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SNAP-Ed physical activity interventions in low-income schools are associated with greater cardiovascular fitness among 5th and 7th grade students in California

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ABSTRACT

Introduction: California's Department of Public Health (CDPH) distributes Supplemental Nutrition Assistance Program-Education (SNAP-Ed) funding, known as CalFresh Healthy Living (CFHL) in California, to local health departments to implement school-based physical activity/nutrition interventions. We determined the association between intervention presence/dose and student cardiorespiratory fitness and BMI.

Methods: This cross-sectional, observational study included 5th and 7th grade students with 2016–17 FitnessGram® results who attended SNAP-Ed eligible California schools. Intervention group students attended schools with CDPH-CFHL interventions during October 2015-September 2016 (n = 904 schools; 97,504 students, 49% female); comparison group students attended schools without CDPH-CFHL interventions (n = 3,506 schools; 372,298 students, 49% female). Adjusted multilevel models determined the association between school-level intervention presence/dose and students' cardiorespiratory fitness (estimated VO_2max) and BMI z-score, and tested for effect modification by student grade and sex.

Results: Students attending intervention schools demonstrated greater VO_2max (males: 0.18 mL/kg per min, 95% CI: 0.03, 0.34; females = 0.26 mL/kg per min, 95% CI: 0.13, 0.39) and lower BMI z-scores (males: −0.03, 95% CI: −0.05, −0.02; females = -0.02, 95% CI: −0.04, −0.01) than students in comparison schools. Students in schools with the highest intervention levels demonstrated higher VO_2max (0.37 (95% CI: 0.06, 0.16) and 0.22 (95% CI: 0.02, 0.42), respectively), than comparison students, with the strongest associations seen for females and 7th graders.

Conclusion: On average, students in schools with CDPH-CFHL physical activity interventions demonstrated better cardiorespiratory fitness and slightly lower BMI z-scores than students in comparable schools without such programing. Investment in these interventions may positively impact students' cardiorespiratory health, though further causal investigation is warranted.

1. Introduction

Daily physical activity (PA) is an important determinant of youth physical and psychosocial health, as well as an important aspect of youth obesity prevention (National Research Council, 2012; Janssen and LeBlanc, 2010). However only 22% of children ages 6 to 19 years achieve the recommended 60 min of moderate-to-vigorous PA on five or more days of the week (National Research Council, 2012) and in 2018, only 42% of youth in the United States (U.S.) were considered physically fit (Alliance, 2018). Increased cardiovascular fitness in youth is associated with improved academic performance, as well as lower risk for metabolic syndrome and developing cardiovascular disease later in life (Janssen and LeBlanc, 2010; Twisk et al., 2002; Álvarez-Bueno et al., 2020). Maintaining a healthy weight is similarly associated with lower risk for multiple health complications (type 2 diabetes, cardiovascular disease, hypertension, etc.) in youth (Dietz, 1998; Kelsey et al., 2014). Youth from low-income families and youth of color have a higher prevalence of obesity, are less likely to participate in regular PA, and are

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less likely to meet cardiorespiratory fitness benchmarks than their higher-income and white peers (Bowser et al., 2016; Whitt-Glover et al., 2009; Johnston et al., 2007; Eaton et al., 2008; Madsen et al., 2010).

Because youth spend up to half of their waking hours in school, schools are a critical venue for obesity prevention and PA promotion (National Research Council, 2012). The U.S. Department of Agriculture recommends that obesity prevention efforts funded by the Supplemental Nutrition Assistance Program Education (SNAP-Ed, known as CalFresh Healthy Living (CFHL) in California), use multicomponent policy, systems, and environmental (PSE) change interventions i.e., changes to school or district nutrition or PA related policies, systems, and/or environments in addition to direct education (nutrition or PA activities/lessons where participants are actively engaged in the learning process with an educator) and/or indirect education (nutrition or PA information and/or resource distribution in which participants are not actively engaged with an educator).

California has more public school students than any other US state, and is among the most racially/ethnically and economically diverse (National Center for Education Statistics, 2019). The California Department of Public Health's Nutrition Education and Obesity Prevention Branch annually distributes over $50 million in CFHL funding to local health departments to implement PA and nutrition interventions, which primarily occur in the school setting (hereafter referred to as CDPH-CFHL interventions). This constitutes the largest single source of on-going funding for nutrition and PA education, promotion and environmental supports in California. To be CFHL-eligible, schools must either have at least 50% of enrolled students eligible for free or reduced-price meals or be located in a census tract or block group where at least 50% of the population is at or below 185% of the federal poverty line. School-level interventions are selected locally within the parameters of federal SNAP-Ed guidelines and state-level CFHL goals and guidance.

Published evaluation studies of school-based SNAP-Ed interventions have been limited in number and largely qualitative, focusing on schools' readiness and capacity to implement such programs (Pope et al., 2020; Lee et al., 2019). While interventions that focus on PSE changes are becoming more common (Gleason et al., 2018), most studies have reported on the influence of direct education, and found limited impact on student weight status (Molitor et al., 2016; Long et al., 2013; United States Department of Agriculture, Food and Nutrition Service, 2012). Further, the majority of these studies focus on nutrition-related interventions and outcomes; few studies aiming to increase student PA do not demonstrate increased PA and lack objective measures of student health or fitness (Lee et al., 2019; Cheng et al., 2015; Bea et al., 2015; Hecht et al., 2013). The impact of these types of multicomponent, complex, school-based interventions on student health outcomes remains unclear and warrants further study.

Better understanding school-based CDPH-CFHL efforts is critical for making future programmatic and funding decisions in California and other states. In particular, examining outcomes among racially/ethnically diverse and low-income students is necessary for understanding the potential for this work to reduce health disparities. The purpose of this study is to determine the association between the presence and dose of CDPH-CFHL interventions in schools and student fitness (estimated VO_2max) and body mass index (BMI z-scores).

2. Methods

2.1. Study design and sample

This observational, cross-sectional study included California public school 5th and 7th grade students with complete state fitness testing and sociodemographic data from school year 2016–17 who attended CFHL-eligible schools (n = 5,310 schools; 567,410 students). Students attending schools where state agencies other than the CDPH were implementing CFHL interventions (n = 327 schools; 31,970 students) and students attending schools where CDPH-CFHL interventions focused only on nutrition or had missing intervention information (n = 547 schools; 63,293 students) were excluded. Students in the youngest grade served in the school were also excluded, as those students would not have received the intervention at that school the prior year. The intervention group included 97,504 5th and 7th grade students in the 904 CFHL-eligible schools that implemented CDPH-CFHL PA interventions between October 2015 and September 2016. The comparison group consisted of 372,298 5th and 7th grade students in the 3,506 California public schools that did not have any CFHL interventions during the same time period (Fig. 1).

3. CDPH-CFHL intervention

Dose and presence of CDH-CFHL interventions in federal fiscal year 2016 were calculated using data from structured on-line reports completed by local health department staff and contractors. The method for calculated dose is reported in more detail elsewhere (Hewawitharana et al., 2019). In short, intervention sub-scores (or dose) defined as intervention reach times intervention intensity were calculated for each of three types of interventions (direct education, indirect education, and PSE change). Intensity scores were based on breadth of the PSE changes made, number of hours of direct education and number of distinct materials and events for indirect education. Intervention fidelity was either not relevant or not measured. The three sub-scores were scaled and combined to create two scores for each school: one for schools' PA interventions and one for schools' combined interventions, scoring both nutrition and PA interventions (PA + nutrition intervention score). A binary indicator of whether *any* CDPH-CFHL PA intervention was present in the school was also created. Intervention dose scores, schools were categorized into one of five groups (no, low, medium–low, medium–high, and high intervention), using naturally occurring cut points in the distribution of the score.

4. Student fitness

Student-level FitnessGram data was obtained from the California Department of Education. In the spring of each school year, California public school 5th, 7th, and 9th grade students participate in the FitnessGram®, a battery of six tests. Aerobic capacity (Test 1) is evaluated using estimates of VO_2max (maximal oxygen uptake), which reflects the maximum rate at which the cardiovascular, respiratory, and muscular systems take in, transport, and use oxygen during PA.(The California Department of Education, 2017) Aerobic capacity (estimated VO_2max in mL/kg per min) was calculated from student 1-mile run, (Cureton et al., 1995) Progressive Aerobic Cardiovascular Endurance Run (PACER),(Mahar et al., 2018) and 1-mile walk(Kline et al., 1987; McSwegin et al., 1998) test data per the FitnessGram guidelines (Plowman and Meredith, 2013). If a student had data from more than one test, his/her highest VO_2max value was used. VO_2max values were considered implausible if they were 3 standard deviations above/below the sample mean age- and sex-specific VO_2max values. Body composition (Test 2) is measured by either (a) body mass index (BMI) assessed using a scale and stadiometer/ruler (most common) or (b) percent body fat, assessed by skinfold measurements or bioelectrical impedance analyzer. BMI z-scores were calculated from student height, weight, sex, and age data using the U.S. Centers for Disease Control growth charts (Kuczmarski et al., 2000) and corresponding SAS program (available at https://www.cdc.gov/nccdphp/dnpao/growthcharts/ resources/sas.htm). Abdominal strength and endurance (Test 3) is assessed via the number of curl-ups completed. Upper body strength and endurance (Test 4) is measured by either number of (a) push-ups completed; (b) modified pull-ups completed; or (c) seconds holding a flexed-arm hang. Flexibility is assessed via the back saver sit-and-reach (Test 5) and a shoulder stretch (Test 6). A binary indicator of whether a student met sex- and age-appropriate standards (i.e. in the "Healthy Fitness Zone" (HFZ)) for each of the six FitnessGram tests was also included.

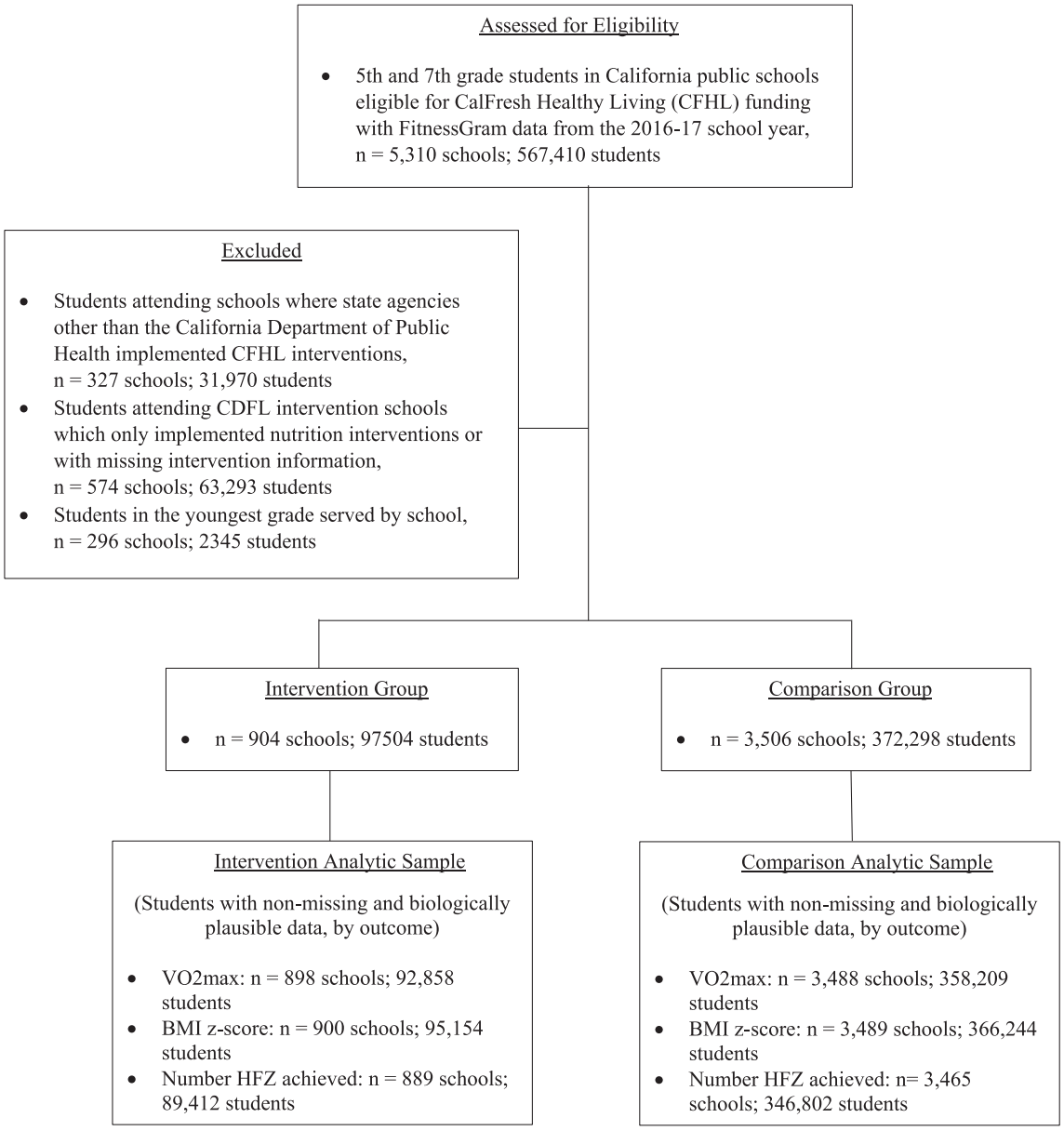

Fig. 1. Study sample flow chart.

5. School- and Student-level covariates

School-level demographic data, including the proportion of students who qualify for free or reduced-price meals (FRPM), total school enrollment, and urbanicity were downloaded from the California Department of Education (California Department of Education, 2019). Urbanicity was collapsed into 3 categories (city, suburban, or town/rural). School type was coded as "elementary" if the school educated students in any combination of grades kindergarten (K)-6; "middle" if the school educated students in any combination of grades 6–9; and "combination" if the school was not elementary or middle but educated students in other combinations of grades K-12. Student-level demographic data were provided by the California Department of Education, and included student age, sex (male or female), and race/ethnicity (African American, American Indian/Alaska Native, Asian, Pacific Islander/Native Hawaiian, Filipino, Latinx, or White).

5.1. Statistical analysis

In order to determine the association between (1) the presence of any CDPH-CFHL PA intervention in schools, (2) schools' CDPH-CFHL PA intervention score, and (3) schools' CDPH-CFHL PA + nutrition intervention score and student (a) VO_2max, (b) BMI z-score, and (c) the number of HFZ zones achieved, we used linear (outcomes a and b) and Poisson (outcome c) multilevel models. All models accounted for clustering by school and included fixed effects for school-level (school type, total enrollment, proportion of students eligible for FRPM, and urbanicity) and student-level (age, sex, race/ethnicity, grade) characteristics. For all models we also examined effect modification by grade (5th vs. 7th) and sex (male vs. female) and display stratified results where present. Effect modification by sex and by grade were present for the models with VO_2max as the outcome; therefore, we additionally tested for three-way (group by grade by sex) interaction for these models and display stratified results when present. Alpha was set at 0.05 for all models. Analyses were performed in SAS, version 9.4.

6. Results

The final study sample included 904 intervention schools (97,504 students) and 3,506 comparison schools (372,298 students). Schools with CDPH-CFHL PA interventions were slightly larger (mean enrollment 576 vs. 540; $p < 0.001$), were more likely to be elementary schools (74% vs. 61%, $p < 0.001$), and had a higher proportion of students eligible for FRPM (0.8 vs. 0.7; $p < 0.001$), than comparison schools. Students in intervention schools were predominantly 5th graders (67%); male (51%); and Latinx (70%; Table 1).

Fifty-five percent of intervention schools offered direct education interventions, 34% offered indirect education interventions, and 37% implemented PSE interventions. The distribution of the types and combinations of PA-related interventions offered varied by schools' CDPH-CFHL PA intervention score (Table 2). Whereas the majority of the schools in the low CDPH-CFHL PA intervention score category (96.9%) implemented either only direct education or only indirect education interventions, the majority of schools with medium–high PA intervention scores (87.7%) did only PSE interventions and most of the schools with high PA intervention scores (61.4%) did PSE changes plus direct education and/or indirect education.

Of the 376 schools that implemented PSE changes, 79% worked at the school district level (usually on written district-level policies) and 10% worked on written school-level wellness policies. PA-related PSE changes (other than written policies) included: strategies related to classroom PA (4%); active transport (3%); before/afterschool PA (3%); PA facilities (3%); PE (1%); and recess PA (1%). The 4 most common nutrition-related PSE changes (other than written wellness policies) were: work related to gardens (10%); classroom/event foods (7%); food procurement (5%); and nutrition marketing (5%).

All but five of the schools included some nutrition interventions in addition to PA interventions. Many different curricula, educational, and promotional materials were implemented. The most common were: Serving Up My Plate: A Yummy Curriculum (18%); Power Play! School Idea and Resource Kit (18%); Power Play! Community Youth Organization Idea & Resource Kit (15%); CATCH (Coordinated Approach to Child Health, 15%); and SPARK (Sports, Play and Active Recreation for Kids, 11%). Curriculum fidelity was not measured.

Adjusting for key school- and student-level covariates, students attending schools with any CDPH-CFHL PA interventions demonstrated an average higher estimated VO_2max than students in comparison schools, with significant interaction by sex ($p < 0.001$): male students demonstrated slightly lower associations for estimated VO_2max (0.18 mL/kg per min, 95% CI 0.03, 0.34) than female students (0.26 mL/kg per min, 95% CI 0.13, 0.39; Table 3).

There was significant interaction by grade and by sex for the association between CDPH-CFHL PA scores and student VO_2max ($p < 0.001$ for both grade and sex; Table 3). Fifth graders in schools with medium–high CDPH-CFHL PA scores demonstrated 0.27 mL/kg per min (95% CI: 0.02, 0.52) higher VO_2max scores than comparison 5th graders. Seventh graders in schools with medium–high (0.56 mL/kg per min; 95% CI: 0.04, 1.08) and high (0.25 mL/kg per min; 95% CI: 0,06, 0.44) CDPH-CFHL PA scores demonstrated higher VO_2max compared to 7th graders in comparison schools. Male students in schools with medium–high CDPH-CFHL PA scores demonstrated 0.30 mL/kg per min (95% CI: 0.02, 0.57) higher VO_2max scores compared to comparison males. Females in schools with medium–high CDPH-CFHL (0.44 mL/kg

Table 1
Study sample[A] demographic characteristics.

	Intervention schools	Comparison schools	p-value[B]
SCHOOL CHARACTERISTICS	(n = 904 schools)	(n = 3506 schools)	
School type, n (%)			
Elementary (any combination of grades K-6)	670 (74.1)	2144 (61.2)	**<0.001**
Middle (any combination of grades 6–9)	103 (11.4)	479 (13.7)	0.072
Combination (any other combinations)	131 (14.5)	883 (25.2)	**<0.001**
School urbanicity, n (%)			
City	381 (42.2)	1489 (42.5)	0.861
Suburban	376 (41.6)	1350 (38.5)	0.090
Town/rural	147 (16.3)	667 (19.0)	0.056
Student enrollment (mean ± SD)	576.3 ± 257.8	539.7 ± 305.5	**<0.001**
Proportion of students who qualify for free or reduced-priced meals (mean ± SD)	0.8 ± 0.14	0.7 ± 0.2	**<0.001**
STUDENT CHARACTERISTICS	(n = 97504 students)	(n = 372298 students)	
Age in years (mean ± SD)	11.1 ± 0.04	11.27 ± 0.02	**<0.001**
5th graders, n (%)	64,802 (66.5)	210,549 (56.6)	**<0.001**
Female, n (%)	47,569 (48.8)	182,262 (49.0)	0.389
Race/ethnicity, n (%)			
African American or Black	7086 (7.3)	23,217 (6.2)	**0.007**
American Indian or Alaska Native	615 (0.6)	2569 (0.7)	0.374
Asian	6474 (6.6)	22,017 (5.9)	0.248
Filipino	1571 (1.6)	7917 (2.1)	**<0.001**
Hispanic or Latino	68,042 (69.8)	227,942 (61.2)	**<0.001**
Pacific Islander or Native Hawaiian	542 (0.6)	1961 (0.5)	0.510
White	10,001 (10.3)	71,779 (19.3)	**<0.001**
Multiracial	3173 (3.3)	14,896 (4.0)	0.087

[A] The sample included 5th and 7th grade California public school students with school year 2016–17 state fitness (FitnessGram®) data. Students attending schools with California Department of Public Heath CalFresh Healthy Living interventions during October 2015-September 2016 comprised the intervention group (n = 904 schools; 97,504 students). Students in SNAP-Ed-eligible schools without CalFresh Healthy Living interventions during the same period were comparisons (n = 3,506 schools; 372,298 students).

[B] P-values for difference between California Department of Public ealthH CalFresh Healthy Living intervention and comparison schools and students calculated using unpaired t-tests for continuous characteristics and using chi-squared tests for binary characteristics, and adjusting for clustering by school for student characteristics.

Table 2
Types of physical activity-related interventions[A] by California Department of Public Health's CalFresh Healthy Living (CDPH-CFHL) intervention score[B].

Types of physical activity-related interventions offered, number of schools (%)	CDPH-CFHL physical activity intervention score(n = 904 schools) Low(n = 288 schools)	Medium-Low(n = 233 schools)	Medium-High(n = 251 schools)	High(n = 132 schools)
Direct Education only	201 (69.8)	106 (45.5)	3 (1.2)	26 (19.7)
Indirect Education only	78 (27.1)	53 (22.8)	0 (0.0)	0 (0.0)
Direct education and indirect education	9 (3.1)	72 (30.9)	1 (0.4)	21 (15.9)
Policy, systems, and environmental change (PSE)	0 (0.0)	0 (0.0)	220 (87.7)	4 (3.0)
PSE and direct education	0 (0.0)	0 (0.0)	7 (2.8)	34 (25.8)
PSE and indirect education	0 (0.0)	1 (0.4)	19 (7.6)	32 (24.2)
PSE, direct education, and indirect education	0 (0.0)	1 (0.4)	1 (0.4)	15 (11.4)

[A] Schools implemented physical activity (PA)-related interventions which were categorized into 3 types: direct education (e.g. PA activities/lessons where participants are actively engaged in the learning process with an educator; indirect education (e.g. PA information and/or resource distribution in which participants are not actively engaged with an educator); and policy, systems, and environmental change interventions (PSE's; e.g. changes to school or district PA related policies, systems, and/or environments.)

[B] The intervention sample included schools serving 5th and 7th grade students with CDPH-CFHL Living interventions during October 2015-September 2016.

Table 3
Adjusted ssociations[A] between school-level California Department of Public Health's CalFresh Healthy Living (CDPH-CFHL) intervention score and student-level VO2max, by student sex and by student grade.

	Estimated VO_2max (mL/kg per min)							
	Males		Females		5th graders		7th graders	
	# of schools;# of students	β ± SE(95% CI)	# of schools;# of students	β ± SE(95% CI)	# of schools;# of students	β ± SE(95% CI)	# of schools;# of students	β ± SE(95% CI)
By presence of any CDPH-CFHL physical activity-related intervention								
No intervention	3473 schools; 183,119 students	Reference	3451 schools; 175,090 students	Reference	N/A[B]	N/A[B]	N/A[B]	N/A[B]
Any CDPH-CFHL PA-related intervention	**897 schools; 47,590 students**	**0.18 ± 0.08* (0.03, 0.34)**	**897 schools; 45,268 students**	**0.26 ± 0.07** (0.13, 0.39)**	N/A[B]	N/A[B]	N/A[B]	N/A[B]
By CDPH-CFHL physical activity intervention score								
No intervention	3473 schools; 183,119 students	Reference	3451 schools; 175,090 students	Reference	2860 schools; 202,186 students	Reference	1304 schools; 156,023 students	Reference
Low	288 schools; 17,617 students	0.20 ± 0.13 (−0.05, 0.45)	288 schools; 16,542 students	0.20 ± 0.11 (−0.01, 0.40)	248 schools; 21,794 students	0.18 ± 0.11 (−0.05, 0.40)	77 schools; 12,365 students	0.22 ± 0.26 (−0.28, 0.72)
Medium-low	229 schools; 11,904 students	−0.04 ± 0.14 (−0.32, 0.25)	229 schools; 11,362 students	0.06 ± 0.12 (−0.18, 0.29)	207 schools; 16,934 students	−0.06 ± 0.13 (−0.31, 0.19)	58 schools; 6332 students	0.58 ± 0.31 (−0.03, 1.19)
Medium-high	**249 schools; 12,019 students**	**0.30 ± 0.14* (0.02, 0.57)**	**249 schools; 11,533 students**	**0.44 ± 0.12** (0.22, 0.67)**	**199 schools; 13,967 students**	**0.27 ± 0.13* (0.02, 0.52)**	**74 schools; 9585 students**	**0.56 ± 0.27* (0.04, 1.08)**
High	131 schools; 6050 students	0.32 ± 0.19 (−0.05, 0.68)	**131 schools; 5831 students**	**0.41 ± 0.16* (0.11, 0.71)**	122 schools; 9471 students	0.29 ± 0.16 (−0.02, 0.60)	16 schools; 2410 students	1.03 ± 0.54 (−0.02, 2.08)
By CDPH-CFHL physical activity + nutrition intervention score								
No intervention	3473 schools; 183,119 students	Reference	3451 schools; 175,090 students	Reference	2860 schools; 202,186 students	Reference	1304 schools; 156,023 students	Reference
Low	194 schools; 12,373 students	0.24 ± 0.15 (−0.06, 0.53)	194 schools; 11,438 students	0.17 ± 0.13 (−0.08, 0.42)	163 schools; 14,528 students	0.16 ± 0.14 (−0.11, 0.43)	53 schools; 9283 students	0.30 ± 0.30 (−0.29, 0.88)
Medium-low	196 schools; 10,752 students	−0.00 ± 0.15 (−0.30, 0.30)	196 schools; 10,223 students	0.19 ± 0.13 (−0.06, 0.44)	177 schools; 14,603 students	0.09 ± 0.14 (−0.18, 0.36)	49 schools; 6372 students	0.11 ± 0.33 (−0.53, 0.76)
Medium-high	155 schools; 7293 students	0.33 ± 0.18 (−0.01, 0.67)	**155 schools; 7022 students**	**0.49 ± 0.15** (0.20, 0.77)**	115 schools; 7004 students	0.24 ± 0.17 (−0.09, 0.57)	**66 schools; 7311 students**	**0.67 ± 0.29* (0.11, 1.23)**
High	352 schools; 17,172 students	0.19 ± 0.12 (−0.04, 0.42)	**352 schools; 16,585 students**	**0.25 ± 0.10* (0.06, 0.44)**	321 schools; 26,031 students	0.16 ± 0.10 (−0.04, 0.36)	**57 schools; 7726 students**	**0.74 ± 0.30* (0.16, 1.33)**

[A] Data calculated from linear multilevel models accounting for clustering by school and adjusted for school-level (school urbanicity; proportion of students who qualify for free or reduced-price meals; student enrollment) and student-level (age; race/ethnicity; grade (for models stratified by sex); and sex (for models stratified by grade) covariates.

[B] Stratified data presented for models with statistically significant two-way interaction; Effect modification by grade for the binary outcome "Presence of any CDPH CHFL intervention" was not evident.

* $p < 0.05$.

** $p < 0.001$.

per min; 95% CI: 0.22, 0.67) and high (0.41 mL/kg per min; 95% CI: 0.11, 0.71) CDPH-CFHL PA scores demonstrated higher VO_2max compared to females in comparison schools.

Three-way effect modification (intervention score by grade by sex) was present for the association between CDPH-CFHL PA + nutrition intervention scores and student VO_2max ($p = 0.007$; Table 4). Associations between medium–high CDPH-CFHL PA + nutrition interventions and student VO_2max values were greatest among 7th grade males (0.74 mL/kg per min; 95% CI: 0.09, 1.38), followed by females in 7th (0.58 mL/kg per min; 95% CI: 0.03,1.12), and 5th grades (0.39 mL/kg per min; 95% CI: 0.07, 0.72). Associations between high CDPH-CFHL PA + nutrition interventions and student VO_2max were significant for 7th grade males (0.69 mL/kg per min; 95% CI:0.03, 1.36) and for 7th grade females (0.69 mL/kg per min; 95% CI: 0.12, 1.25).

Student BMI z-scores were on average lower in schools with any CDPH-CFHL PA interventions than for students in comparison schools and trended lower across intervention score groups, with evidence of effect modification by sex ($p = 0.034$; Table 5); on average, BMI z-scores were slightly lower for males (−0.03, 95% CI: −0.05, −0.02) than for females (−0.02, 95% CI: −0.04, −0.01). However, BMI z-scores were statistically significantly lower only for students in schools with low CDPH-CFHL PA (−0.06, 95% CI: −0.09, −0.03 for males and −0.03, 95% CI: −0.06, −0.00 for females) and low CDPH-CFHL PA + nutrition intervention scores (−0.07, 95% CI: −0.10, −0.03 for males and −0.04, 95% CI: −0.08, −0.00 for females) compared to students in comparison schools.

The only significant difference with regard to number of HFZ's achieved (0–6) was for students in schools with low CDPH-CFHL PA (0.02, 95% CI: 0.00, 0.04) and low CDPH-CFHL PA + nutrition intervention scores (0.02, 95% CI: 0.00, 0.04), who had a statistically significantly higher number of HFZ zones achieved, compared to students in comparison schools.

7. Discussion

This study found that 5th and 7th grade students attending schools with CDPH-CFHL PA interventions demonstrated slightly higher estimated VO_2max scores and slightly lower BMI z-scores than students in comparison schools without CDPH-CFHL interventions. Findings from this observational cross-sectional study suggest that investment in these interventions may positively impact the health of some of California's highest-need students; CDPH-CFHL funds currently reach over 90,000 students in more than 900 schools, the majority of whom are economically disadvantaged students of color. Furthermore SNAP-Ed is

Table 4
Adjusted associations[A] between school-level California Department of Public Health's CalFresh Healthy Living (CDPH-CFHL) intervention score and student-level VO_2max, by student sex and grade[B].

	VO_2maxmL/kg per min							
	Males				**Females**			
	5th grade		**7th grade**		**5th grade**		**7th grade**	
	Number of schools; number of students	β ± SE(95% CI)	Number of schools; number of students	β ± SE(95% CI)	Number of schools; number of students	β ± SE(95% CI)	Number of schools; number of students	β ± SE(95% CI)
By CDPH-CFHL physical activity + nutrition intervention score								
No intervention	2833 schools; 103,448 students	Reference	1292 schools;79,671 students	Reference	2818 schools; 98,738 students	Reference	1255 schools; 76,352 students	Reference
Low	163 schools; 7562 students	0.24 ± 0.16(−0.08, 0.56)	53 schools; 4811 students	0.16 ± 0.34(−0.50, 0.81)	163 schools; 6966 students	0.10 ± 0.13(−0.16, 0.35)	53 schools; 4472 students	0.35 ± 0.29(−0.21, 0.91)
Medium-low	176 schools; 7472 students	−0.03 ± 0.16(−0.34, 0.28)	48 schools; 3280 students	0.03 ± 0.38(−0.71, 0.77)	176 schools; 7131 students	0.22 ± 0.13(−0.04, 0.47)	49 schools; 3092 students	0.07 ± 0.32(−0.56, 0.69)
Medium-high	115 schools; 3513 students	0.12 ± 0.20(−0.28, 0.52)	**63 schools; 3780 students**	**0.74 ± 0.33*(0.09, 1.38)**	**114 schools; 3491 students**	**0.39 ± 0.16*(0.07, 0.72)**	**66 schools; 3531 students**	**0.58 ± 0.28*(0.03, 1.12)**
High	321 schools; 13,162 students	0.13 ± 0.12(−0.11, 0.37)	**57 schools; 4010 students**	**0.69 ± 0.34*(0.03, 1.36)**	321 schools;12,869 students	0.17 ± 0.10(−0.03, 0.36)	**57 schools; 3716 students**	**0.69 ± 0.29*(0.12, 1.25)**

** $p < 0.001$.
[A] Data calculated from linear multilevel models accounting for clustering by school and adjusted for school-level (school urbanicity; school type; proportion of students who qualify for free or reduced-price meals; student enrollment) and student-level (age; race/ethnicity) covariates.
[B] Stratified data presented for models with statistically significant 3-way (group by grade by sex) interaction.
* $p < 0.05$.

implemented on an on-going basis in all 50 United states; identification and implementation of effective, scalable SNAP-Ed-funded strategies could have a positive impact on student health at the national level. While these observational findings are promising, causal investigation is needed to determine the impact of these programs on student fitness and weight status.

In the most recent Cochrane Review of school-based programs for promoting PA and fitness in children and adolescents ages 6–18 years, which included 44 randomized controlled trials, school interventions led to improved VO_2max ranging from 1.6 to 3.7 mL/kg per min (Dobbins et al., 2013). While the magnitude of the difference seen in our cross-sectional study (0.22 mL/kg per min for all students; 0.18 for males and 0.26 for females) is smaller than what is typically detected from randomized studies, this is not unexpected, given the unprescribed nature of the CDPH-CFHL PA interventions that varied widely in reach, intensity, and focus on increasing student fitness. It is also important to note that the vast majority of schools with CDPH-CFHL PA interventions (99%) also implemented nutrition interventions. Still, even small changes in VO_2max can positively impact student cardiorespiratory health (Janssen and LeBlanc, 2010; Dobbins et al., 2013) especially given the wide potential reach of these interventions. Further, improvements in fitness may be most beneficial to students with low fitness and higher BMI z-scores. With the available data it was not possible to test this hypothesis; this would be important to address in future studies (Majdzadeh et al., 2015; Lang et al., 2018).

In the intervention score analysis, only students in schools with medium–high and high intervention scores demonstrated significantly higher VO_2max than students in comparison schools. Previous studies have also shown that the strength and reach of school-based PA and nutrition interventions matter, with the observational literature consistently demonstrating that the more PA students receive, the greater the health benefit (Janssen and LeBlanc, 2010). Similarly, multiple studies have shown stronger results of classroom-based PA and physical education interventions on student academic outcomes when PA is of higher duration, intensity and frequency.(Watson et al., 2017; Konijnenberg and Fredriksen, 2018) This threshold effect was observed for the association with VO_2max and both the PA-only and the PA + nutrition intervention scores. However, the relationship with the PA-only score was more linear; we saw a similar effect size for medium–high and high scores, whereas with the PA + nutrition intervention score relationship, the effect size was lower for the high score than for the medium–high score. This is not unexpected given that theoretically, nutrition interventions would not be expected to impact students' VO_2max.

Schools with interventions that included PA-related PSEs were found almost exclusively in the medium–high and high PA intervention scores, whereas schools in the low and medium low intervention categories conducted almost exclusively direct education and/or indirect education. This suggests that the threshold effect observed with regard to the association between intervention score category and VO_2max, could indicate higher effectiveness of PSE interventions which predominated in the two highest intervention score categories. Further study is required to confirm this hypothesis.

The relationship between both CDPH-CFHL PA and PA + nutrition intervention scores and student VO_2max was stronger among 7th grade than 5th grade students. It is possible that these PA interventions were easier to implement in middle schools, given they typically have a higher number of both physical education teachers (who are specifically trained to increase student PA and fitness) and facilities dedicated to PA (i.e. gymnasiums, playing fields), as compared to elementary schools (Thompson et al., 2019, 2013; Institute of Medicine, 2013. The association between CDPH-CFHL PA and PA + nutrition intervention scores was also stronger for females than for males. Together, these findings are not unexpected, given that aerobic fitness in youth is known to vary in relation to age, maturation, and sex.(Armstrong et al., 2011) Given known sex-related disparities in youth fitness, with girls typically less

Table 5
Adjusted associations[A] between school-level California Department of Public Health's CalFresh Healthy Living (CDPH-CFHL) intervention scores and student-level BMI z-score, by sex[B].

	BMI z-score			
	Males		Females	
	Number of schools; number of students	BMI z-scoremL/kg per minβ ± SE (95% CI)	Number of schools; number of students	BMI z-scoremL/kg per minβ ± SE(95% CI)
By presence of any CDPH-CFHL physical activity-related intervention				
No intervention	3476 schools; 186,839 students	Reference	3453 schools; 179,405 students	Reference
Any CDPH-CFHL physical activity-related intervention	**899 schools; 48,633 students**	**−0.03 ± 0.01*** **(−0.05, −0.01)**	**898 schools; 46,521 students**	**−0.02 ± 0.10*** **(−0.04, −0.01)**
By CDPH-CFHL physical activity intervention score				
No intervention	3476 schools; 186,839 students	Reference	3453 schools; 179,405 students	Reference
Low	**288 schools; 17,998 students**	**−0.06 ± 0.02**** **(−0.09, −0.03)**	**288 schools; 16,957 students**	**−0.03 ± 0.02*** **(−0.06, −0.00)**
Medium-low	230 schools; 12,145 students	−0.03 ± 0.02 (−0.06, 0.01)	230 schools; 11,628 students	−0.02 ± 0.02(−0.06, 0.01)
Medium-high	249 schools; 12,336 students	−0.02 ± 0.02 (−0.05, 0.02)	249 schools; 11,902 students	−0.03 ± 0.02(−0.06, 0.01)
High	132 schools; 6154 students	−0.01 ± 0.02 (−0.06, 0.03)	131 schools; 6034 students	0.00 ± 0.02 (−0.04, 0.05)
By CDPH-CFHL physical activity + nutrition intervention score				
No intervention	3476 schools; 186,839 students	Reference	3453 schools; 179,405 students	Reference
Low	**194 schools; 12,663 students**	**−0.07 ± 0.02**** **(−0.10, −0.03)**	**194 schools; 11,766 students**	**−0.04 ± 0.02*** **(−0.08, −0.00)**
Medium-low	196 schools; 10,959 students	−0.02 ± 0.02 (−0.06, 0.01)	196 schools; 10,436 students	−0.02 ± 0.02(−0.05, 0.02)
Medium-high	155 schools; 7496 students	−0.02 ± 0.02 (−0.07, 0.02)	**155 schools; 7257 students**	**−0.05 ± 0.02*** **(−0.09, −0.01)**
High	354 schools; 17,515 students	−0.02 ± 0.02 (−0.05, 0.01)	353 schools; 17,062 students	−0.01 ± 0.01 (−0.04, 0.02)

[A] Data calculated from linear multilevel models accounting for clustering by school and adjusted for school-level (school urbanicity; school type; proportion of students who qualify for free or reduced-price meals; student enrollment) and student-level (age; grade; race/ethnicity) covariates.

[B] Stratified data presented for models with statistically significant two-way interaction; Evidence of effect modification by student grade was not present.

* $p < 0.05$.

** $p < 0.001$.

likely to meet aerobic capacity standards compared to boys, and considering the known drop off in student PA and fitness during adolescence (particularly for female students), identifying interventions that are effective during the middle school years, especially for female students, is particularly important (Bowser et al., 2016; Dumith et al., 2011; Konty et al., 2020).

We saw a small, but statistically significant, difference in BMI z-scores between students exposed to any CDPH-CFHL PA intervention and comparison students (−0.03 for all students; −0.03 for males; and −0.02 for females). However, the difference in BMI z-score of 0.03 is small and may not be clinically meaningful (for a 10-year-old girl with obesity, this would represent a difference in weight of less than a pound). Yet it is important to note that the trend for BMI was consistent; we observed slightly lower BMI z-scores across all intervention score groups compared to the comparison group. The small nature of these differences is not surprising; while interventions focused on increasing school-day PA have demonstrated positive impact on student fitness, they have rarely been shown to improve student weight status (Dobbins et al., 2013). In fact, a review of reviews on school-based interventions to control childhood obesity (Majdzadeh et al., 2015) indicated that implementation of multi-component interventions in schools does not necessarily improve student BMI.

The lack of association between the number of HFZs achieved and exposure to any CDPH-CFHL PA intervention, may be explained by the focus of CDPH-CFHL PA interventions on increasing moderate to vigorous PA, as opposed to specifically improving strength or flexibility. Further, given the established weak relationship between overall student fitness and flexibility (Committee on Fitness Measures and Health Outcomes in Youth, 2012), coupled with the challenge of decreasing student BMI via school-based PA interventions, these null findings with regard to the number of HFZs achieved are similarly predictable.

Several limitations deserve mention. First, data on the presence and dose of CDPH-CFHL interventions prior to 2015 were not available, nor were student FitnessGram data, precluding a longitudinal analysis, as well as limiting our ability to examine effect modification by student fitness and BMI prior to intervention implementation. Relatedly, the cross-sectional study design limits our ability to draw causal conclusions. Secondly, the CDPH-CFHL interventions were highly heterogeneous. While this was likely critical to their success (schools could choose approaches that they believed would work in their unique setting with their specific school and community population), it limits our ability to identify a single PA intervention that would work to improve student fitness across all schools. Third, CDPH-CFHL intervention scores were based on data self-reported by local health departments and their partners, which could bias these findings. Finally, while the high racial/ethnic and socioeconomic diversity of our study sample is an asset for understanding the potential for these types of interventions to impact student health in California, our findings may not be generalizable to less diverse education settings.

In this observational, cross-sectional study, 5th and 7th grade students in California public schools with any CDPH-CFHL PA interventions demonstrated greater cardiorespiratory fitness, and slightly lower BMI z-score, compared to students in schools without such programming. These findings suggest investment in this programming, particularly interventions that include PSE change and those targeting increased student PA and fitness, may positively impact student cardiorespiratory health, particularly for 7th grade students and females. Although differences were small, the reach of SNAP-Ed programming nationally is so extensive that continuing and expanding efforts to improve fitness through this funding mechanism could have a meaningful impact on population-level student health. Further investigation of the causal impact of these interventions on student fitness is necessary.

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CRediT authorship contribution statement

Hannah R. Thompson: Conceptualization, Investigation, Methodology, Writing - original draft. **Sridharshi C. Hewawitharana:** Data curation, Methodology, Investigation, Formal analysis, Software, Writing - review & editing, Project administration. **Janice Kao:** Conceptualization, Investigation, Data curation, Writing - review & editing. **Carolyn Rider:** Conceptualization, Investigation, Data curation, Writing - review & editing. **Evan Talmage:** Conceptualization, Investigation, Software, Data curation, Writing - review & editing. **Wendi Gosliner:** Conceptualization, Investigation, Methodology, Writing - review & editing. **Lauren Whetstone:** Funding acquisition, Resources, Writing - review & editing, Supervision. **Gail Woodward-Lopez:** Funding acquisition, Conceptualization, Methodology, Writing - review & editing, Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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