Estimating intervention dose of the multilevel multisite children's healthy living program intervention

Jean Butel,[1] Kathryn L. Braun,[2] Claudio R. Nigg,[2] Rachael Leon Guerrero,[3] Travis Fleming,[4] Andrea Bersamin,[5] Patricia Coleman,[6] Rachel Novotny[1]

[1] Colege of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, HI 96822, USA

[2] Office of Public Health Studies, University of Hawaii at Manoa, Honolulu, HI 96822, USA

[3] University of Guam, Mangilao, GU

[4] American Samoa Community College, Mapusaga, AS

[5] University of Alaska at Fairbanks, Fairbanks, AK 99775, USA

[6] Northern Marinas College, Saipan, MP

Correspondence to: J Butel,
jbutel@hawaii.edu

Abstract

Increased community collective efficacy (CE), defined as social cohesion among neighbors and their willingness to intervene for common good, is associated with improved community health outcomes. However, processes to increase CE and estimate its dose within an intervention are not well understood. The 2 year Children's Healthy Living (CHL) intervention aimed to improve child behaviors known to affect obesity. We used data from CHL to estimate CE dose and examine its association with a successful outcome from CHL—reduction in children's recreational screen time. Monthly reports from nine intervention communities were quantified, and CE dose was calculated for each community overall, at 4 time intervals (6, 12, 18, and 24 months), and for each CE building block—social bonding, social bridging, social leveraging, empowerment, and civic engagement. CE dose at each time interval and change in screen time was correlated using Spearman's rho. Next, communities were categorized as having a high CE dose or a low CE dose, and differences between four high-dose and five low-dose communities were compared using a two-tailed t-test. The correlation between change in screen time and CE dose was significant (r_s = 0.83, p = .003). Significantly more activities facilitating empowerment and civic engagement were conducted in high-dose communities, which were more likely to show improvements in screen time, than in low-dose communities. This method of estimating an intervention's CE dose and examining change over time and effect of CE and its building blocks on intervention outcomes shows promise.

Keywords

Collective efficacy, Childhood obesity, Community intervention, Intervention dose

INTRODUCTION

Collective efficacy (CE) is defined as "social cohesion among neighbors combined with their willingness to intervene on behalf of the common good" [1] (p. 918). Social cohesion consists of social capital sub-components (social bonding, social bridging, and social leveraging), and the willingness to act/intervene involves the sub-components of empowerment and civic engagement [2]. In this paper, social bonding, social bridging, social leveraging, empowerment, and civic engagement are referred to as building blocks of CE [2–5] (Table 1).

Improving CE shows promise for improving health outcomes. For example, communities with higher

Implications

Practice: Implementation of activities addressing collective efficacy building blocks empowers communities to make positive changes.

Policy: Interventions have the ability to unite and empower communities resulting in civic engagement.

Research: Establishing a method to measure collective efficacy dose provides a tool for researchers to examine complex multilevel interventions.

CE have lower prevalence of obesity, depression, and risk-taking behaviors and lower rates of morbidity and mortality when compared with similar communities with lower CE [6–9]. Higher CE also has been found to be associated with spending fewer hours watching television, playing computer games, and engaging in social media (known as recreational screen time), and screen time has been positively associated with overweight and obesity [7].

There has been some research examining how social capital can increase social cohesion and CE [2,10,11]. However, strategies to increase CE have not been well described, and likely entail intervening at multiple levels of the socio-ecological model (SEM)—including interpersonal, intrapersonal, organizational, community, and policy [12]. There is a lack of research on how to operationalize CE concepts in interventions and use CE as a focus of change and a unit of measure in multilevel community interventions [13–15].

Based on the literature, a model of the CE mechanism of action was developed that shows how intervention activities—such as hands-on training, leadership development, peer mentorship, community events, directed projects, and advocacy—can strengthen the five CE building blocks which, in turn, increase CE and improve health outcomes (Fig. 1) [12]. However, no published literature was found on recommended "dose" of CE and CE-building-block

Table 1 | Hierarchical chart of collective efficacy components

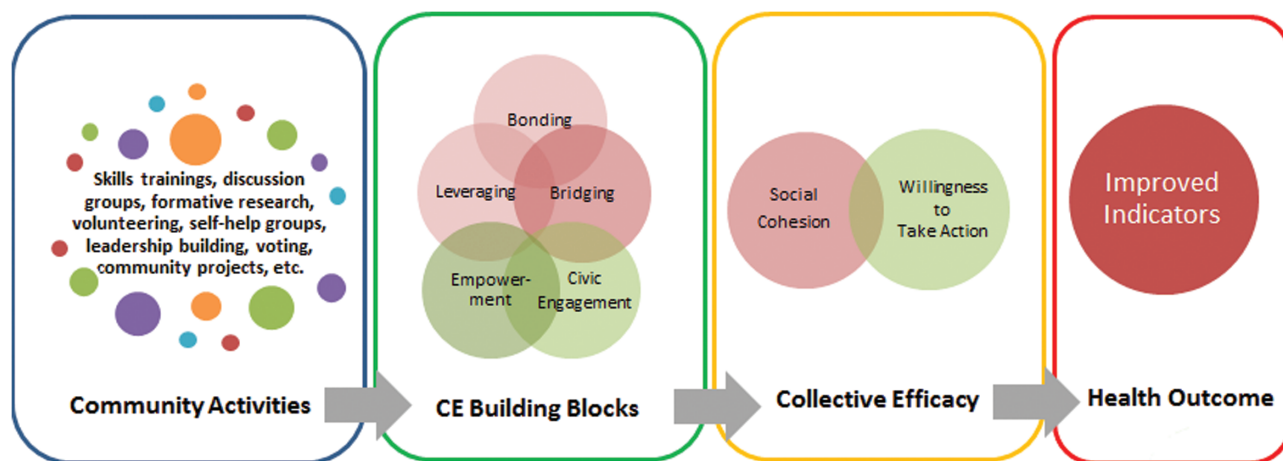| Collective efficacy	
Components	
Social Cohesion	Willingness to Act
Sub-components (building blocks)	
Social Bonding: local ties within neighborhoods or groups [3] (i.e., Alliance between community place-based education groups)	Empowerment: builds individual and group capacity to make choices and turn them into desired outcomes [5] (i.e., training caregivers to incorporate physical activity into the classroom)
Social Bridging: distant ties to other groups in the community [3] (i.e., a land-based community non-profit working with community health center to increase access to fruits and vegetables)	Civic Engagement: activities in which community members or groups take part in policy and/or community change [2] (i.e., advocating for new playground equipment)
Social Leveraging: linkages between the community and groups with power and/or resources [4] (i.e., health group sponsoring a "double bucks" EBT program at local farmer's market)	

Fig 1 | Collective efficacy mechanisms to action model [12].

activities in interventions, or how to measure them. The purpose of this study was to address this gap in the CE literature by examining the following research questions. How can CE dose be measured? Did the overall CE dose and the dose of the five CE building blocks in a multilevel intervention correlate with change in screen time overall and over the 2 year intervention?

MATERIALS AND METHODS

Comprehensive analysis of complex interventions can serve as a guide for the estimation of dose in CE-guided interventions. The Children's Healthy Living (CHL) program was a multicomponent, multilevel, multisite intervention aimed at preventing young child obesity. CHL intervention effects were tested through a cluster randomized controlled trial (CRCT) in five jurisdictions (Alaska, American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, and Hawai'i), where nine communities received the intervention, and nine matched communities served as delayed-intervention controls [16]. Communities were

selected based on population size of greater than 1,000 and having more than 25% of the population of indigenous/native ancestry [16]. Institutional Review Board (IRB) approval or ceding of approval to the University of Hawai'i at Mānoa was obtained in each jurisdiction.

The CHL CRCT aimed to evaluate the intervention's impact on anthropometric indicators including body mass index (BMI) and waist circumference, acanthosis nigricans, and six behavioral objectives for children age 2–8 years—increasing fruit and vegetable intake, water consumption, physical activity, and sleep duration and reducing recreational screen time and sugar-sweetened beverage consumption [16]. The intervention had a significant positive effect on decreasing acanthosis nigricans, waist circumference, overweight and obesity status, and recreational screen time [17].

Over the 2 year intervention period (January 2013 through December 2014), each of the nine CHL intervention communities submitted monthly process reports to the CHL coordinating center. The monthly report categorized activities based on

four strategies: (a) POLICY—Review and improve assessment data as needed for policy and physical environment related to six CHL behaviors; (b) ENVIRONMENT—Partner and advocate for environmental change; (c) SOCIAL MARKETING—Promote the CHL behavioral messages; (d) CAPACITY BUILDING—Train the trainers. These reports were used to first estimate intervention dose and then to estimate CE dose.

A method to estimate intervention dose was developed using methods from Glasgow [18], who presented a method combining reach and effectiveness, and concepts from Cheadle [19], who defined population dose as "the estimated community-level change in the desired outcome expected to result from a given community-change strategy" (p. 74). Cheadle et al. [20] applied this population−dose model to Kaiser Permanente's Community Health Initiative to increase physical activity in middle-school students. Strategies were coded as having "low," "medium," or "high" effect potential, and the investigators found that communities with a "high dose" had more positive behavioral outcomes.

Building on Cheadle et al., CHL activity dose was the product of the reach of the activity into the target population, and the expected effectiveness of the strategy on the target population. A CHL activity dose was calculated (Activity Dose = Number of activities conducted x effectiveness score x total number of participants/intended number of participants) for each intervention activity. The number of activities came from the monthly reports and the effectiveness score was based on the relative intervention effectiveness (0.33 for low to 1.00 for high) based on expert opinion (CN). The overall CHL intervention dose was summation of the CHL activity doses. Preliminary testing found a direct, inverse relationship between community intervention dose and recreational screen time, that is, the higher the CHL intervention dose, the greater the decrease in reported screen time among young children.

To calculate CE dose, the CE intervention dose was weighted by the extent to which it facilitated each CE building block—social bonding, social bridging, social leveraging, empowerment, and civic engagement by expert opinion (CN). We defined social bonding activities as those that helped develop strong relationships within the community, social bridging activities as those that connected diverse groups within the community, social leveraging activities as those that utilized resources from organizations outside the community, empowerment activities as those transferring new skills to community members, and civic engagement activities as those in which community members advocated for policies favorable to childhood obesity prevention and activities that created changes in the community. A community gardening activity, for example, may have brought community members together (social

bonding) with extension workers (social bridging) and secured free gardening materials and supplies for the community (social leveraging). Another activity may have trained community members in advocacy (empowerment) and helped them present an issue to government officials (civic engagement).

To assign weights, a rubric was developed using concepts of CE [1,21] with anchoring vignettes to determine the extent to which level of an activity addressed each CE building block. These statements were similar to anchoring statements used to assess community readiness in the CHL readiness survey [22] and the Collaboration Readiness tool [23]. Because the CE building block concepts are difficult to quantitatively measure, the vignettes provided scale anchors that enabled activity comparisons. There were five statements for each building block to determine the building block achievement level. The five anchoring vignettes related to the following levels: (a) not addressed; (b) addressed a little; (c) addressed somewhat; (d) mostly addressed; and (e) completely addressed. A weighted value of 0, 0.25, 0.5, 0.75, or 1.0 was assigned, respectively (Table 2).

Assignment of the CE building block weights to each activity (coding) was done by the first author (J.B.) using the following protocol: (a) Read text in the "what was done" column of the monthly intervention process reports; and (b) Identify the anchoring vignette that best fit the texts for each CE building block. For example, a monthly report stated *"Community Leaders attended food safety training and received certification from the Board of Health."* Because the activity completely focused on skills building, a weighted value of 1.0 for empowerment was given (Table 2). The second reviewer (Michael Butel) completed a validation check of each community's scoring done by the primary reviewer. The two reviewers discussed and resolved scoring differences. There was 96% agreement between the two reviewers, with the remaining 4% of the scores achieving agreement following discussion.

The assessed CE building block weighted value for each intervention activity was multiplied by the respective activity dose (Table 2) to obtain a dose of each CE building block (social bonding, social bridging, social leveraging, empowerment, and civic engagement) for each community. The total community CE intervention dose was the sum of all five CE building block doses accumulated from all intervention activities.

The unit of randomization and data analysis in the CHL intervention was the community. In a preliminary intervention analysis, one outcome variable that improved more in the intervention than control communities was recreational screen time, which decreased in intervention communities and increased in control communities [24]. Screen time was measured in hours/day with a modified six-item questionnaire [25] completed by child's parent or

Table 2 | CE building block rubric and scoring example

CE Building Block (Vignette)	Not at all 0	A little 0.25	Somewhat 0.50	A lot 0.75	Completely 1	Example Activity Score	Example CE Activity Dose[a]
Social Bonding (e.g., built strong relationships in the community [23])	Building strong relationships not addressed	Little relationship building addressed	Some relationship building addressed	Considerable relationship building included	Activity completely focused on building strong relationships	A little (0.25)	0.10
Social Bridging (e.g., included different groups [23])	Did not include another group	Group(s) with many similarities included	Somewhat similar group(s) included	Included a few diverse groups	Several diverse groups included	A little (0.25)	0.10
Social Leveraging (e.g., secured outside resources [23])	No utilization of outside resources	Little use of outside resources	Some use of outside resources	Considerable use of outside resources	Mainly consisted of outside resources	A lot (0.75)	0.29
Empowerment (e.g., skills building [23])	Not addressed	Activity focused a little on skills building	Skills building was secondary to the activity	Skills building was a primary focus	Activity completely focused on skills building	Completely (1.0)	0.39
Civic Engagement (e.g., actively worked toward policy and/or community change [22,23])	Not addressed	Discussed policy and/or community change but not primary to activity	Planned for future policy and/or community change	Very involved with policy and/or community change but not currently active	Actively worked toward targeted policy and/or community change	Not addressed (0.0)	0

[a]Example CE intervention activity dose = 0.39. To obtain CE intervention activity dose, the example activity score was multiplied by 0.39.

caregiver. To reduce the effect of extreme values, the log mean of screen time was estimated and used as the outcome variable in this study. The log mean is a measure of central tendency that computes the arithmetic mean of logarithm-transformed values. CHL outcome changes were calculated using statistical models that included adjustments for sex and age distribution in the community, accounted for sample weights, and stratified by community [17]. Sex and age variables were used to adjust prevalence estimates because previous research established sex and age as significant predictors of overweight and obesity among children [26]. Sample weights were constructed for each CHL participant to represent how many individuals in their respective community each participant's answer represented. Individual case weights were created in order to produce more accurate population estimates from the study sample and involved the reciprocal of the probability of selection. Participants were sampled using a stratified sampling method in order to better estimate prevalence for each of the CHL communities. Subsequently, the model included stratification by CHL community. Spearman's correlation was used to estimate the relationship between change in adjusted log mean screen time and CE intervention dose overall and of its five building blocks from baseline to 24 months of intervention (in four 6 month intervals).

To explore the importance of CE intervention dose and implementation order of CE building blocks, the communities were divided into two groups based on its bimodal distribution. Four communities with an overall CE intervention dose of >200 (range 210.1−465.6, mean 277.8) were placed in the high-dose group, and five communities with an overall CE intervention dose below 150 (range 104.8−141.3, mean 121.4) were placed in the low-dose group. Group means were calculated for overall CE intervention dose and dose of each CE building block for the four intervention intervals. To assess differences in mean CE dose overall and by its building blocks over time in high-dose and low-dose groups, two-tailed t-tests were performed. SAS 9.4 was used for analysis.

RESULTS

Sum of CE doses

The CE intervention dose totals for each of the nine intervention communities ranged from 104.78 to 465.60, with a median of 141.26 (Table 3). The dose for each specific CE building block varied and is shown in Table 3. Among all nine intervention communities, intervention dose was highest for social leveraging (499.54) and lowest for civic engagement (171.21), indicating that activities associated with social leveraging were done most often and activities related to civic engagement were done most infrequently. Activities to facilitate social

Table 3 | Change in screen time (hr/day) and CE intervention dose, CHL-wide, and by community

	Low-CE intervention dose group					High-CE intervention dose group			
	Com 1	Com 2	Com 3	Com 4	Com 5	Com 6	Com 7	Com 8	Com 9
Total CE	104.78	106.95	120.98	132.99	141.26	216.82	465.60	210.10	218.81
Social Bonding	26.60	13.18	22.87	25.10	37.70	39.55	103.12	36.47	41.36
Social Bridging	13.17	35.23	25.24	29.11	22.00	49.58	106.58	26.98	39.87
Social Leveraging	29.65	40.38	37.07	40.02	37.78	69.69	124.44	60.09	60.47
Empowerment	27.86	16.99	26.09	27.93	41.19	39.36	85.99	46.27	42.14
Civic Engagement	7.51	1.16	9.70	10.83	2.60	18.69	45.46	40.29	34.97
Adjusted log mean change in screen time	.15	.13	.01	-.04	-.05	-.06	-.08	-.14	-.16

bonding, social bridging, and empowerment had intermediary doses (345.96, 347.76, and 353.83, respectively). The percentage of the total CE dose for each building block was similar at each 6 month time interval, reflecting no definitive order to implementation of CE building blocks in the intervention, CHL-wide (Fig. 2).

Based on bimodal distribution, four communities with overall CE intervention dose of >200 (range 210.10−465.60, mean 277.80) were placed in the high-dose group, and five communities with an overall CE intervention dose below 150 (range 104.78−141.26, mean 121.40) were placed in the low-dose group. The four high-dose communities had greater change in log mean screen time (range −0.16 to −0.06, mean −0.11), whereas in the five low-dose communities, screen time change was lower (0.15 to −0.05, mean 0.04; Table 3). High-dose communities were different from low-CE intervention dose communities in number of activities coded to each of the five building blocks. For example, civic engagement CE building block dose ranged from 18.69 to 45.46 in high-CE intervention dose communities versus 1.16 to 10.83 in low-CE intervention dose communities. This suggests that activities that facilitated empowerment and civic engagement were key in decreasing screen time.

Correlation to screen time by building block and over time

As shown in Table 4, Spearman's correlations confirmed a statistically significant inverse relationship between overall CE dose and log mean screen time in young children (r_s = −0.83, CI −0.96, −0.33) [27]. The correlations between each CE building block dose and change in log mean screen time also are shown in Table 4. Change in screen time was significantly correlated with the CE building blocks of social leveraging, empowerment, and civic engagement (r_s = −0.72, −0,72, and −0.75, respectively). Examination of the four time intervals showed a significant correlation to change in screen time at time intervals one and three. However, not all CE building blocks showed significant correlations with change in screen time. At time interval one, social bonding CE building block (r_s = −0.72, CI −.93, −.06) and empowerment CE building block (r_s = −0.63, CI −.90, −.10) were correlated to change in screen time. At time interval three, total CE intervention dose (r_s = −0.77, CI −.94, −.16) and the CE building blocks of social bridging (r_s = −0.72, CI −.93, −.06), social leveraging (r_s = −0.82, CI −.96, −.29), and civic engagement (r_s = −0.75, CI −.94, −.16) were correlated to change in screen time. This suggests that activities of building trust (social bonding) and developing skills (empowerment) in communities were needed prior to reaching out to other groups (social bridging), engaging outside resources (social leveraging), and implementing community change activities (civic engagement) to effect change in screen time in CHL communities.
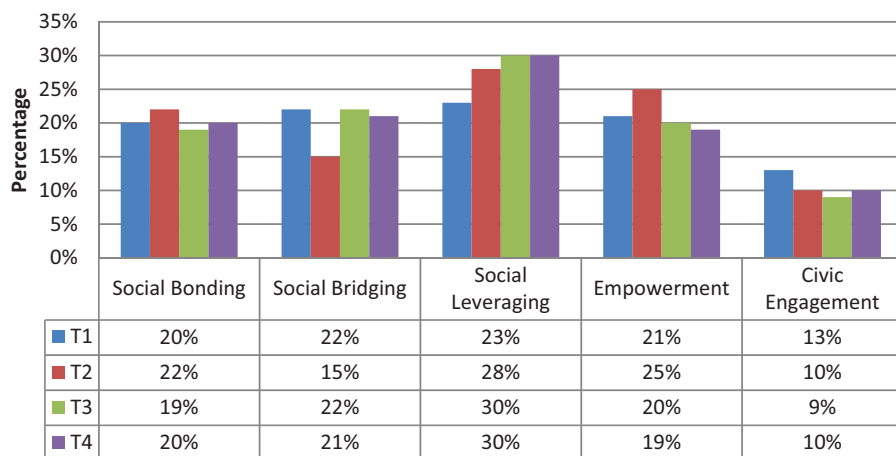
	Social Bonding	Social Bridging	Social Leveraging	Empowerment	Civic Engagement
T1	20%	22%	23%	21%	13%
T2	22%	15%	28%	25%	10%
T3	19%	22%	30%	20%	9%
T4	20%	21%	30%	19%	10%

Fig 2 | CHL-wide CE building block percentage of total collective efficacy intervention dose by intervention time interval (*n* = 4 time intervals of 6 months each).

Table 4 | Spearman's correlation between overall collective efficacy intervention dose and CE building block doses and change in log mean screen time (hr/day) over time

	r_s	CI (95%)
Overall		
Total Collective Efficacy	**−0.83**	**(−.96, −.33)**
Social Bonding	−0.65	(−.91, .07)
Social Bridging	−0.55	(−.88, .21)
Social Leveraging	**−0.72**	**(−.93, −.06)**
Empowerment	**−0.72**	**(−.93, −.06)**
Civic Engagement	**−0.75**	**(−.94, −.13)**
Time Interval 1 (0–6 months)		
Total Collective Efficacy	−0.65	(−.91, .07)
Social Bonding	**−0.72**	**(−.93, −.06)**
Social Bridging	−0.43	(−.84, .35)
Social Leveraging	−0.52	(−.87, .25)
Empowerment	**−0.63**	**(−.90, −.10)**
Civic Engagement	−0.29	(−.83, .38)
Time Interval 2 (6–12 months)		
Total Collective Efficacy	**−0.42**	**(−.84, .36)**
Social Bonding	−0.07	(−.70, .63)
Social Bridging	**−0.15**	**(−.74, .58)**
Social Leveraging	**−0.62**	**(−.90, .12)**
Empowerment	−0.25	(−.78, .51)
Civic Engagement	**−0.58**	**(−.89, .18)**
Time Interval 3 (12–18 months)		
Total Collective Efficacy	−0.77	(−.94, −.16)
Social Bonding	−0.68	(−.92, .01)
Social Bridging	−0.72	(−.93, −.06)
Social Leveraging	−0.82	(−.96, −.29)
Empowerment	−0.63	(−.91, .09)
Civic Engagement	−0.75	(−.94, −.16)
Time Interval 4 (18–24 months)		
Total Collective Efficacy	−0.57	(−.89, .19)
Social Bonding	−0.62	(−.87, .28)
Social Bridging	−0.27	(−.78, .50)
Social Leveraging	−0.33	(−.81, .44)
Empowerment	−0.27	(−.78, .50)
Civic Engagement	−0.50	(−.90, .12)

Bold values are significant at a 95% CI.

Difference in CE building blocks between high- and low-intervention dose groups

To compare CE building blocks between high- and low-intervention dose communities, means were compared for total CE intervention dose and the dose for each CE building block (Table 5). There was a significant difference in means between the high- and low-dose groups for the CE building blocks of empowerment (0.05 for overall and 0.04 at time interval 2) and civic engagement (0.001 for overall and 0.02, 0.04, and 0.02 at time intervals 2, 3, and 4, respectively) with borderline significance for total CE, social bridging, and social leveraging. This finding indicates that civic engagement may have been a factor in the differences seen between communities.

DISCUSSION

This cross-case analysis of the CHL intervention implementation had two main findings: (a) communities with higher CE intervention doses realized greater decreases in recreational screen time among their children and (b) activities facilitating empowerment and civic engagement were key in decreasing screen time in the CHL intervention.

CE intervention dose correlated with community change in screen time

In the nine CHL intervention communities, there was a strong negative correlation of total CE intervention dose and change in screen time in young children. Communities with total CE intervention

Table 5 | Mean differences in overall collective efficacy intervention dose and CE building block doses between high ($n = 4$) and low ($n = 5$) dose CE groups, over time

	Group mean (SD)		p Value
Overall	High	Low	
Total CE	277.8 (125.2)	121.4 (15.9)	.09**
Social Bonding	55.1 (32.1)	25.1 (8.8)	.15
Social Bridging	55.8 (35.1)	25.0 (8.2)	.10**
Social Leveraging	78.7 (30.8)	37.0 (4.3)	.07**
Empowerment	53.4 (21.9)	28.0 (8.6)	.05*
Civic Engagement	34.9 (11.6)	6.4 (4.3)	.001*
Time Interval 1 (0–6 months)			
Total CE	31.0 (40.3)	7.0 (0.4)	.32
Social Bonding	6.8 (8.7)	0.9 (1.2)	.27
Social Bridging	6.5 (8.7)	2.0 (1.9)	.38
Social Leveraging	6.2 (8.3)	2.3 (1.7)	.33
Empowerment	7.1 (8.9)	1.0 (1.3)	.26
Civic Engagement	4.3 (5.8)	0.8 (0.7)	.31
Time Interval 2 (6–12 months)			
Total CE	59.7 (34.2)	19.7 (9.4)	.10**
Social Bonding	12.8 (10.0)	4.7 (2.8)	.23
Social Bridging	8.4 (7.8)	3.4 (1.0)	.29
Social Leveraging	17.4 (8.1)	5.3 (1.9)	.05*
Empowerment	14.4 (7.2)	5.3 (3.7)	.04*
Civic Engagement	6.6 (4.1)	1.0 (1.4)	.02*
Time Interval 3 (12–18 months)			
Total CE	101.9 (53.4)	44.1 (18.7)	.06**
Social Bonding	18.6 (13.0)	9.1 (5.7)	.19
Social Bridging	23.2 (14.1)	9.1 (6.3)	.09**
Social Leveraging	29.9 (15.2)	13.5 (7.2)	.07**
Empowerment	17.2 (9.5)	10.9 (5.5)	.25
Civic Engagement	12.9 (6.7)	1.5 (1.5)	.04*
Time Interval 4 (18–24 months)			
Total CE	85.3 (50.8)	50.6 (20.5)	.07**
Social Bonding	16.7 (5.2)	10.4 (4.4)	.08**
Social Bridging	17.7 (8.2)	10.4 (7.3)	.20
Social Leveraging	25.1 (5.8)	15.9 (7.9)	.09**
Empowerment	14.7 (5.0)	10.9 (4.5)	.26
Civic Engagement	10.0 (4.8)	3.0 (3.4)	.02*

*Significant difference in mean ($p \leq .05$).
**Borderline significant difference in mean ($p \leq .10$).

dose of greater than 200 saw greater decrease in screen time from baseline to 24 months than those with less than 200. This suggests that a minimal CE dose may be needed to realize positive outcomes from community-change interventions.

Activities facilitating social leveraging (activities that brought in resources from outside the community) were conducted most often across communities, whereas activities facilitating civic engagement (activities that brought community members together to champion policy or community change) were conducted least frequently. However, high-dose communities conducted significantly more activities to facilitate civic engagement. High-dose communities also engaged in more activities that built community skills (empowerment) than low-dose communities, and a higher dose of empowerment activities was associated with greater reductions in screen time.

To ensure sustainability of the CHL intervention, a guiding principle was to "support what was already working in the community" [28]. This may have been why activities supporting social leveraging were most frequently performed. Specifically, resources provided to communities by the CHL grant and through land grant colleges' connections to other agencies were categorized into the social leveraging CE building block. Leveraging activities also are a quick way to secure community engagement and win community support for intervention implementation. Involving communities in civic engagement activities likely requires time, as one must first develop community relationships, capacity, social structures, and opportunities for involvement [2,29]. The need to establish community relationships and capacity in CHL intervention communities took time and may explain the lower civic engagement doses, compared with other CE building blocks.

Activities facilitating empowerment and civic engagement were key

Empowerment and civic engagement are the two building blocks of the CE component "willingness to act" [12]. These two CE building blocks appeared to be key in effecting positive change in the CHL intervention, as indicated by both their significant correlation with change in screen time and significant differences in group means between high- and low-dose intervention communities. This supports research that suggests that empowerment (the capacity of communities to make choices and transform choices into desired outcomes) is a factor in the ability to act, which affects CE [5,30]. Empowerment in this study focused on capacity building activities such as arming teachers with new strategies to promote child health and developing advocacy skills in community leaders. This finding is also supported in the literature review by Butel and Braun [12] which showed that interventions offering activities to improve civic engagement were more likely to

have improved community health compared with interventions that did not attempt to improve civic engagement. Civic engagement activities for this study were defined as activities that guided the community to consciously work toward policy and/or community change. As an example of working towards a policy change, one community worked with preschools to write wellness policies incorporating nutrition and physical activity standards. In another community, members came together to refurbish playgrounds and build walking paths.

There was not a significant difference between civic engagement CE intervention doses of the high- and low-CE intervention groups at time interval one, suggesting that civic engagement activities took time (at least 6 months) to develop. Empowerment and social bonding showed a strong relationship to change in screen time at time interval one, indicating empowerment and social bonding activities were implemented first. This finding agrees with the literature, as Collins [2] found civic engagement was partially mediated by social capital, in particular social bonding, and empowered individuals were more civically engaged and reported higher levels of CE.

Limitations

This study was limited by the size of the sample ($n = 9$ intervention communities). Thus, the analysis was limited to exploratory methods to estimate CE dose and associate it with outcomes. Also, the vignettes contained in the building block rubric may have been biased by the researcher. To address this, prior literature [22,23] was used to ensure the statements were grounded in the literature, and a second reviewer was utilized to ensure consistency and reliability. The guiding role of the CHL coordinating center and the mechanism of reporting the activities may have affected the determination of CE intervention dose. Additionally, the sustainability of the intervention activities and the long-term effect of the intervention on change in screen time and CE are not known. Additionally, these findings may not be generalizable to non-Pacific populations.

CONCLUSION

The CHL intervention wove all five CE building blocks into CHL intervention activities. The simultaneous development of social cohesion through building strong community relationships (social bonding), opening up the community to additional resources (social leveraging), and bringing in different viewpoints (social bridging), along with building capacity (empowerment) and identifying opportunities to act for the common good (civic engagement) may have created connected communities that felt supported in their efforts to address childhood obesity. This method of tracking and determining CE intervention dose holds promise for evaluating

implementation of large multilevel interventions in communities. It is a dynamic method that has potential to assist in determining how much and which types of intervention activities are needed to achieve positive health outcomes in the community. Further development and testing of the method are needed.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. IRB approval was obtained from the University of Hawaii at Manoa, the University of Guam, and the University of Alaska at Fairbanks. This article does not contain any studies with animals performed by any of the authors.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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Compliance with Ethical Standards

Conflicts of interest: All Authors declare that they have no conflicts of interest.

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