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Differential effects of a school-based obesity prevention program: A cluster randomized trial

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Abstract

School-based healthy living interventions are widely promoted as strategies for preventing obesity. The peer-led Healthy Buddies™ curriculum has been shown to improve obesity-related outcomes in school-aged children. We examined whether these improvements existed among subgroups of children stratified by sex, income level and urban/rural geography. In a cluster-randomized controlled trial, elementary schools in Manitoba, Canada, were randomly allocated to Healthy Buddies™ (10 schools, 340 students) or standard curriculum (10 schools, 347 students). Healthy Buddies™ participants had 21weekly lessons on healthy eating, physical activity and self-efficacy, delivered by children age 9–12 to children age 6–8. We assessed pre- and post-intervention body mass index (BMI) *z*-scores, waist circumference, healthy living knowledge, dietary intake and self-efficacy among the younger children. Compared to standard curriculum (n = 154), Healthy Buddies™ participants (n = 157) experienced a greater reduction in waist circumference (−1.7 cm; 95% confidence interval [CI][−2.8, −0.5 cm]) and improved dietary intake (4.6; 95% CI [0.9, 8.3]), healthy living knowledge (5.9; 95% CI [2.3, 9.5]) and self-efficacy (5.3; 95% CI [1.0, 9.5]) scores. In subgroup analyses, effects for waist circumference (−2.0 cm; 95% CI [−3.6, −0.5]), healthy living knowledge (9.1; 95% CI [4.4, 13.8]) and self-efficacy (8.3; 95% CI [3.3, 13.3]) were significant among boys. Dietary intake (10.5; 95% CI [5.5, 15.4]), healthy living knowledge (9.8; 95% CI [4.5, 15.0]) and self-efficacy (6.7; 95% CI [0.7, 12.7]) improved among urban-dwelling but not rural-dwelling children. Healthy Buddies™ was effective for boys and children living in urban settings. Enhanced curricula may be needed to improve program effectiveness for select subgroups of school-aged children.

KEYWORDS

childhood obesity, health outcomes, health promotion, healthy living intervention, inequalities, randomized controlled trial, school-based intervention, socio-economic factors

1 | INTRODUCTION

The childhood obesity epidemic in North America is a prominent public health concern. Canada and the United States rank among the top six OECD countries for childhood obesity prevalence (Organization for Economic Cooperation and Development, 2014), and currently 30%–40% of North American children aged 5–17 are obese or overweight (Sassi, 2010; Senate Committee on Social Affairs, 2016). Childhood obesity rates have increased more than threefold in the last three decades, which is alarming given the deleterious impacts that obesity is shown to have on short- and long-term health (World Health Organization, 2000). Childhood obesity has been linked to cardiovascular disease, type 2diabetes and other related chronic conditions later in life (Llewellyn, Simmonds, Owen, & Woolacott, 2016; Reilly & Kelly, 2011).

The structural and social determinants of health play a role in the childhood obesity epidemic. While overweight and obesity rates have increased among all children, this is especially pronounced for children with low socio-economic backgrounds (Krueger & Reither, 2015; Lane, Bluestone, & Burke, 2013), for children living in rural areas (The National Survey of Children's Health, 2011; Tu, Mâsse, Lear, Gotay, & Richardson, 2015) and in some instances for males versus females (Ogden, Carroll, Kit, & Flegal, 2014). These inequities in childhood obesity translate into even greater health disparities as children reach adulthood (Krueger & Reither, 2015). Interventions in childhood obesity need to take obesity risk factors, structural and socio-demographic factors into consideration.

Schools are an ideal setting for obesity prevention efforts in children (Baranowski, Cullen, Nicklas, Thompson, & Baranowski, 2002; Bleich et al., 2018; Verrotti, Penta, Zenzeri, Agostinelli, & De Feo, 2014). Most school-based lifestyle or healthy living interventions use multipronged approaches by encouraging higher levels of physical activity, healthier eating behaviours, and positive attitudes around self-esteem and body image (Brown & Summerbell, 2009; van Stralen et al., 2011; Waters et al., 2011). The primary goal of most programs is to reduce body mass index (BMI) or BMI *z*-scores, waist circumference and/or percent body fat among school-age children. However, very few studies have examined the extent to which such programmes selectively benefit subgroups of children. Failing to address the social determinants of health in program delivery can inadvertently widen health inequities in the population as a whole (Curbing Childhood Obesity: A Federal, Provincial and Territorial Framework for Action to Promote Healthy Weights, 2012).

Our research team has conducted a cluster-randomized controlled trial examining the differential effect of the Healthy Buddies™ school-based obesity prevention curriculum in Manitoba, Canada (Santos, Durksen, Rabbanni, Chanoine, Lamboo Miln, et al., 2014b). These results show that Healthy Buddies™ was, on average, associated with improved obesity-related outcomes among participants. The present study examines the extent to which these obesity-related outcomes varied by participant sex, income level and urban/rural residence.

Key messages

- Childhood obesity rates can vary substantially between male and female children and across different socio-economic groups and geographical regions.
- The Healthy Buddies™ curriculum improved obesity-related outcomes in children, but the effects were seen mainly in boys and children living in lower income neighbourhoods or urban areas.
- As well, improved health behaviour outcomes among urban and rural subgroups in the intervention arm were largely driven by children living in urban areas.
- These findings highlight opportunities to enhance the Healthy Buddies™ curriculum to more broadly improve participants' health and to ensure it is relevant for all subgroups of children.

2 | METHODS

2.1 | Setting and participants

Healthy Buddies™ is a school-based, peer-led healthy living intervention for children designed and initiated by the British Columbia Children's Hospital (Stock et al., 2007). In 2009, three Manitoba government departments (Health, Education and the Manitoba Healthy Child Office) partnered to conduct a cluster-randomized controlled trial to test the effect of this programme in Manitoba schools. An overview of the 833schools eligible to participate in the original study is provided in Figure 1. Eligible schools were required to provide their curriculum in English (tobe consistent with the original Healthy Buddies™ protocol) and had to have at least 200 students enrolled in grades 1–6 combined. Sixty-one schools expressed an interest in participating. Ten of these schools were randomly selected from urban areas and 10from rural areas stratum, and using a random number generator, five schools from each geography were allocated to an intervention arm and five to a standard curriculum study arm. Each study arm therefore comprised 10schools equally divided between urban and rural geography. The randomization and allocation were conducted by an investigator who was not involved in data collection. Additional details of the randomization process are discussed elsewhere (Santos, Durksen, Rabbanni, Chanoine, Lamboo, Mayer, et al., 2014a).

2.2 | Intervention and comparison group

Details of the Healthy Buddies™ intervention and the overall effect of the intervention on anthropometric and behavioural outcomes in

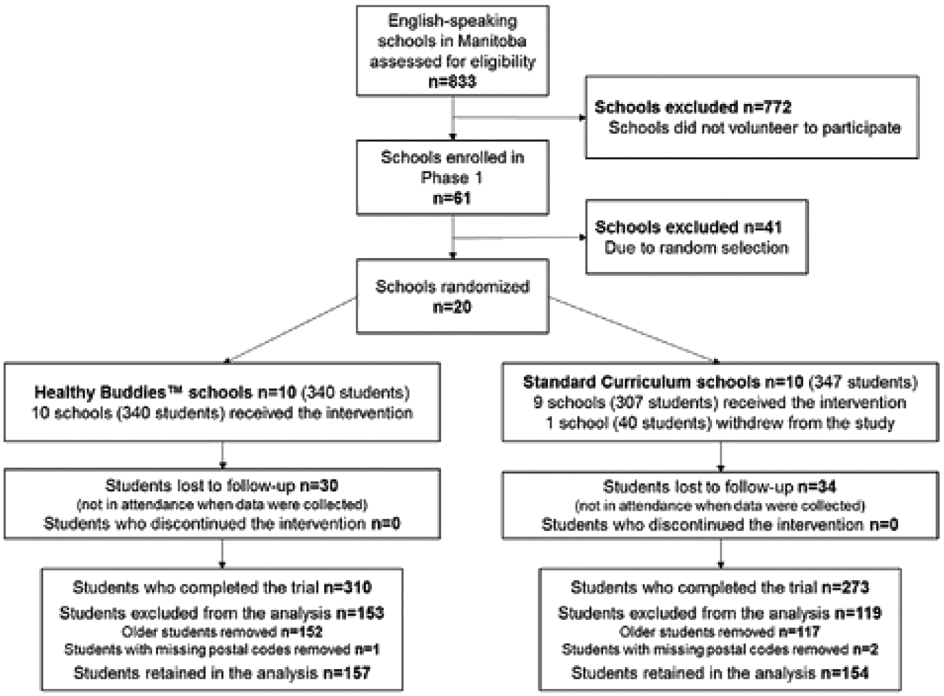

FIGURE 1 Study design and cohort development. Allocation of participating schools and students in the Manitoba Healthy Buddies™ randomized controlled trial

Canadian children have been previously described (Ronsley, Lee, Kuzeljevic, & Panagiotopoulos, 2013; Santos et al, 2014b). Briefly, Healthy Buddies™ consists of 21 healthy living lessons taught weekly in the classroom. Two teachers from each Healthy Buddies™ school received training to deliver the curriculum. Children in grades 4 to 6 (mentors; aged 9–12 years) were paired with children in grades 1 to 3 (mentees; aged 6–8 years), and weekly lesson plans were delivered in two stages: first from teachers to mentors in a 45-min lesson, followed by a 30-min mentor-to-mentee session held later that week. These lessons included topics on nutritious and non-nutritious foods/beverages and energy balance ("Go Fuel!"); healthy body image, self-efficacy, healthy growth and development, and media literacy ("Go Feel Good!"); and two 30-min structured physical activity sessions per week in the gymnasium ("Go Move!"). Children in schools randomized to the control condition received standard health and physical education curriculum.

2.3 | Study measures

The present study aimed to determine whether improvements documented in the Healthy Buddies™ intervention in Manitoba (Santos et al., 2014a) were experienced by all children taking part in the intervention and across several different social determinants; thus, the current study reports on only those outcomes previously shown to be significantly improved by the Healthy Buddies™ intervention in Manitoba. The main outcome measures were BMI *z*-scores and waist circumference. Outcome measures were collected at the beginning (September 2009) and end (May 2010) of the academic year during day visits to each school. Research assistants responsible for collecting study outcomes were trained in anthropometric measurement and blinded to trial arm assignment. To develop BMI *z*-scores, height (centimetres) and weight (kilograms) were measured in duplicate using a portable floor scale and stadiometer. Raw BMI scores were converted to *z*-scores based on the Centers for Disease Control and Prevention growth charts (National Center for Health Statistics, 2009). Waist circumference (in centimetres) was measured using a flexible tape at the iliac crest.

2.3.1 | Secondary outcomes

Secondary outcomes were measured using a modified version of the instrument developed by the Healthy Buddies™ research group at the BC Children's Hospital (Stock et al., 2007); they included measures related to health behaviour and learning: self-reported dietary intake, healthy living knowledge and self-efficacy. The instrument was simplified for the younger children in the study: instead of using words to score each answer, smiley/neutral/sad faces were used, and the number of questions was reduced to accommodate classroom schedules and time constraints at participating schools.

- Self-reported dietary intake was measured by asking students to report how often they ate different types of foods (using pictures of 14 different foods and a 3-point scale for frequency – a lot, a little, never). Responses to these questions were categorized as positive (2 points), neutral (1 point) or negative (0 points), and scored as a percentage of total possible points out of 28.
- Healthy living knowledge was measured using 26 items, each on a 2-point scale, for which the student identified a behaviour as healthy or not. Responses were scored as the percent of items the student scored correctly.

- Self-efficacy was assessed using 10 items, each on a 2-point scale. Responses were scored as the percentage of total possible points received.

For all domains, scores represented the percentage of possible points received and higher scores reflected improved outcomes (e.g. better knowledge of nutritious foods and beverages, more self-confidence and a more positive body image). Santos etal. (2014a) present additional details on the measures used in the Healthy Buddies™ trial in their paper.

2.3.2 | Equity measures

Participants were divided into subgroups by sex, urban/rural geography and income quintile, collectively measured at study baseline. Urbanicity and income quintiles were assigned by linking each participant's de-identified personal health information number to the comprehensive Population Health Research Data Repository at the Manitoba Centre for Health Policy, University of Manitoba. The Repository includes six-digit postal codes, which can be grouped into dissemination areas. Dissemination areas inside Winnipeg are assigned urban status, whereas those outside Winnipeg are assigned rural status. As well, average household incomes for each dissemination area are publicly available and can be allocated to five area-level income quintiles, each comprising 20% of the population (Manitoba Centre for Health Policy, 2008).

2.4 | Data management and statistical analysis

2.4.1 | Inclusion and exclusion criteria

Students were excluded from participating in Healthy Buddies™ if parental consent to participate was not received (both study groups) or if they had a condition that limited their ability to participate in physical activity (identified by the teacher; intervention group only). In total, 340 students consented to participate in the intervention and 347 consented to participate in the control arm. Of these participants, 64 were lost to follow-up (e.g. these children were not in class when either baseline or follow-up study measures were collected), and three had missing postal codes. Students lost to follow-up were distributed almost equally across study groups (data not shown). No students asked to discontinue the study. Our final analysis was conducted on 157 Healthy Buddies™ and 154 usual care mentees.

2.4.2 | Missing data

Select data were missing for <3% (baseline measurements) to 10%–13% (outcomes) of the children. We used the Markov Chain Monte Carlo method to perform multiple imputations (with 10 iterations) to handle missing data (Rubin, 1987). Outcomes were calculated separately for each imputed data set and then combined to produce a single estimate of the treatment effect. Sensitivity analyses were conducted on participants with complete data (n = 135 Healthy Buddies™, n = 131 standard curriculum) to verify that the results were consistent with those for the intention-to-treat population (results not shown).

Sample size was determined using a predefined ratio of 1:1 between intervention and control schools, assuming two classes/school with a classroom size of 25 to 30 children. A sample size of 10 clusters (schools) per group and 19 individuals per cluster provided 80% power to detect a difference of 1.38 cm in waist circumference between groups, assuming a standard deviation of 3.0 cm and an intra-cluster correlation of 0.30. This sample provided adequate power to detect a difference of 0.008 cm between groups, assuming a standard deviation of 0.03 cm and an intracluster correlation of 0.04.

2.4.3 | Statistical analysis

Descriptive analyses to test for differences in baseline characteristics used linear mixed modelling with maximum likelihood estimation to account for the nested and repeated nature of data. We compared the difference over time for each outcome by intervention arm. We included interaction terms between each subgroup (sex, urbanicity and income quintile) and the intervention arm to test whether Healthy Buddies™ was effective across all subgroups. Models incorporated random intercepts with a variance components covariance structure. Each model produced a 'differences of mean differences' value that compared the intervention and control arms' change in outcome within each subgroup. We used bootstrapping techniques to calculate 95% confidence intervals for effect estimates. All tests of significance were determined at the 0.05 critical value. All analyses were conducted in SAS version 9.4.

2.5 | Ethics considerations

The trial protocol was approved by the Biomedical Research Ethics Board at the University of Manitoba, Canada (HREB #H2011:294).

3 | RESULTS

Overall, analyses were conducted on 157 mentees who received the Healthy Buddies™ intervention and 154 mentees who received the standard curriculum. The participants' descriptive characteristics are listed in Table 1. Seventy-five percent of participants were 8 years of age or younger, 52% were male and 50% lived in an urban area. Participants were more likely to reside in lower income neighbourhoods (30% in Q1) than higher income neighbourhoods (5% in Q5). Despite randomization, the two groups differed slightly at baseline by some socio-demographic characteristics. A greater proportion of the children in the control arm were younger and lived in an urban area.

TABLE 1 Descriptive characteristics of study participants

Characteristic		Overall *N* = 311	Healthy Buddies™ *N* = 157	Standard curriculum *N* = 154	*P* value
		N (%)	*N* (%)	*N* (%)	
Age	≤8	232 (74.6)	95 (60.5)	137 (89.0)	<0.000**
	>8	79 (25.4)	62 (39.5)	17 (11.0)	
Sex	Male	161 (51.7)	82 (52.2)	79 (51.3)	0.870
	Female	150 (48.2)	75 (47.8)	75 (48.7)	
Geography	Urban	156 (50.2)	69 (44.0)	86 (55.8)	0.035*
	Rural	155 (49.8)	88 (56.1)	68 (44.2)	
Income quintile	Q1 (lowest)	93 (29.9)	46 (29.3)	47 (30.5)	0.814
	Q2	61 (19.6)	29 (18.5)	32 (20.8)	0.608
	Q3	33 (10.6)	21 (13.4)	12 (7.8)	0.108
	Q4	73 (23.5)	33 (21.0)	40 (26.0)	0.302
	Q5 (highest)	14 (4.5)	6 (3.8)	8 (5.2)	0.560

*$P < 0.05$
**$P < 0.001$.

Baseline outcome measures are presented in Table 2. These measures were similar between groups, except that average waist circumference was statistically greater in the Healthy Buddies™ group compared with children who received the standard curriculum.

The results of the multivariable analyses are presented in Table 3. Changes in BMI *z*-scores remained minimal and did not differ significantly overall or within any subgroup. The Healthy Buddies™ curriculum yielded a significant reduction in waist circumference among lower income children, male children and children living in rural areas. The intervention significantly improved healthy living knowledge and self-efficacy among males and dietary intake and healthy living knowledge among children living in urban regions. Healthy Buddies™ also improved healthy living knowledge among children living in lower income neighbourhoods and dietary intake among children living in higher income neighbourhoods.

4 | DISCUSSION

Similar to previous experimental trials of school-based healthy living interventions (Burke, Meyer, Kay, Allensworth, & Gazmararian, 2014; Jansen et al., 2011; Kriemler et al., 2010) and the original cluster randomized controlled trial of Healthy Buddies™ in Manitoba (Santos et al., 2014b), our study showed that Healthy Buddies™ improved obesity-related outcomes in children, but the positive effects were largely restricted to boys and to children living in lower income neighbourhoods or urban areas. Furthermore, changes in behavioural outcomes (dietary intake, healthy living knowledge and self-efficacy) were driven primarily by children living in urban areas. These findings suggest that the Healthy Buddies™ curriculum may need to be enhanced to ensure it is relevant for all subgroups of children.

Systematic reviews of randomized trials of school-based obesity interventions have yielded mixed results (Harris, Kuramoto, Schulzer, & Retallack, 2009; Mei et al., 2016; Oosterhoff, Joore, & Ferreira, 2016; Sobol-Goldberg, Rabinowitz, & Gross, 2013; Waters et al., 2011), possibly because very few trials evaluate the differential effect of the structural and social determinants of health on the effectiveness of interventions. However, childhood obesity rates can vary substantially between male and female children (Dietz, 1997) and across different socio-economic groups (Roberts, Shields, de Groh, Aziz, & Gilbert, 2012) and geographical regions (Shields & Tjepkema, 2006). These underlying social determinants may contribute to the disparity

TABLE 2 Baseline measures for study participants

Characteristic	Healthy Buddies™ *N* = 157	Standard curriculum *N* = 154	*P* value
	Mean (SEM)	Mean (SEM)	
BMI *z*-score	0.66 (0.1)	0.63 (0.1)	0.828
Waist circumference (cm)	62.79 (0.7)	60.47 (0.7)	0.017*
Dietary intake	57.15 (1.1)	57.28 (1.1)	0.936
Healthy living knowledge	76.65 (0.9)	78.55 (1.1)	0.190
Self-efficacy	83.20 (1.2)	86.31 (1.1)	0.056

Note. Dietary intake, healthy living knowledge, and self-efficacy are scored out of 100.
Abbreviation: SEM, standard error of the mean.
*$P < 0.05$.

TABLE 3 Treatment effect of the Healthy Buddies™ curriculum by subgroups

		Healthy Buddies™		Standard curriculum		Treatment effect[a,b]	
Subgroup	Outcome	Mean difference	95% CI	Mean difference	95% CI	Difference of mean differences	95% CI
Overall	BMI z-score	0.04	[−0.01, 0.10]	−0.01	[−0.07, 0.04]	0.05	[−0.04, 0.15]
	Waist circumference	−0.71	[−1.39, −0.03]	0.97	[0.30, 1.63]	−1.68	[−2.85, −0.51]**
	Dietary intake	3.22	[0.96, 5.48]	−1.39	[−3.72, 0.94]	4.61	[0.95, 8.27]*
	Healthy living knowledge	6.71	[4.44, 8.99]	0.82	[−1.50, 3.13]	5.89	[2.30, 9.50]**
	Self-efficacy	5.93	[3.15, 8.71]	0.68	[−2.16, 3.52]	5.25	[0.99, 9.51]*
Higher income (Q3-Q5)	BMI z-score	0.02	[−0.06, 0.11]	−0.05	[−0.14, 0.03]	0.07	[−0.06, 0.21]
	Waist circumference	−1.27	[−2.28, −0.27]	−0.38	[−0.63, 1.39]	−1.65	[−3.36, 0.06]
	Dietary intake	4.57	[1.04, 8.10]	−2.24	[−5.73, 1.25]	6.81	[1.77, 11.83]**
	Healthy living knowledge	9.25	[5.70, 12.80]	2.75	[−0.81, 6.32]	6.50	[1.20, 11.80]*
	Self-efficacy	6.05	[1.63, 10.47]	1.30	[−3.09, 5.70]	4.75	[−2.22, 11.71]
Lower income (Q1-Q2)	BMI z-score	0.05	[−0.02, 0.12]	0.01	[−0.06, 0.09]	0.04	[−0.10, 0.18]
	Waist circumference	−0.35	[−1.25, 0.54]	1.38	[0.52, 2.23]	−1.73	[−3.31, −0.14]*
	Dietary intake	2.35	[−0.61, 5.32]	−0.78	[−3.84, 2.29]	3.13	[−1.84, 8.11]
	Healthy living knowledge	5.10	[2.20, 8.00]	−0.52	[−3.51, 2.46]	5.62	[0.84, 10.40]*
	Self-efficacy	5.85	[2.27, 9.43]	0.25	[−3.49, 3.99]	5.60	[0.24, 10.96]*
Male	BMI z-score	0.01	[−0.07, 0.09]	−0.01	[−0.09, 0.08]	0.02	[−0.11, 0.14]
	Waist circumference	−0.68	[−1.68, 0.31]	1.33	[0.37, 2.28]	−2.01	[−3.55, −0.48]*
	Dietary intake	2.52	[−0.06, 5.64]	−1.84	[−4.96, 1.29]	4.36	[−0.48, 9.19]
	Healthy living knowledge	7.14	[3.99, 10.29]	−1.92	[−5.13, 1.30]	9.06	[4.36, 13.76]***
	Self-efficacy	7.06	[3.23, 10.90]	−1.22	[−5.10, 2.67]	8.28	[3.31, 13.25]**
Female	BMI z-score	0.08	[0.00, 0.15]	−0.03	[−0.10, 0.05]	0.11	[−0.06, 0.26]
	Waist circumference	−0.74	[−1.66, 0.19]	0.59	[−0.24, 1.51]	−1.33	[−3.18, 0.54]
	Dietary intake	3.98	[0.66, 7.29]	−0.89	[−4.35, 2.56]	4.87	[−0.59, 10.33]
	Healthy living knowledge	6.25	[3.00, 9.50]	3.70	[0.32, 7.08]	2.55	[−2.97, 8.07]
	Self-efficacy	4.69	[0.75, 8.62]	2.68	[−1.37, 6.73]	2.01	[−4.74, 8.75]
Urban	BMI z-score	0.06	[−0.02, 0.15]	0.04	[−0.03, 0.12]	0.02	[−0.12, 0.16]
	Waist circumference	0.16	[−0.86, 1.18]	1.26	[0.40, 2.13]	−1.10	[−2.69, 0.48]
	Dietary intake	7.03	[3.56, 10.50]	−3.43	[−6.37, −0.49]	10.46	[5.48, 15.44]***
	Healthy living knowledge	7.35	[4.00, 10.70]	−2.40	[−5.44, 0.64]	9.75	[4.47, 15.03]***
	Self-efficacy	6.23	[2.03, 10.43]	−0.49	[−4.23, 3.26]	6.72	[0.75, 12.69]*
Rural	BMI z-score	0.02	[−0.05, 0.10]	−0.09	[−0.17, 0.00]	0.11	[−0.04, 0.26]
	Waist circumference	−1.39	[−2.25, −0.53]	0.59	[−0.40, 1.58]	−1.98	[−3.69, −0.27]*
	Dietary intake	0.20	[−2.79, 3.18]	1.31	[−2.34, 4.96]	−1.11	[−6.43, 4.20]
	Healthy living knowledge	6.21	[3.22, 9.21]	4.89	[1.52, 8.25]	1.32	[−3.55, 6.20]
	Self-efficacy	5.69	[2.02, 9.36]	2.16	[−2.13, 6.45]	3.53	[−2.80, 9.87]

Abbreviations: BMI, body mass index; CI, confidence interval.

[a]Results are adjusted for age, sex, income and geography.

[b]The effect of the Healthy Buddies™ curriculum is calculated as the difference in mean differences between pre- and post-intervention means in each subgroup. For example, in the higher income group, dietary intake increased by an average of 4.57 points in the Healthy Buddies™ arm and decreased by an average of 2.24 points in the standard curriculum arm. The difference between these two mean differences is 6.81).

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

in trial results. Policymakers have emphasized the importance of public health approaches that recognize and address the social determinants of health (Federal/Provincial and Territorial Advisory Committee on Population Health, 1994, 1999; The Honourable Wilbert Joseph Keon - Chair & The Honourable Lucie Pépin - Deputy Chair, 2009). Indeed, there is evidence that health promotion approaches that taking sex and gender differences into account is more likely to be successful (Keleher, 2004; Ostlin, Eckermann, Mishra, Nkowane, & Wallstam, 2006). The data presented here support this evidence: an established peer-led intervention yielded promising results overall but had dramatically different results among subgroups of children stratified by social factors. These observations support the need for obesity prevention programmes that are appropriate and accessible for all participants, regardless of their sex, income level or area of residence.

We found that the Healthy Buddies™ curriculum reduced waist circumference and improved scores for healthy living knowledge and self-efficacy in male children. However, the intervention had no effect on these outcomes measured in female children. There is limited literature on sex or gender differences in obesity prevention efforts among children (Flynn et al., 2006; Sweeting, 2008). Some research suggests that sex-specific interventions may be more effective than general approaches (Fulton, McGuire, Caspersen, & Dietz, 2001; Stone, McKenzie, Welk, & Booth, 1998; Waters et al., 2011). For example, boys tend to respond better to physical activity interventions than girls (Doak, Visscher, Renders, & Seidell, 2006). It may also be important to consider whether girls are adequately represented in the curriculum materials or to develop content specifically relevant for girls for future trials. Investigating the different effects for male and female children could help explain mechanisms of behaviour change and may aid in optimizing these programmes for both boys and girls (Kremers, de Bruijn, Droomers, van Lenthe, & Brug, 2007).

Income is considered one of the primary social determinants of health, shaping overall living conditions and health-related behaviours (Mikkonen & Raphael, 2010). Healthy Buddies™ improved waist circumference, healthy living knowledge and self-efficacy among lower income participants and healthy living knowledge and dietary intake among higher income participants. People residing in socioeconomically disadvantaged areas may not have access to quality resources to support healthier living; the lack of change in dietary intake scores among lower-income children may reflect limited access to healthier food choices in these families. Although it is encouraging to see significant improvements among both higher and lower income groups, low-income populations face a range of barriers to accessing and benefitting from healthy living programmes, and evidence on tailored interventions for this group remains inconclusive (Cleland, Tully, Kee, & Cupples, 2012; Everson-Hocket al., 2013).

Obesity rates vary substantially across different geographical regions, and in the province of Manitoba, prevalence among rural and northern-dwelling children is much higher than among urban-dwelling children (Shields & Tjepkema, 2006; Yu, Protudjer, Anderson, & Fieldhouse, 2010). Previous studies have identified several factors that may contribute to this trend, including limited access to recreational facilities or high quality diets in rural or remote areas (Navarro, Voetsch, Liburd, Bezold, & Rhea, 2006). We found that improved health behaviour outcomes among the urban and rural subgroups were largely driven by children living in urban areas, whereas children from rural regions saw a decrease in waist circumference. It is unclear if these factors were related to resources for physical activity and healthy eating, or class sizes, which may have been different in schools in rural settings.

Finally, the measures chosen to evaluate obesity interventions in school-aged children are an important consideration. In our study, even though we observed decreases in waist circumference, there were no significant changes in BMI *z*-scores in the overall group, nor among any of the subgroups. BMI is a commonly used measure in randomized trials of obesity interventions, despite there being little consensus on the best way to assess children's adiposity in clinical settings (Daniels, 2009). Recent literature supports the use of waist-to-hip ratio and waist-to-height ratio as alternatives to BMI in overweight and obese children (Palmieri, Henshaw, Carter, & Chowdhury, 2018). However, there is still a need for an established standard definition for waist circumference: the National Institutes of Health recommend waist measurement be done at the ileac crest, and the World Health Organization recommends midway between the ileac crest and the last palpable rib (World Health Organization, 2008). Measurements such as waist-to-height ratio also need to be validated in real-life practice settings and in non-overweight/obese children (Gordon & Siegel, 2018). In clinical practice and clinical trials, a myriad of other factors affecting obesity measures come into play, including cost, ease of measurement (especially among young children) and accuracy. Defining obesity by anthropometric means is perhaps most important in settings where the risk of poor outcomes might otherwise escape surveillance. Ultimately, having meaningful, standardized measures and definitions would be beneficial for future obesity research.

4.1 | Strengths and limitations

The primary strength of this analysis is the use of a cluster-randomized design and a modestly large, generalizable sample of children. The ability to link programme data to the population-based data within a provincial repository to obtain information on socioeconomic status was also a key strength for this analysis. In addition, the socio-demographic variability of the study sample allowed us to conduct these in-depth subgroup analyses. There were also some important limitations. Despite randomization, we observed some differences between intervention and control groups at baseline, although this was accounted for in our analyses. School-level randomization, rather than individual-level randomization, introduced the risk of school-specific confounding; however, intraclass correlation values for each outcome were minimal, suggesting that variance between schools accounted for only a small portion of the overall variance. For feasibility reasons, obesity was assessed using anthropometric measures, despite previously discussed limitations of these measures.

Finally, the Healthy Buddies™ curriculum does not address any possible unintended consequences due to weight stigma, bullying or anxiety, nor is there currently any qualitative research on Healthy Buddies™ which could shed light on these potential effects. Bullying may well be a reason for the limited impact of Healthy Buddies on outcomes in some groups of children.

5 | CONCLUSION

The Healthy Buddies™ curriculum for promoting children's healthy living was differentially effective in a diverse population. Specifically, boys and children living in urban settings and lower income neighbourhoods benefitted from the intervention. These findings highlight opportunities to examine and enhance the curriculum to more broadly improve participants' health. Given the structural conditions that predispose people to obesity and other chronic illness, individual-level behaviour change alone may not always be sufficient for lasting health improvements (Labonté, 2011; Navarro et al., 2006). Ultimately, multi-level interventions that broaden the societal distribution of power, income, goods and services across the population are required to fully address the differential effects of healthy living interventions in order to better manage high rates of obesity among Canadian children.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

This study was conceived and designed jointly by NCN, MB, AK, DC, MD, JMM and RS. The analyses were conducted by JS. All authors, including JEE, MC, EB and LC, as well as those previously mentioned, were involved in interpretation and discussion of the findings. The manuscript was drafted by NCN, MD and JEE, and all other authors reviewed it critically before it was finalized. MA participated in the study design and statistical analyses, interpretation of results, and review and edit of the manuscript for scientific and intellectual content. She reviewed and approved the final version of the published paper.

TRIAL REGISTRATION

NCT01979978 (clinicaltrials.gov).

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APPENDIX A

ID: _____

Child Initials:_____

Administrator Initials: _____

Healthy Living Questionnaire

Date: _____/_____/_____

Title: Healthy Buddies
Ethics Number: _____
School ID:
Primary Girl

To be read by an assessment administrator

Confidentiality:

Your privacy will be respected. Your name and your initials will not be shared with anyone without your permission and your parent's written permission.

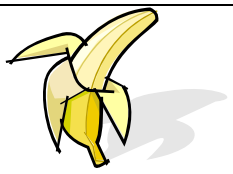
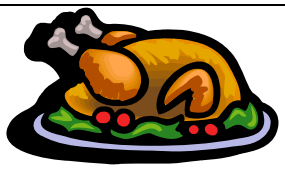
This form has nothing to do with your school marks or grades or your report card. Your teacher and your principal will not know the answers. Your parents or guardians will not know your answers. We want to know what you think about food and fun things to do. What you think about yourself and others. Your answers are whatever is true for you. There are no wrong answers. Researchers at the University of Manitoba are interested in what you think and feel and how that may change this school year.

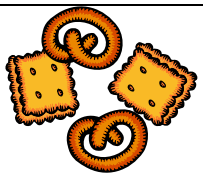
Consent:
Your parent/guardian has given permission for you to answer these questions. If you agree to answer this questionnaire please fill it out. If you do not agree, just tell your teacher and that's okay. Tell your teacher or the person in the front of the class from the University. You will not get in trouble if you don't answer the questions.

A. Please listen to the following statements and answer them based on how true they are for you. Your answers are your opinions about yourself. The information is completely confidential and will not be graded. Please be as honest about yourself as possible.

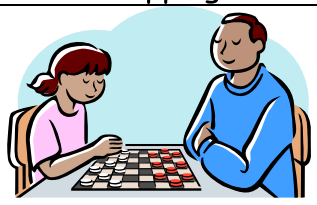
		YES	NO
1	I am happy to be me.		
2	There are lots of special things about me.		
3	I am proud of things about myself.		
4	I can help other people.		
5	I am an important person – just as important as the people around me.		

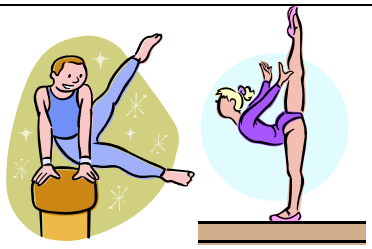
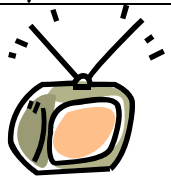
B. Are these foods/drinks healthy for you? Are they good for your body?

	YES	NO
 Carrots		
 Banana		
 Candy		
 Yogurt		
 Chocolate Bar		
 Turkey		
 Pizza		

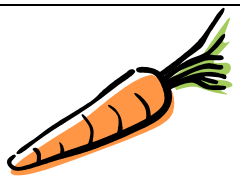
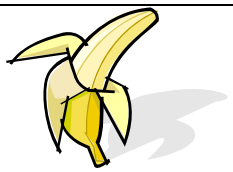
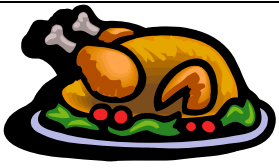
 Fish		
 Crackers		
 Cheese spread		
 Juice		
 Pop		
 Water		
 Milk		

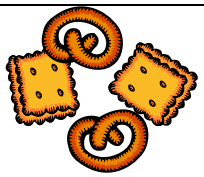
C. Do these activities make your heart muscle strong?

	YES	NO
 Riding a bike		
 Reading or looking at books		
 Skipping		
 Playing board games		
 Dancing		
 Playing on the computer		

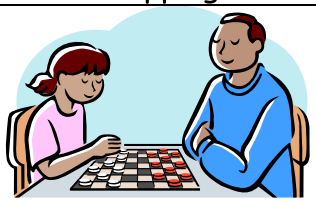
 Gymnastics		
 Watching television		
 Swimming		
 Playing Video games		
 Skateboarding		
 Arts and crafts		

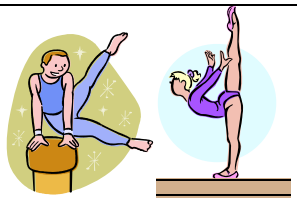
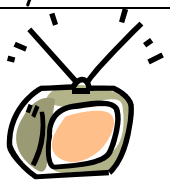
D. How often do you eat these foods/drinks?

	A LOT	A LITTLE	NEVER
 Carrots	✓✓✓	✓	✗
 Banana	✓✓✓	✓	✗
 Candy	✓✓✓	✓	✗
 Yogurt	✓✓✓	✓	✗
 Chocolate Bar	✓✓✓	✓	✗
 Turkey	✓✓✓	✓	✗
 Pizza	✓✓✓	✓	✗

 Fish	✓✓✓	✓	✗
 Crackers	✓✓✓	✓	✗
 Cheese spread	✓✓✓	✓	✗
 Juice	✓✓✓	✓	✗
 Pop	✓✓✓	✓	✗
 Water	✓✓✓	✓	✗
 Milk	✓✓✓	✓	✗

E. How often do you do these activities?

	A LOT	A LITTLE	NEVER
 Riding a bike	✓✓✓	✓	✗
 Reading or looking at books	✓✓✓	✓	✗
 Skipping	✓✓✓	✓	✗
 Playing board games	✓✓✓	✓	✗
 Dancing	✓✓✓	✓	✗
 Playing on the computer	✓✓✓	✓	✗

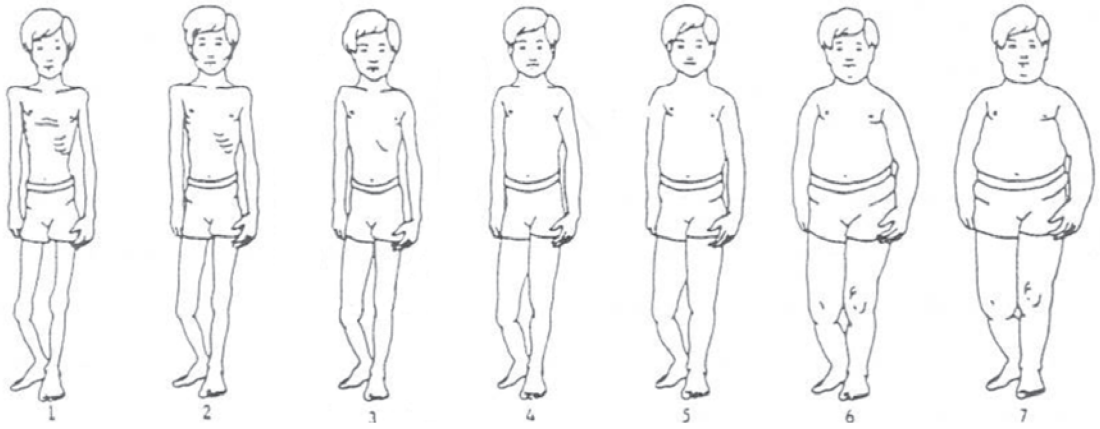
 Gymnastics	✓✓✓	✓	✗
 Watching television	✓✓✓	✓	✗
 Swimming	✓✓✓	✓	✗
 Playing Video games	✓✓✓	✓	✗
 Skateboarding	✓✓✓	✓	✗
 Arts and crafts	✓✓✓	✓	✗

F. The following pictures show boys and girls of different shapes and sizes. Look at the pictures of the kids and answer the questions. There are no wrong answers. Just answer the questions based on what you think and feel.

1. Circle the picture that looks most like you…

2. Circle the picture that shows the way you want to look…

3. Circle the picture that shows the way you think is best for boys to look…



G. Please listen to the following statements and answer them based on how true they are for you. Your answers are your opinions (how you feel) about yourself. Your answers are completely private and will not be graded or seen by your teacher, friends or family. Please be as honest as possible.

		YES	NO
1	I am friendly, kind and helpful.		
2	It is more important to be good on the inside than to look good on the outside.		
3	I play with the older kids at school.		
4	It's ok for people's bodies to have different shapes and sizes.		
5	I get along with other students in my class.		

ID: _____

Child Initials:_____

Administrator Initials: _____

Healthy Living Questionnaire

Date: _____/_____/_____

Title: Healthy Buddies
Ethics Number: _____
School ID:
Primary Boy

To be read by an assessment administrator

Confidentiality:

Your privacy will be respected. Your name and your initials will not be shared with anyone without your permission and your parent's written permission.

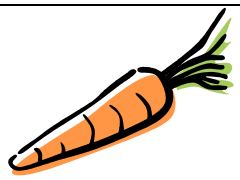
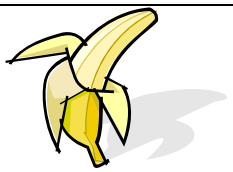
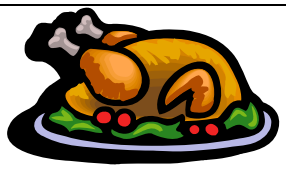
This form has nothing to do with your school marks or grades or your report card. Your teacher and your principal will not know the answers. Your parents or guardians will not know your answers. We want to know what you think about food and fun things to do. What you think about yourself and others. Your answers are whatever is true for you. There are no wrong answers. Researchers at the University of Manitoba are interested in what you think and feel and how that may change this school year.

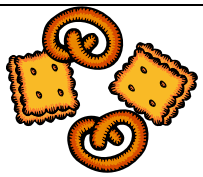
Consent:
Your parent/guardian has given permission for you to answer these questions. If you agree to answer this questionnaire please fill it out. If you do not agree, just tell your teacher and that's okay. Tell your teacher or the person in the front of the class from the University. You will not get in trouble if you don't answer the questions.

A. Please listen to the following statements and answer them based on how true they are for you. Your answers are your opinions about yourself. The information is completely confidential and will not be graded. Please be as honest about yourself as possible.

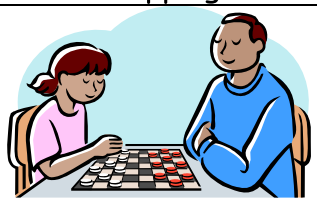
		YES	NO
1	I am happy to be me.		
2	There are lots of special things about me.		
3	I am proud of things about myself.		
4	I can help other people.		
5	I am an important person – just as important as the people around me.		

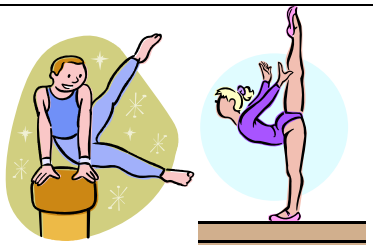
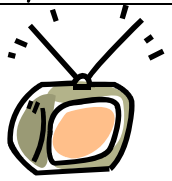
B. Are these foods/drinks healthy for you? Are they good for your body?

	YES	NO
 Carrots		
 Banana		
 Candy		
 Yogurt		
 Chocolate Bar		
 Turkey		
 Pizza		

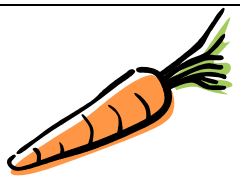
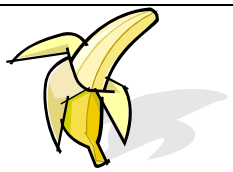
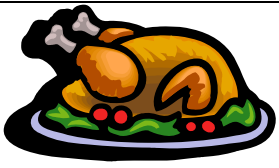
 Fish		
 Crackers		
 Cheese spread		
 Juice		
 Pop		
 Water		
 Milk		

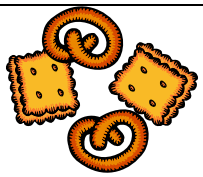
C. Do these activities make your heart muscle strong?

	YES	NO
 Riding a bike		
 Reading or looking at books		
 Skipping		
 Playing board games		
 Dancing		
 Playing on the computer		

 Gymnastics		
 Watching television		
 Swimming		
 Playing Video games		
 Skateboarding		
 Arts and crafts		

D. How often do you eat these foods/drinks?

	A LOT	A LITTLE	NEVER
 Carrots	✓✓✓	✓	✗
 Banana	✓✓✓	✓	✗
 Candy	✓✓✓	✓	✗
 Yogurt	✓✓✓	✓	✗
 Chocolate Bar	✓✓✓	✓	✗
 Turkey	✓✓✓	✓	✗
 Pizza	✓✓✓	✓	✗

 Fish	✓✓✓	✓	✗
 Crackers	✓✓✓	✓	✗
 Cheese spread	✓✓✓	✓	✗
 Juice	✓✓✓	✓	✗
 Pop	✓✓✓	✓	✗
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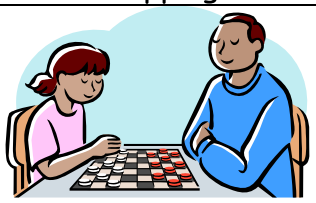
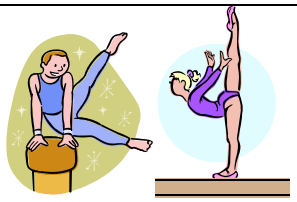
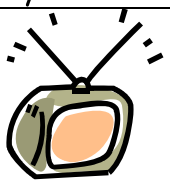
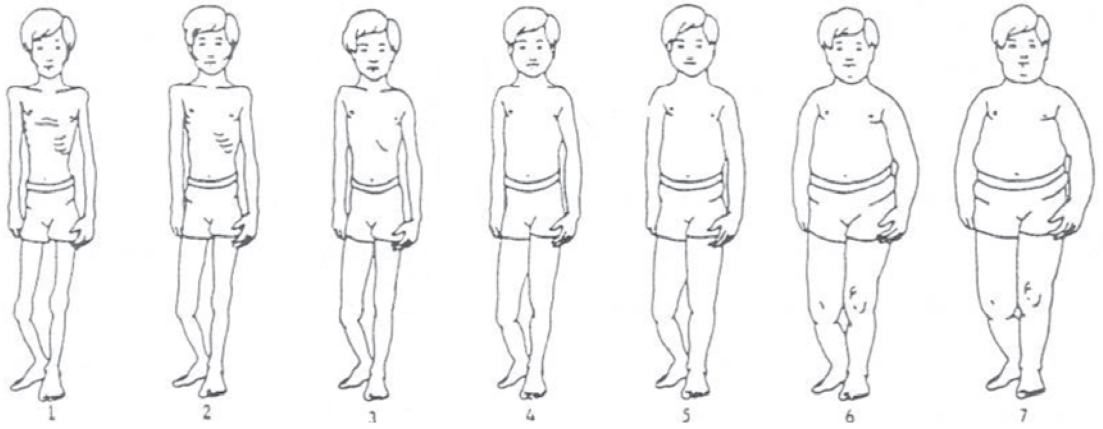
 Playing board games	✓✓✓	✓	✗
 Dancing	✓✓✓	✓	✗
 Playing on the computer	✓✓✓	✓	✗

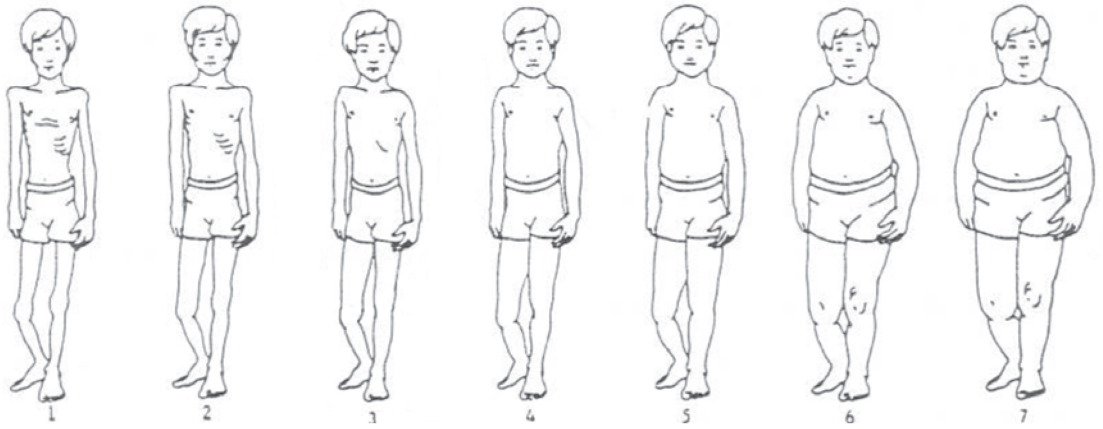
 Gymnastics	✓✓✓	✓	✗
 Watching television	✓✓✓	✓	✗
 Swimming	✓✓✓	✓	✗
 Playing Video games	✓✓✓	✓	✗
 Skateboarding	✓✓✓	✓	✗
 Arts and crafts	✓✓✓	✓	✗

F. The following pictures show boys and girls of different shapes and sizes. Look at the pictures of the kids and answer the questions. There are no wrong answers. Just answer the questions based on what you think and feel.

1. Circle the picture that looks most like you…



2. Circle the picture that shows the way you want to look…



3. Circle the picture that shows the way you think is best for girls to look…

G. Please listen to the following statements and answer them based on how true they are for you. Your answers are your opinions (how you feel) about yourself. Your answers are completely private and will not be graded or seen by your teacher, friends or family. Please be as honest as possible.

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