Background Childhood obesity is a growing epidemic and has become a public health priority in developed countries [1,2].The commitment of APPLE Schools is to schools "in need". In the fall of 2007, school jurisdictions were asked to identify schools located in socioeconomically disadvan- taged neighborhoods or that had otherwise challenges, included grade 5 in the grade configuration, had a princi- pal supportive of the concept of CSH and the focus on healthy living, and schools with transient rates lower than 60%. The principals then agreed to: a) support the inter- vention by dedicating time directed to the project; b) com- mit to a three-and-a-half year involvement; c) participated in ongoing and new research; d) provide office space for the facilitator and access to infrastructure support; e) include the facilitator as part of the school staff; f) create supportive healthy living policies, and g) participate in meetings of other APPLE Schools administrators and facil- itators. The recommendations by the school jurisdictions for 7 urban and 3 rural APPLE Schools with an average school size of 350 students were accommodated. To examine the effectiveness of APPLE Schools, diet, physical activity, and health among students were mea- sured through annual surveys using identical survey Fung et al. International Journal of Behavioral Nutrition and Physical Activity 2012, 9:27 Page 3 of 9 http://www.ijbnpa.org/content/9/1/27 tools as the Raising healthy Eating and Active Living Kids in Alberta (REAL Kids Alberta) evaluation. In 2008, 345 home surveys and parental consent forms were distributed to parents. Of the 317 (92%) students who returned completed consent forms, 306 (97%) received parental consent to participate in the study. A total of 293 students completed the survey, resulting in a student participation rate of 85%. Similarly, data was collected among 344 and 394 consenting students and their parents from the 10 APPLE Schools in 2009 and 2010 respectively. The student participation rate in 2009 and 2010 was 84%, which is considered high for school- based research. REAL Kids Alberta survey The Raising healthy Eating and Active Living Kids in Alberta (REAL Kids Alberta) is a large population-based survey that collects data on health, nutrition, physical activity, lifestyle factors, and measured height and weight among grade 5 students, and data on the school and home environment among their parents and school administra- tors. The aim of REAL Kids Alberta is to assess the impact of the provincial government's initiatives to promote healthy weights among children and youth in Alberta in 2008 and 2010 [31]. Details regarding the measures used as part of REAL Kids Alberta, including dietary intake, physical activity, and obesity, are provided below and are available through the project's website: http://www. REALKidsalberta.ca. The REAL Kids Alberta evaluation used a one-stage stratified random sampling design. The sampling frame includes all elementary schools in Alberta with grade 5 students with the exception of private schools (4.7% of all Albertan students), francophone schools (0.6%), on-reserve federal schools (2.0%), charter schools (1.7%) and colony schools (0.8%) [32]. Schools were stratified according to the following geographical areas: 1) metropolitan: Calgary and Edmonton, each with populations of about 1 million people; 2) city: other municipalities with more than 40,000 residents; and 3) rural-town: municipalities with less than 40,000 residents. Schools were randomly selected within each of these geographical strata to achieve a balanced number of students in each stratum. Of the 184 invited schools, 148 (80.4%) participated in the study in 2008. Envelopes containing parental consent forms and a home survey were sent home to 5,321 students. Of the 3,704 (70%) students with completed consent forms, 3,645 (98%) received

parental consent to participate in the study. Trained evaluation assistants visited each school to admin- ister the student surveys and baseline data was collected among 3,421 students, resulting in a student participation rate of 64%. These surveys were repeated among grade 5 students of the same schools in 2010. However, within the random sample, 7 schools in 2010 refused to participate or were not available for other reasons (i.e. school closures); these schools were replaced by 10 addi- tional schools. Therefore in 2010, 5,597 home surveys were distributed to parents from 151 randomly selected schools, of which 3,687 (66%) students returned consent forms to schools. Of these students, 3,656 (99%) received parental consent to participate and 3,469 were present to complete student surveys. A total of 3,398 participating students and their parents completed surveys, resulting in a participation rate of 61% in 2010. Survey Tools Assessment of Dietary Intake Students completed the Harvard Youth/Adolescent Food Frequency Questionnaire (FFQ), which has been exten- sively validated for use in nutrition research among chil- dren and youth 33,34. Student's caloric intake and intake of fruits and vegetables were calculated based on reported intake from the FFQ and from the Canadian Nutrient Files [35]. Overall diet quality was measured using the Diet Quality Index - International (DQI) score, a compo- site measure of diet quality ranging from 0 to 100 with higher scores indicating better diet quality and includes aspects of diet adequacy, variety, balance and moderation [36,37]. Assessment of Physical Activity Physical activity levels were measured using the Physical Activity Questionnaire for older Children (PAQ-C), which has been demonstrated to be a valid and reliable measure of general moderate to vigorous physical activity levels over a 7-day period [38,39]. The PAQ-C score ranges from 0 to 5 with higher scores indicating higher levels of physical activity. Assessment of Obesity Student standing height was measured to the nearest 0.1 centimeter after students had removed their shoes and body weight was measured to the nearest 0.1 kilogram on calibrated digital scales. Body mass index (BMI) was calcu- lated as weight divided by height2 (kg/m2). Obesity was defined using the International Obesity Task Force (IOTF) BMI cut-off points that are adjusted to age and sex specific categories for children and youth [40]. Socioeconomic factors Information on household income (< $50,000; $50,001 - $100,000; and$100,000) and parental education attain- ment levels (secondary or less, college, university or above) were determined from household questionnaires completed by parents. Statistical analysis All statistical analyses pertaining to the Alberta population were weighted to account for the design effect and repre- sent provincial estimates of the grade 5 student population in Alberta. Differences between baseline and two-year Fung et al. International Journal of Behavioral Nutrition and Physical Activity 2012, 9:27 Page 4 of 9 http://www.ijbnpa.org/content/9/1/27 post-intervention characteristics were assessed using the Chi-square test, Rao-Scott Chi-square or t-test where appropriate. The Rao-Scott Chi-square test was applied to examine differences in weighted estimates by adjusting for the design effect [41,42]. As observations of students are nested within those of their schools, multilevel regression methods were used to examine the effect of CSH. Odds ratios (OR) and 95% confidence intervals (CI) were calculated from multilevel logistic regression models examining the independent association of obesity with the CSH intervention. Regres- sion coefficients (b) and 95% CI were obtained from multi- level linear regression models with fruits and vegetables consumption, dietary quality, dietary energy intake, and physical activity level as outcomes. All analyses were adjusted for the

confounding potential of gender, geo- graphic residency, household income, and parental educa- tion. Analyses pertaining to dietary intake were further adjusted for energy intake; observations with reported dietary energy intakes less than 500 kcal or more than 5,000 kcal were excluded [43]. In subanalyses, we standar- dized the number of servings of fruit and vegetable con- sumption by assuming that each child consumes 2,000 kcal each day [43]. We used the interaction term (defined as the product of the year variable and the binary interven- tion variable Yes = APPLE Schools, No = Provincial sample) in the adjusted multilevel models to estimate the difference in regression coefficients as a measure of inter- vention effect: the change among students attending APPLE Schools relative to those attending other schools in Alberta. STATA version 11 (StataCorp, College Station, TX, USA) was used to perform the statistical analysis. This study, including data collection and parental informed consent forms, was approved by the Health Research Ethics Board at the University of Alberta. Results Characteristics of the grade 5 students at baseline in 2008 and two-years post-intervention are shown in Table 1. With respect to gender, parental education, household income and place of residency, grade 5 students attending APPLE Schools in 2008 did not statistically differ from grade 5 students attending APPLE Schools in 2010. In 2010, relative to 2008, students attending APPLE Schools had higher intakes of fruits and vegetables, had lower calo- ric intakes, were more active, and were less likely to be obese (Table 1 and Figures 1 and 2). Temporal changes in provincial estimates of fruit and vegetable consumption, and caloric intake between 2008 and 2010 were less pro- nounced. Physical activity levels in the province increased between 2008 and 2010 but not with the same magnitude as APPLE Schools. Furthermore, in contrast to the 1.8% Table 1 Characteristics of grade 5 students attending APPLE Schools and other schools in Alberta in 2008 and 2010 Independent Variable Gender Girls Boys Parental Education Secondary or less College University or above Household Income Less than $50,000 $50,001 - $100,000 >$100,000 Geographic Residency Metropolitan City Rural-town Mean servings of fruits & vegetables per day Mean dietary energy intake (kcal) per day Mean DQI score Mean PAQ-C score Obese (%) APPLE Schools 2008 2010 50.7 56.8 49.3 43.2 30.5 24.1 41.1 42.8 28.5 33.2 34.5 31.0 37.4 41.6 28.1 27.4 65.1 62.9 0.0 0.0 34.9 37.1 4.60 5.08 2094 1844 63.2 62.3 3.01 3.16 12.5 10.7 Pb 0.10 0.14 0.62 0.53 0.02 < 0.01 0.30 < 0.01 0.45 Provinciala 2008 2010 Pb 51.5 50.5 48.5 49.5 27.2 25.3 39.7 39.4 33.1 35.3 24.3 24.4 39.8 37.9 35.9 37.7 0.42 0.23 0.41 0.91 46.8 46.6 15.2 14.9 38.0 38.5 4.88 4.73 0.09 1924 1897 0.31 62.8 62.5 0.23 3.19 3.17 0.41 6.9 8.8 0.01 APPLE Schools = Alberta Project Promoting active Living and healthy Eating Schools; DQI = Diet Quality Index; PAQ-C = Physical Activity Questionnaire for older Children a Estimates weighted to be representative of the grade 5 student population b p-values derived using the Chi-square test, Rao-Scott Chi-square or t-test where appropriate Fung et al. International Journal of Behavioral Nutrition and Physical Activity 2012, 9:27 Page 5 of 9 http://www.ijbnpa.org/content/9/1/27 Figure 1 Dietary energy intake and fruits and vegetables consumption among children by intervention exposure. Figure 2 Self-reported physical activity and prevalence of obesity among children by intervention exposure. Fung et al. International Journal of Behavioral Nutrition and Physical Activity 2012, 9:27 Page 6 of 9 http://www.ijbnpa.org/content/9/1/27 decline in the prevalence rates of obesity among APPLE Schools, the provincial obesity rates increased by 1.9% between 2008 and 2010 (Table 1). After controlling for the

effect of a child's gender, household income, parental education, and location of residency, multilevel regression analysis showed that stu- dents attending APPLE Schools in 2010 had better diets compared to students attending APPLE Schools in 2008, as characterized by a statistically significant increase of 0.39 serving/day in fruits and vegetables consumption, a statistically significant decrease of 237 kcal/day in diet- ary energy intake, and an increase in overall diet quality. Students attending APPLE Schools in 2010 were also significantly more physically active than those in 2008. Moreover, we observed a 16% decline in the odds of being obese (adjusted OR, 0.84; 95% CI, 0.52, 1.36) among students attending the APPLE Schools two years into the intervention relative to baseline (2008). In con- trast, students elsewhere in the province seemed to have exhibited opposite trends over the same two-year per- iod. Adjusted regression analysis showed that students elsewhere in Alberta saw a decrease of 0.12 serving/day in the consumption of fruits and vegetables and a decrease in diet quality. At the provincial level, no sub- stantial changes were observed in levels of physical activity and only a modest decline in energy intake was observed. Moreover, students attending schools else- where in Alberta saw a 37% increase in the odds of being obese (adjusted OR, 1.37; 95% CI, 1.11, 1.70). The change in APPLE Schools relative to the change in Alberta represents the intervention effect. The change in fruits and vegetables consumption of students attending APPLE Schools relative to those attending other Albertan schools was 0.55 serving/day and borderline significant (Table 2: 95% CI, -0.02, 1.13). APPLE Schools students' changes in physical activity and calorie consumption were also statistically significant relative to changes elsewhere in the province (Table 2). The odds of being obese in 2010 relative to 2008 was 39% lower (Table 2 OR, 0.61; 95% CI, 0.35, 1.06) among students from APPLE Schools com- pared to students elsewhere in the province, although this was only borderline significant. This is equivalent to a multivariable-adjusted 2.2% reduction in the prevalence of obesity among APPLE Schools between 2008 to 2010 as compared to a multivariable-adjusted 2.8% increase in the prevalence of obesity elsewhere in Alberta over the same two-year period. Discussion The present study demonstrates the effectiveness of a CSH intervention in fostering healthy behaviors in terms of improvements in healthy eating and active living. Over a two-year period, APPLE Schools changed their school environments and attending students reported increases in the consumption of fruits and vegetables along with decreases in energy intake, were more physically active, and exhibited less obesity compared to students else- where in the province. Public health research is increasingly aiming to identify "best practice" and "practice based evidence" rather than to demonstrate universal evidence because the success of public health programs is greatly affected by contextual factors [44].That these schools were "in need" of health promotion was reflected in the poor diets and low levels of physical activity among students attend- ing these schools at baseline in 2008. However, two years into the intervention, students attending APPLE Schools had improved their eating behaviours and physical activity levels such that they approximated or exceeded the pro- vincial average. Given the substantial morbidity and diminished quality of life associated with poor diet, physi- cal inactivity and childhood obesity, studies are needed to demonstrate the cost-effectiveness of CSH prevention programs considering that obese children have higher healthcare cost than normal weight children [47]. Such economic analyses will better guide public health decision makers in directing resources towards broader implemen- tation of

school–based interventions and may be instru– mental in informing various policies across North America. Strengths of the current study include its large repre– sentative sample, high response rate for school–based research, pre–intervention measurements, and the use of measured height and weight to assess body weight sta– tus. However, as with most population–based observa– tional studies, the present study is subject to limitations. First of all, the 10 APPLE Schools were selected by school jurisdictions rather than randomly, which limits the generalizability of the results. Responses to question– naires remain subjective and are prone to reporting error. Although individuals have a tendency to over– report levels of physical activity, it has been shown that self–reported measures of physical activity are correlated with objective measures among children [48]. Similarly, we acknowledge the imprecision associated with the assessment of dietary energy intake through the FFQ and therefore have standardized the number of servings of fruit and vegetable consumption based on energy intake. Despite the use of a validated FFQ for this age group, limitations of self–report apply to the assessment of dietary intake in which studies have shown that indi– viduals are more likely to underreport energy intake [49]. Moreover, CSH aims to improve various aspects of the school environment such that they support improved dietary patterns and physical activity among students. The implementation was tailored and devel– oped distinctively in each of the 10 APPLE Schools. Although randomized control trials provide the highest level of evidence for the evaluation of interventions, they may not be optimal for the evaluation of interven– tions that are tailored and develop distinctively. Further– more, we opted for evaluation of prevalence rates that speak better to the needs of public health decision makers rather than incidence rates by following selected students over time. Conclusions In conclusion, the APPLE Schools program demon– strated positive results in the improvement of dietary habits and physical activity levels among grade 5 stu– dents in Alberta. This suggests that the AVHPS "best practice" approach to CSH is transferable outside of the original schools in Nova Scotia to another setting, a "next practice".The AVHPS project, a successful grassroots project, is recognized as a "best practice" of CSH in Canada [28]. However, to our knowledge, no earlier stu– dies have addressed the transferability of "best practice", Table 2 Effect of Comprehensive School Health on diet, physical activity and body weight among grade 5 students two years from baseline Fruits and vegetables consumption per day (b and 95% CI) Dietary energy intake (kcal) per day (b and 95% CI) DQI score (b and 95% CI) PAQ–C score (b and 95% CI) Obesity (Odds Ratio and 95% CI) APPLE Schoolsa 0.39 (0.00, 0.78) −236.51 (−366.22, −106.81) Alberta Schoolsb (−0.29, 0.06) (−78.34, 26.56) (−0.77, 0.31) (−0.01, 0.06) Intervention Effect: Change in APPLE Schools over time relative to the coinciding change in Alberta schools (95% CI)b 0.55 (−0.02, 1.13) −212.11 (−315.07, −109.16) 1.14 (−0.55, 2.83) 0.10 (0.01, 0.20) 0.61 (0.35, 1.06) 0.96 (−0.28, 2.19) 0.13 (0.03,0.23) 0.02 0.84 (0.52, 1.36) 1.37 (1.11, 1.70) −0.12 −25.89 −0.23 APPLE Schools = Alberta Project Promoting active Living and healthy Eating Schools; DQI = Diet Quality Index; PAQ–C = Physical Activity Questionnaire for older Children a APPLE Schools were surveyed annually from 2008 to 2010; therefore analysis included additional measurements from 2009 b Estimates weighted to be representative of the grade 5 Alberta student population All estimates were adjusted for child's gender, household income, parental education, and rural residency.More– over, children with high body mass index (BMI) often * Correspondence: paul.veugelers@ualberta.ca School of Public Health, University of

Alberta, 6–50 University Terrace, 8303 – 112 St, Edmonton, AB T6G 2 T4, Canada become obese adults, who are at increased risk of develop– ing obesity–related diseases, such as type 2 diabetes, cardio– vascular disease, and certain types of cancer, and place significant financial burden on healthcare systems [8–10].[http:// cbpp–pcpe.phac–aspc.gc.ca/].2.3.4.5.6.7.8.9.10.11.12.13.14.15.16.17.18.19.20.21.22.23.24.25.26.27.28.29.30.31.32.33.34..35.36.37.38.39.40.41.42.43.44.46.47.48.49