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

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Short title: CHL social ecological model and beverages

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**Ethical Standards Disclosure:** This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the institutional review boards at the University of Alaska, University of Guam, and University of Hawai‘i at Mānoa (which also oversaw human subjects research procedures for Northern Marianas College and American Samoa Community College). Caregivers provided written informed consent to participate and children provided assent.
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 analyzed from nine intervention arm communities. Implemented intervention activities targeting reduced SSB and increased water consumption were coded by SEM level (child, caregiver, organization, community, policy). Child SSB and water intakes were assessed by caregiver-completed two-day dietary records. Multilevel linear regression models examined associations of changes in beverage intakes with activity frequencies at each SEM level.


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/day/activity; 95% CI: 0.09, 1.15) and water-for-SSB substitution (operationalized as SSB minus water: -0.88 mL/day/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
Introduction

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—are common dietary targets to limit excess, nutrient-poor calories that may contribute to chronic disease risks\(^{(2-5)}\). Following a social ecological model (SEM) of health behavior\(^{(6, 7)}\), 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 behaviors\(^{(2, 3)}\). 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 Program (CHL) was a multilevel, multicomponent community-randomized trial that took place between 2013 and 2015 in 27 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 favorable intervention effects on anthropometric and acanthosis nigricans outcomes, significant differences in behavioral outcomes between children in the intervention and comparison communities were not observed\(^{(8)}\). Further process-oriented investigation is required to understand these findings, particularly toward 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, versus other behavioral 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 (9 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 comprised of five to seven members representing local academic institutions and community-based organizations. These CHL jurisdiction project teams led the selection of intervention activities from a template of 19 activities, of which 14 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 organizations 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 standardized 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, organization, community, 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; organization-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 two-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), SSBs 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 two-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 with CHL guidance to drink water instead of SSBs 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/day) 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 (operationalized 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\(^\text{(10)}\). 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 \((T2 \text{ minus } T1)\) 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 behaviors 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/day of SSBs at T1 and 155 (SD 173) mL/day at T2. Children consumed an average 357 (SD 256) mL/day of water at T1 and 385 (SD 301) mL/day at T2. The estimated average daily substitution of water-for-SSBs was greater at T2 (-300 (SD 343) mL/day) than T1 (-190 (SD 297) mL/day).

**Intervention activities and beverage intakes**
Table 3 describes the estimates and corresponding 95% confidence intervals 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 ($p = 0.03$) and water-for-SSB substitution ($p = 0.04$) over time. Although not statistically significant, activities implemented at the organization- and policy-levels also suggested greater water-for-SSB substitution at T2 versus T1 ($p < 0.10$).

**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. At a broader scale across 130 U.S. 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 2 of 11 targeted dietary behaviors) and lower consumption of sugar from SSBs among school-aged children. 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) per day. For children exposed to the average implemented 44 water-targeted activities per community (Table 2), this translates to an increase in water consumption of approximately 26 mL (~5 US tsp) per day, or 0.75 cups per
week. SEM levels interact to influence individual behavior\(^6,7,18\), 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 of children. Future research will incorporate SEM levels using “dose” measures calculated from activity frequency, effectiveness, and reach\(^19\) toward 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 favorable 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 behaviors among young children in the USAP region, yet further research is warranted to investigate effective strategies for reducing SSB consumption and additional behavioral 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\(^1\). Further, the analysis utilizes rigorous quantitative measures of SSB and water consumption from two days of dietary records, in addition to standardized 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 generalizability 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 utilized in examining other behavioral and biologic outcomes relevant to multilevel childhood obesity prevention interventions.
References


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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>T1</th>
<th>T2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Total participants</td>
<td>1343</td>
<td>53.7</td>
<td>1158</td>
</tr>
<tr>
<td>Age group, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-5y</td>
<td>606</td>
<td>45.1</td>
<td>531</td>
</tr>
<tr>
<td>6-8y</td>
<td>737</td>
<td>54.9</td>
<td>627</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>677</td>
<td>50.4</td>
<td>582</td>
</tr>
<tr>
<td>Girls</td>
<td>666</td>
<td>49.6</td>
<td>576</td>
</tr>
<tr>
<td>Race/ethnicity, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>115</td>
<td>8.6</td>
<td>117</td>
</tr>
<tr>
<td>Black</td>
<td>6</td>
<td>0.5</td>
<td>16</td>
</tr>
<tr>
<td>Asian</td>
<td>81</td>
<td>6.0</td>
<td>66</td>
</tr>
<tr>
<td>Native Hawaiian, Pacific Islander</td>
<td>803</td>
<td>59.8</td>
<td>695</td>
</tr>
<tr>
<td>American Indian, Alaskan Native</td>
<td>17</td>
<td>1.3</td>
<td>5</td>
</tr>
<tr>
<td>More than one race/ethnicity</td>
<td>312</td>
<td>23.2</td>
<td>247</td>
</tr>
<tr>
<td>Unknown</td>
<td>9</td>
<td>0.7</td>
<td>12</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>SEM level</th>
<th>Example activities</th>
<th>SSB activities</th>
<th>Water activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total across communities</td>
<td>By community</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Child</td>
<td>Sugar counting game</td>
<td>27</td>
<td>4.0</td>
</tr>
<tr>
<td>Caregiver</td>
<td>Training for educators and home care providers</td>
<td>105</td>
<td>15.7</td>
</tr>
<tr>
<td>Organization</td>
<td>Strengthening or implementing wellness policies in childcare or preschool settings</td>
<td>77</td>
<td>11.5</td>
</tr>
<tr>
<td>Community</td>
<td>Social marketing; advocacy for clean water access</td>
<td>405</td>
<td>60.7</td>
</tr>
<tr>
<td>Policy</td>
<td>Advocacy for SSB tax and other legislation</td>
<td>53</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td><strong>Total activities across levels</strong></td>
<td><strong>667</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

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

a More than 90% of all activities (n = 617) targeted both SSB and water behaviors together.
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, 2013-2015a

<table>
<thead>
<tr>
<th>Intervention activities</th>
<th>Change in SSB intake (mL/day) per single SSB activity</th>
<th>Change in water intake (mL/day) per single water activity</th>
<th>Change in replacement of SSB intake by water intake (mL/day)b per single SSB activity</th>
<th>Change in replacement of SSB intake by water intake (mL/day)b per single water activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate 95% CI p</td>
<td>Estimate 95% CI p</td>
<td>Estimate 95% CI p</td>
<td>Estimate 95% CI p</td>
</tr>
<tr>
<td>SEM level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child</td>
<td>-1.34 -9.05, 6.37 0.67</td>
<td>3.57 -7.44, 14.58 0.44</td>
<td>-3.72 -10.06, 2.63 0.19</td>
<td>-4.75 -12.78, 3.28 0.19</td>
</tr>
<tr>
<td>Caregiver</td>
<td>0.26 -1.14, 1.66 0.65</td>
<td>0.56 -1.09, 2.21 0.42</td>
<td>-0.31 -1.80, 1.18 0.61</td>
<td>-0.23 -1.75, 1.30 0.72</td>
</tr>
<tr>
<td>Organization</td>
<td>0.08 -2.06, 2.22 0.93</td>
<td>4.20 -0.61, 9.01 0.07</td>
<td>-4.02 -8.08, 0.04 0.05</td>
<td>-3.72 -7.34, -0.11 0.05</td>
</tr>
<tr>
<td>Community</td>
<td>-0.24 -0.77, 0.30 0.31</td>
<td>0.62 0.09, 1.15 0.03</td>
<td>-0.72 -1.55, 0.10 0.07</td>
<td>-0.88 -1.72, -0.03 0.04</td>
</tr>
<tr>
<td>Policy</td>
<td>-2.47 -7.60, 2.67 0.27</td>
<td>1.48 -1.60, 4.56 0.27</td>
<td>-3.80 -7.93, 0.33 0.06</td>
<td>-3.80 -8.11, 0.51 0.07</td>
</tr>
<tr>
<td>Overall</td>
<td>-0.09 -0.33, 0.15 0.38</td>
<td>0.33 -0.07, 0.72 0.09</td>
<td>-0.37 -0.75, 0.02 0.06</td>
<td>-0.41 -0.83, 0.01 0.05</td>
</tr>
</tbody>
</table>

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

* 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.

b Operationalized as SSB intake minus water intake.