 and T2 were assessed by 2-day caregiver-completed dietary records using standard procedures, as described previously[10]. Briefly, caregivers completed hand-written dietary records with help from food models, utensils and instructional materials on two randomly assigned non-consecutive days (weekdays and/or weekend days) within a 7-day period[10]. Dietary intake data were entered into the Pacific Tracker 3 (PacTrac3) software (v3·1; University of Hawaii, HI), an update to PacTrac2[13]. Similar to national nutrition surveys[14], SSB included regular soft drinks, fruit drinks, sports drinks, energy drinks, sweetened coffees and sweetened teas. Water intake included water consumed as a beverage alone. Daily SSB and water intakes in milliliters (ml) were averaged across the 2-day dietary records, weighted at 5/7 for weekdays and at 2/7 for weekend days and adjusted for within-person variance across days using variance components[15]. In alignment

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with CHL guidance to drink water instead of SSB and recent research recommendations from the 2019 Healthy Eating Research 'Healthy Beverage Consumption in Early Childhood' report, a beverage substitution measure was also estimated (SSB minus water) at T1 and T2[2].

Statistical methods

The distribution and mean (SD) number of implemented SSB and water activities at each SEM level were calculated across the nine intervention communities. Mean (SD) beverage intakes (ml/d) were calculated for T1 and T2. Multilevel linear regression models examined associations between the number of implemented SSB and water activities, overall and for each SEM level, with community changes over time in child SSB intake, water intake and water-for-SSB substitution (operationalised as SSB minus water intake). Models accounted for the complex intervention design with jurisdiction as strata and clustering within community and included adjustment for child age and sex[10]. The significance of the association of intervention activities on change in beverage consumption was performed using a Wald test of a contrast of the estimate of the unit change in intakes between the two time points (T2 minus T1) per single activity. All analyses were performed using SAS v9.4.

Results

Analysis was limited to children in intervention communities with dietary records: *n* 1343 at T1 (88·5 % of enrolled children; mean age 65·5 (SD 21·2) months) and *n* 1158 at T2 (86·3 % of enrolled children; mean age 65·5 (SD 22·2) months). Most children were of Native Hawaiian or Pacific Islander descent (Table 1).

Intervention activities

On average, each community implemented 74 (SD 39) SSB activities and 72 (SD 40) water activities during the 24-month CHL intervention (Table 2). Of the total 667 SSB activities and 649 water activities implemented across communities, more than 90 % (*n* 617) targeted both SSB and water behaviours together. In examining the distribution of activities across SEM levels, community-level activities were most common (61 % of total activities) and child-level activities were least common (4 %). There was considerable heterogeneity in the number of implemented activities by community. The 'most active' community implemented 159 SSB and 162 water activities, respectively, whereas the 'least active' community implemented 38 SSB and 38 water activities.

Beverage intakes

On average, intervention group children consumed 167 (SD 165) ml/d of SSB at T1 and 155 (SD 173) ml/d at T2. Children consumed an average 357 (SD 256) ml/d of water at T1 and 385 (SD 301) ml/d at T2. The estimated average daily substitution of water-for-SSB was greater at T2 (−300 (SD 343) ml/d) than T1 (−190 (SD 297) ml/d).

Intervention activities and beverage intakes

Table 3 describes the estimates and corresponding 95 % CI for community changes in children's SSB and water intakes per single intervention activity at each SEM level and overall. No significant associations were observed between SSB activities and child SSB intake. Each additional community-level water activity was associated with increased water intake ($P = 0{\cdot}03$) and water-for-SSB substitution ($P = 0{\cdot}04$) over time. Although not statistically significant, activities implemented at the organisation- and policy levels also suggested greater water-for-SSB substitution at T2 *v.* T1 ($P < 0{\cdot}10$).

Discussion

We examined changes in young children's SSB and water intakes during the CHL trial in relation to implemented beverage-related intervention activities across levels of the SEM. From baseline to 24-month follow-up, additional community-level intervention activities were significantly associated with increased water intake, alone and relative to SSB intake, among young children in the USAP region.

Few studies have deconstructed complex multilevel interventions like CHL to understand the mechanisms of influence on individual-level dietary outcomes[16]. At a broader scale across 130 US communities, the retrospective Healthy Communities Study contributed to this area by documenting an association between a greater number of implemented community-based nutrition-related intervention activities over a 10-year period (of which SSB and water intakes were two of eleven targeted dietary behaviours) and lower consumption of sugar from SSB among school-age children[17]. Children's water intake was not assessed, nor were paired relationships between beverage-specific intervention strategies and beverage intakes. The current study offers additional evidence in support of community-level interventions aiming to promote children's consumption of healthy beverages.

The magnitude of observed associations between intervention activities and children's beverage intakes was small. For each implemented activity at the community level, the increase in water consumption was approximately 0·6 ml (~1/8 US tsp)/d. For children exposed to the average implemented forty-four water-targeted activities per community (Table 2), this translates to an increase in water consumption of approximately 26 ml (~5 US tsp)/d, or 0·75 cups/week. SEM levels interact to influence individual behaviour[6,7,18], yet our analysis examined activities at each level separately given the challenges to compare, for example, one policy-level activity that potentially reaches thousands of children to one caregiver-level activity that reaches a small group

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Table 1 Characteristics of intervention group children with dietary records (*n* 2501) participating in the Children's Healthy Living trial at baseline (T1) and 24 months (T2), US-Affiliated Pacific region, 2013–2015

	T1		T2		Total	
Characteristic	*n*	%	*n*	%	*n*	%
Total participants	1343	53·7	1158	46·3	2501	100·0
Age group						
2–5 years	606	45·1	531	45·9	1137	45·5
6–8 years	737	54·9	627	54·2	1364	54·5
Sex						
Boys	677	50·4	582	50·3	1259	50·3
Girls	666	49·6	576	49·7	1242	49·7
Race/ethnicity						
White	115	8·6	117	10·1	232	9·3
Black	6	0·5	16	1·4	22	0·9
Asian	81	6·0	66	5·7	147	5·9
Native Hawaiian, Pacific Islander	803	59·8	695	60·0	1498	59·9
American Indian, Alaskan Native	17	1·3	5	0·4	22	0·9
More than one race/ ethnicity	312	23·2	247	21·3	559	22·4
Unknown	9	0·7	12	1·0	21	0·8

of children. Future research will incorporate SEM levels using 'dose' measures calculated from activity frequency, effectiveness and reach[19] towards helping communities decide how to allocate intervention resources for maximum benefit[16].

The distribution of intervention activities across SEM levels – with many community-level activities and few child-level activities – in part reflects the overarching CHL strategy focused on capacity building and broader-scale changes to the social and physical environment[8,10]. The limited number of policy-level interventions was likely reflective of the two-year study duration. Large-scale policy change (such as SSB taxation) requires time to plan and implement. In CHL, the planning period was shortened due to the amount of time required to collect and prepare baseline data for communities to consider in their strategic planning of policy advocacy efforts.

The considerable overlap of intervention activities targeting SSB and water consumption together (more than 90 %) reflects CHL's positive deviance approach and emphasis on positive health messaging. We observed favourable associations between intervention activities, water intake and water-for-SSB substitution, but not SSB intake. The water-for-SSB beverage substitution analysis provides initial insight to the clustering of dietary behaviours among young children in the USAP region, yet further research is warranted to investigate effective strategies for reducing SSB consumption and additional behavioural patterns (e.g. with screen time and sleep).

A major strength of this study is the large sample of young children across the USAP region – a historically underrepresented population in research that is at elevated risk for chronic diseases later in life[1].

Table 2 Number of implemented sugar-sweetened beverage and water activities by level of the social ecological model during the Children's Healthy Living trial, US-Affiliated Pacific region, 2013–2015

		SSB activities					Water activities				
		Total across communities		By community			Total across communities		By community		
SEM level	Example activities	*n*	%	Mean	SD	Range	*n*	%	Mean	SD	Range
Child	Sugar counting game	27	4·0	3·0	3·5	0, 9	26	4·0	2·9	3·1	0, 9
Caregiver	Training for educators and home care providers	105	15·7	11·7	13·2	1, 38	100	15·4	11·1	13·2	0, 37
Organisation	Strengthening or implementing wellness policies in childcare or preschool settings	77	11·5	8·6	5·7	1, 20	78	12·0	8·7	6·0	1, 20
Community	Social marketing; advocacy for clean water access	405	60·7	45·0	19·4	21, 75	393	60·6	43·7	19·6	19, 79
Policy	Advocacy for SSB tax and other legislation	53	8·0	5·9	5·2	1, 17	52	8·0	5·8	5·1	1, 17
Total activities across levels*		667	100·0	74·1	39·1	38, 159	649	100·0	72·1	39·5	38, 162

SEM, social ecological model; SSB, sugar-sweetened beverage.
*More than 90 % of all activities (*n* 617) targeted both SSB and water behaviours together.

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Table 3 Changes in children's daily sugar-sweetened beverage and water intakes (n 2501) in relation to implemented intervention activities by social ecological model levels during the Children's Healthy Living trial, US-Affiliated Pacific region, 2013–2015*

	Change in SSB intake (ml/d) per single SSB activity			Change in water intake (ml/d) per single water activity			Change in replacement of SSB intake by water intake (ml/d)† per single SSB activity			Change in replacement of SSB intake by water intake (ml/d)† per single water activity		
Intervention activities	Estimate	95 % CI	*P*	Estimate	95 % CI	*P*	Estimate	95 % CI	*P*	Estimate	95 % CI	*P*
SEM level												
Child	−1·34	−9·05, 6·37	0·67	3·57	−7·44, 14·58	0·44	−3·72	−10·06, 2·63	0·19	−4·75	−12·78, 3·28	0·19
Caregiver	0·26	−1·14, 1·66	0·65	0·56	−1·09, 2·21	0·42	−0·31	−1·80, 1·18	0·61	−0·23	−1·75, 1·30	0·72
Organisation	0·08	−2·06, 2·22	0·93	4·20	−0·61, 9·01	0·07	−4·02	−8·08, 0·04	0·05	−3·72	−7·34, −0·11	0·05
Community	−0·24	−0·77, 0·30	0·31	0·62	0·09, 1·15	0·03	−0·72	−1·55, 0·10	0·07	−0·88	−1·72, −0·03	0·04
Policy	−2·47	−7·60, 2·67	0·27	1·48	−1·60, 4·56	0·27	−3·80	−7·93, 0·33	0·06	−3·80	−8·11, 0·51	0·07
Overall	−0·09	−0·33, 0·15	0·38	0·33	−0·07, 0·72	0·09	−0·37	−0·75, 0·02	0·06	−0·41	−0·83, 0·01	0·05

SEM, social ecological model; SSB, sugar-sweetened beverage.

*Estimated from multilevel linear regression of community beverage intakes on activities, accounting for complex design with jurisdictions as strata and clustering within community and including adjustment for child age and sex. Separate models were fit for activities at each SEM level and for overall activities at all levels.

†Operationalised as SSB intake minus water intake.

Further, the analysis utilises rigorous quantitative measures of SSB and water consumption from 2 days of dietary records, in addition to standardised monthly reports that detail the implementation of intervention activities in each participating intervention community.

Several limitations must be considered. First, this secondary analysis included children in the CHL intervention arm only. Causality of the effect of intervention activities on children's beverage consumption cannot be determined. Second, data were collected in serial cross-sections with two participant groups. We therefore estimated community changes in child beverage intakes over time, not within-child changes. Third, the lack of follow-up data beyond 24 months precludes the ability to examine sustained interventions and policies that may have taken longer to plan and implement, though this data collection is underway. Finally, there may be limited generalisability to other community-based childhood obesity prevention trials and population groups outside of the Pacific region.

Conclusions

In the CHL trial, community-level intervention activities were associated with increased water intake, alone and relative to SSB intake, among young children in the USAP region. The approach applied in this paper can be utilised in examining other behavioural and biological outcomes relevant to multilevel childhood obesity prevention interventions.

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