

An outcome evaluation of an environmental nutrition intervention conducted in an institute of higher learning in Singapore: A cluster-randomized trial

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Abstract

Objective: Evidence for effective food environment interventions to improve the quality of out-of-home foods is limited in Asia. The Healthier Dining Programme (HDP) is a voluntary government programme designed to increase the availability and accessibility of healthier foods and beverages at eateries in Singapore, a multi-ethnic, urbanized and developed nation. The objective of our study was to evaluate effects of the HDP on the out-of-home dietary intakes of consumers at an institute of higher learning.

Design/Setting: We used a cluster-randomized trial design. Six food centers (two food courts and four canteens) at a large university campus were randomly assigned to the intervention or control arm. Participants were university students or staff aged ≥ 18 years ($n=408$) who frequently dined at these six food centers. Relevant data were gathered by interview and a 7-day food diary before and after 10 weeks of the intervention. Generalized estimating equations for logistic and linear regression were used to assess the difference in intake of out-of-home healthier dishes between the two study arms.

Results: Participants in the intervention arm were more likely to have at least one healthier out-of-home dish per week as compared to those in the control arm (84% vs. 65%, unadjusted OR: 2.79 95% CI: 1.59, 4.88). This was due mainly to the higher consumption of dishes prepared with healthier oil blends (unadjusted OR: 3.24 95% CI: 1.95, 5.38) and lower-sodium salt (unadjusted OR: 4.36 95% CI: 1.64, 11.58) in the intervention arm. Whilst saturated and polyunsaturated fat intake in the two arms were comparable, participants in the intervention arm had lower total fat (-1.27 g/1000 kcal, 95% CI: -2.48, -0.06) and monounsaturated fat intakes (-0.50 g/1000 kcal, 95% CI: -0.94, -0.06), from out-of-home dishes as compared with the control arm.

Conclusions: These findings suggest that environmental interventions at institutes of higher learning to increase healthier food availability and accessibility can improve dietary intake from out-of-home foods.

Trial registration: ClinicalTrial.gov, NCT02435264. Registered 5 May 2015 - Retrospectively registered, <https://clinicaltrials.gov/ct2/show/NCT02435264>

NUS Institutional Review Board approval number: 11-137

1.0 Introduction

The world-wide prevalence of diabetes in adults is predicted to increase to 9.9 percent by 2045 (1) with a disproportionately higher burden in the Asia-Pacific region (2). Dietary quality plays an important role in the etiology of type-2 diabetes and other chronic diseases (3). Although determinants of dietary behaviours are multifactorial, the out-of-home eating environment plays a key role. Eating out-of-home has been associated with poorer dietary quality and a higher risk of obesity, type-2 diabetes and cardiovascular diseases (4-7). Hence, interventions that support healthier choices at eating places may be an effective approach for promoting and sustaining healthier dietary behaviours (8-12).

The food environment of institutes of higher learning (IHLs), such as universities, are an important setting for promoting healthy dietary behaviours. Attending university often marks the beginning of independence for young adults who are learning to adapt to an out-of-home environment (12–14). Making healthy dietary choices may be challenging for students who may prioritize taste, price and appeal of foods over healthfulness (15–17). Unhealthy diets characterized by low intake of fruits and vegetables, and high intake of sugary drinks are common among university students in Western settings (18). In a systematic review (13) which examined the effectiveness of dietary interventions conducted at universities, environmental approaches such as point-of-purchase messaging were found to be more effective in improving students' dietary intakes compared to traditional educational approaches. In general, education alone, when uncoupled from environmental or food price improvements, has limited impact on eating behaviours (19–21). Among environmental interventions, the menu labelling approach has been widely investigated (22). Current evidence suggests that menu labelling, when complemented with other strategies such as price incentives and messaging, are more likely to be effective in improving healthy food and beverage selections (23,24). However, the current body of evidence is primarily based on studies from Western settings (25,26), and few studies have been conducted in Asia (27–30). American and Asian young adults (31) have different perspectives on healthy eating.

While the socio-ecological model (32,33) has been increasingly used to design multi-level interventions that address both individual and environmental level risk factors, the effectiveness of multi-level interventions on out-of-home dietary intakes has not been investigated in Asian settings (34). As in many other countries, the urban environment in Singapore, a multi-ethnic and developed nation, is dominated by ubiquitous out-of-home food options high in saturated fat, sodium, and refined carbohydrates (35). Poor dietary intake is one of the leading contributors to ill health and premature death in Singapore (36). With over 20% of Singaporean adults eating daily at workplace or school food centers (8) improving the food environment may be an effective strategy for improving the dietary intakes of Singaporeans.

In Singapore, the Health Promotion Board (HPB), a statutory government body responsible for health promotion activities in Singapore, launched the Healthier Dining Programme (HDP), nationwide in 2014 (35). This voluntary programme aims to improve the nutritional quality of out-of-home foods served at eateries, including those at IHLs by using an approach that seeks to both increase the availability of healthier food options, and consumer demand for these foods (35). However, the effectiveness of this programme has not been evaluated. The implementation of the program by the National University of Singapore (NUS) in 2015 provided a unique opportunity to evaluate the effectiveness of the HDP. Further, there are few published reports of rigorous evaluations of environmental dietary interventions (13). We therefore conducted a cluster-randomized controlled trial to evaluate the effectiveness of NUS's HDP on the intake of healthier out-of-home dishes, dietary fats and fibre among students and staff. We hypothesized that the proportion of consumers having at least one healthier out-of-home dish per week would increase in the intervention arm as compared with the control arm.

2.0 Methods

2.1 The HDP Intervention

The nationally implemented HDP leverages on the principle of reciprocal determinism, a central construct in Bandura's Social Cognitive Theory (37), and on the socioecological model described by McLeroy (32,33) to improve out-of-home dietary intakes by increasing both the demand for and supply of healthier foods. To this end, the programme targeted (i) individual-level factors such as knowledge and attitudes via posters displayed at food centers to increase the demand for healthier foods, and (ii) environmental factors by increasing the availability of healthier choices like wholegrains (i.e. brown rice and wholegrain noodles), and by highlighting lower-calorie options (≤ 500 kcal) on menu boards, and (iii) macro-level factors, specifically the food supply chain to reduce the cost of healthier ingredients to increase their use by food vendors. Several complementary grants were launched by HPB to reduce costs for implementing the programme (38,39). The Healthier Ingredient Scheme incentivises suppliers of healthier ingredients to increase their availability to food vendors at a cost that is comparable to their regular counterparts. The Healthy Dining Grant subsidizes nutrition training, development of healthier menus, and marketing and promotion (39).

The university's Office of Campus Amenities (OCA) which oversees retail and dining services, worked with HPB to adapt and implement the HDP. At NUS, food centers are of two kinds: canteens or food courts—while canteens are serviced by independent food vendors, food courts are managed by food court supervisors and largely house chain stalls. Chain stall workers have less autonomy over the purchase of ingredients as compared to independent food vendors. In general, canteens are not air-conditioned, while food courts are typically air-conditioned and charge higher prices.

To change knowledge and attitudes at the individual level, health communication messages were developed, and these were disseminated via posters (at point-of-purchase and around the food centers) and stall directories. This included six (five informational and one injunctive) types of promotional posters to encourage healthier eating behaviours and increase demand for healthier foods (Supplementary Figure 1).

To improve the availability of healthier meals, all food stalls at the intervention centers that sold lunch/dinner meal items were required to offer at least one lower-calorie dish (defined as 500 kcal or less), were strongly encouraged to use healthier oil blends and encouraged to use lower-sodium salt. In addition, the OCA required that at least two food stalls in each intervention centre offered whole-grain rice. To support the use of healthier ingredients, vendors were provided with nutritionist support and a recommended healthier ingredients supplier who participated in the Healthier Ingredient Scheme (38). While healthier oil and wholegrain rice were provided at costs that were more comparable to less healthier oil blends and white rice, the price of healthier salt was not subsidized. A visual representation of the intervention and intended effects is presented in Figure 1. The nutritionist helped the food stalls to identify menu items that were 500 kcal or less and an effort was made to promote these items by providing an A5-sized point-of-purchase signage. In the event that a food stall did not offer any lower-calorie item, a new recipe was formulated by the nutritionist in consultation with the food vendor. In

addition, the lower-calorie dishes were labelled with the Healthier Choice Symbol (Supplementary Figure 2) on point-of-purchase posters and stall directories (Supplementary Figure 3). In Singapore, the Healthier Choice Symbol logo has been used to identify nutritionally healthier options for packaged foods and is widely recognized by the nation's residents (40). At drinks stalls, lower-sugar beverages were promoted with 'ask for lower sugar options' decals developed by HPB.

2.2 Study aim and design

We aimed to evaluate the effectiveness of the HDP in changing the dietary intakes of staff and students at NUS over a 10-week period. The primary outcome of interest was the between-arm post-intervention difference in proportion of consumers who had at least one healthier out-of-home dish per week. A healthier out-of-home dish was defined as one that was either lower-calorie (≤ 500 kcal), or was prepared using healthier oil blends ($\leq 35\%$ saturated fats content), brown rice or lower-sodium salt; these were the nutritional aspects specifically targeted by the HDP (Supplementary Table 1). The secondary outcomes were differences in dietary fatty acids and fibre intake, and polyunsaturated and saturated fatty acids (P:S) ratio in the intervention arm as compared to the control arm. We hypothesized that the HDP intervention will improve out-of-home dietary intake, specifically that the proportion of participants having at least one healthier dish per week will be significantly higher in the intervention arm as compared to the control arm, and that participants in the intervention arm will have lower saturated fatty acid, a higher P:S ratio and lower fibre intake after exposure to 10-weeks of the intervention.

We used a cluster-randomized controlled trial design with food centers as the unit of randomization (cluster) and consumers as the unit of analysis. Data were collected at baseline and throughout the implementation of the HDP.

2.3 Setting and random allocation

The trial was conducted at the Kent Ridge campus of NUS, which had 10 main food centers; five canteens and five food courts. We excluded food centers housed in residential halls that served only students living on campus ($n = 2$), had previously participated in a trial HDP intervention ($n = 1$), or were planning their own healthier food intervention ($n = 1$). As a result, six centers (four canteens and two food courts) were available for the study (Figure 2).

In August/September 2014, we conducted a pilot study at the six food centers to inform the design of our study prior to randomization. Using convenience sampling, we interviewed 673 consumers to assess how frequently they ate at the food centers and their demographic characteristics. People typically ate at food courts less frequently (median consumption of 1–2 dishes) per week) than at canteens (2–5 dishes per week). Given the differences between food courts and canteens, we performed stratified randomization by center-type to ensure that both the intervention and control arms were equally represented in terms of food courts and canteens (one food court and two canteens each). We also ensured that each stratum

consisted of food centres with similar socio-demographic characteristics of frequent consumers before our statistical advisor randomly allocated them to the intervention (to receive a 10-weeks food vendors' intervention) or control using computer generated codes.

2.4 Study participants and data collection

To ensure adequate exposure to the intervention and to limit contamination, we set inclusion criteria to recruit only frequent consumers of the respective food centers. Specifically, only staff and students aged 18 years or older, who ate at least four times per week at the canteens or two times per week at the food courts were eligible for the study. To reduce drop-out, individuals who were likely to be away at the time of post-intervention data collection were not eligible. We proportionately sampled for gender and occupation status (staff or student) to improve representativeness.

The sample size was estimated based on a proportion difference of 40% (45% in intervention and 5% in control) of consumers who consumed healthier options at least once weekly, with an intra-cluster correlation of 0.15, power of 0.8, and two-sided alpha of 0.05. Based on these estimates we needed 51 participants per food center. As we expected a dropout rate of 25%, informed by other studies conducted in Singapore by our group, we enrolled 68 participants per food centre (408 participants in total).

Participants were recruited via convenience sampling at the six food centers. Participants' flow through our study is shown in Figure 2. The enrolment rates were 27% for control arm and 24% for intervention arm. We started pre-intervention data collection in October 2014 before the start of food vendors' training by the nutritionist and prior to cluster-randomization. The HDP was officially launched to consumers in the intervention arm on 2 February 2015. Post-intervention data were collected about 10 weeks after intervention launch. We engaged an external survey company to recruit and interview participants—the same participants were interviewed at baseline and follow-up visits. The interviewers were trained and shadowed for the first few interviews by a researcher (S. S. S.Y) to ensure data were collected as planned. We asked participants about their perceptions of healthy eating and food environment, awareness of the intervention and socio-demographic characteristics using a structured questionnaire. The questions were adapted from a food-centre pilot study and translated into Chinese, Tamil and Malay to facilitate interviews with participants who were more comfortable in these languages. At the same interview, participants were taught how to keep a 7-day diary to record consumption of out-of-home foods.

Face-to-face interviews were conducted for the pre-intervention survey. To increase participant retention, we sent reminder letters with a token of appreciation and provided the option of completing the post-intervention survey through an online platform. Post-intervention surveys were mostly self-administered except for 12 participants who requested for face-to-face interviews. Participants provided informed consent prior to the start of the pre-intervention survey interview and cluster-randomization. The study was approved by the NUS Institutional Review Board.

2.5 Dietary assessment

To assess out-of-home dietary intakes, we used data collected from the food diaries. Participants were asked to record all foods purchased and consumed from out-of-home eateries, and locations of purchase. For foods obtained from campus eateries, participants were asked to note information on the specific food stall. This allowed us to assign more accurate nutrient values to the dishes that had been modified by the stalls according to HDP goals (oil type, salt type and /or use of brown rice). The food diary information was reviewed and ambiguous entries were clarified in-person or via phone calls by trained researchers before being processed using a locally developed diet analysis software (E-food systems, National University of Singapore Saw Swee Hock School of Public Health and A*Star Singapore Institute for Clinical Sciences). The diet analysis software, which uses food composition data from the HPB FOCOS food composition database (41) and the U.S. Department of Agriculture (USDA) Nutrient Database for Standard Reference (42), allows for the analysis of frequently consumed foods items including prepared dishes (based on standard recipes) and also the addition of dishes with customized recipes. We created alternate versions of existing local dishes by modifying the ingredients accordingly. The nutrient composition of dishes served at the centers was based on information obtained from the nutritionist and during environmental audits of the centers. For foods that were not consumed at the six centers, we used the default food composition values of the database. Portion sizes consumed were based on the self-reported data from the diaries

As described earlier, participants were asked to record only foods consumed out-of-home in the food diaries. We analysed only out-of-home foods which have the potential to be intervened by the HDP through the food vendors. Hence, beverages and pre-packaged food items with nutritional labels or brand logos and ready-to-eat dishes/sandwiches distributed by retail outlets (e.g. supermarkets or convenience stalls) or vending machines were excluded. The decision tree for inclusion of foods recorded by participants in our analysis is shown in Supplementary Figure 4. Dishes that fit the healthier dish description (defined earlier in Section 2.2) were first coded by one researcher (S. S. S. Y.) and then verified by another researcher (T. Z.).

2.6 Data Analysis

Only participants who submitted a food diary were included for the analyses of out-of-home food consumption. Generalized estimating equations (GEE) for logistic regression was applied to compare the proportion of consumers who had at least one healthier out-of-home dish per week between the two study arms. We also conducted GEE logistic regressions for specific healthy dish types. In addition, the models were adjusted for respective baseline dish intake and pre-intervention energy intake from out-of-home foods. Food center-level correlations between the participants were accounted for in the GEE population averaged models. We assumed an exchangeable correlation structure with a robust sandwich variance estimator for the GEE models.

To assess differences in out-of-home dietary intake, separate GEE for linear regression were used to compare the mean P:S ratio and intakes (g/1000 kcal) of monounsaturated fat, polyunsaturated fat, saturated fat, total fat and fibre between groups. Adjustment for baseline dietary and energy intakes from out-of-home foods was further considered.

Categorical outcomes were reported as odds ratios and 95% confidence intervals (CI). Continuous outcomes were presented as mean differences and their associated 95% CI. All data were analysed using a modified intention-to-treat approach, with 2-sided tests at the 5% level of significance on the Stata SE platform (version 13.0 for Windows; StataCorp LP, College Station, TX, USA).

3.0 Results

3.1 Participant characteristics

Baseline characteristics of the 247 (61%) participants who submitted both pre- and post-intervention food diaries are presented in Table 1. They were largely similar to that of the 408 participants enrolled initially (Supplementary Table 2). Of the 247 participants, 56% were women, the median age was 24 years (interquartile range 21 to 33), and the mean body mass index (BMI) was 21.2 (SD 3.5) kg/m². Gender, age distribution, ethnicity, occupation and BMI were comparable between the two groups. There was however some suggestion that the highest education attainment differed between the two arms, with participants in the intervention arm being less likely to have had university education than the control arm. This observed difference could be due to chance hence we did not include education attainment in our adjusted models. The dropout rate was 40% in the control arm and 39% in the intervention arm.

Table 1: Baseline demographics of participants who completed the post-intervention 7-day food diary

Characteristics[#]	Control (n= 123)	Intervention (n= 124)	Total (n= 247)
Gender, N (%)			
Male	52 (42)	56 (45)	108 (44)
Female	71 (58)	68 (55)	139 (56)
Age, median (IQR)	25 (21 to 32)	24 (21 to 34)	24 (21 to 33)
Ethnicity, N(%)			
Chinese	97 (79)	100 (81)	197 (80)
Indian	15 (12)	8 (6)	23 (9)
Malay	5 (4)	7 (6)	12 (5)
Others	6 (5)	9 (7)	15 (6)
Education attainment, N(%)			
Polytechnic and below	63 (51)	82 (66)	145 (59)
University or higher	60 (49)	42 (34)	102 (41)
Occupation, N(%)			
Student	64 (52)	64 (52)	128 (52)
Staff	59 (48)	60 (48)	119 (48)
BMI (kg/m²), mean (SD)	21.1 (3.1)	21.5 (3.8)	21.2 (3.5)

IQR, interquartile range
 BMI, body mass index
 SD, standard deviation

3.2 Primary outcomes

Dietary intakes of participants based on out-of-home healthier dishes before and after the intervention are shown in Table 2. The total number of diary days recorded was similar between the intervention and control arm and for pre- and post-intervention. Pre-intervention, the proportion of participants having at least one healthier dish per week and having a dish with healthier oils was higher in the intervention arm compared with the control arm. Participants in the intervention arm were more likely to have at least one healthier dish per week as compared to those in the control arm post-intervention (unadjusted OR: 2.79 95% CI: 1.59, 4.88). No participant had lower-sodium salt prepared dishes pre-intervention. The proportion of participants having at least one lower-sodium salt prepared dish increased more in the intervention arm compared with the control arm. Compared with participants in the control arm, those in the intervention arm were 3 times more likely to have at least one healthier oil dish (unadjusted OR: 3.24 95% CI: 1.95, 5.38) and 4 times more likely to have at least one lower-sodium salt prepared dish per week (unadjusted OR: 4.36 95% CI: 1.64, 11.58).

The proportion of participants having lower-calorie dishes did not change substantially after the intervention period in either the intervention or control arm. The proportion of participants having at least one brown rice dish per week increased in both the intervention and control arm. The proportion of participants having lower-calorie dishes or brown rice dishes did not differ significantly between the two

arms. Adjusting for baseline consumption of the respective healthier dishes and pre-intervention energy intake from out-of-home foods did not materially alter these conclusions.

3.3 Secondary outcomes

Table 2 shows dietary intakes based on out-of-home foods consumed by participants pre- and post-intervention based on their food diaries. Post-intervention energy intake from out-of-home dishes was higher than pre-intervention energy intake in both arms. After the intervention, only total fat and monounsaturated fatty acid intakes differed between the intervention and control arm.

Participants in the intervention arm had a significantly lower total fat (-1.27 g/1000 kcal, 95% CI: -2.48 , -0.06) and monounsaturated fat intake (-0.50 g/1000kcal, 95% CI: -0.94 , -0.06) as compared with the control arm. Adjusting for baseline intakes of the respective dietary factor and pre-intervention energy intake from out-of-home foods only substantially affected the results for dietary fibre intake; fiber intake became significantly higher in the intervention arm as compared to the control arm (0.21 g/1000 kcal, 95% CI: 0.07 , 0.36).

Table 2: Out-of-home healthier dish intake and dietary quality before and after intervention ^a

^l For participants who submitted both pre- and post-intervention diary

Healthier dishes consist of healthier oil blend prepared dishes, brown rice prepared dishes, lower-sodium salt prepared dish and lower-calorie dishes

Adjusted for baseline intake of the respective dish/dietary factor and pre-intervention energy intake from out of ome foods

P-value was significant in generalized estimating equations model

QR, interquartile range

P:S ratio, polyunsaturated and saturated fatty acids ratio

4.0 Discussion

In this cluster-randomised controlled trial, we evaluated a 10-weeks multi-component intervention to improve dietary quality of out-of-home food consumption conducted on an Asian university campus. The intervention increased the proportion of consumers having at least one healthier out-of-home dish per week. In particular, the intervention increased the consumption of dishes prepared with the healthier oil blend and dishes prepared with lower-sodium salt. In terms of dietary intakes from out-of-home dishes, the intervention decreased the intakes of monounsaturated and total fat.

The intervention mainly increased the consumption of healthier oil blend prepared dishes and lower-sodium salt prepared dishes. These two types of healthier dishes were incorporated by default during

Healthier out-of-home dishes consumption (per week)	Control arm (n= 123)		Intervention arm (n= 124)		Unadjusted	Adjusted
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention		
Total no. of diary days collected	7 (5 to 7)	7 (6 to 7)	7 (6 to 7)	7 (6 to 7)		
	Median (IQR)					
	n (%)				Odds ratio [¶]	
Participants who had at least 1 healthier dish*	44 (35.8%)	80 (65.0%)	68 (54.8%)	104 (83.9%)	2.79 (1.59, 4.88) \diamond	2.54 (1.45, 4.46) \diamond
at least 1 <u>healthier oil blend prepared dishes</u>	18 (14.6%)	66 (53.7%)	40 (32.3%)	98 (79.0%)	3.24 (1.95, 5.38) \diamond	2.98 (1.91, 4.65) \diamond
at least 1 <u>lower-calorie dishes</u>	28 (22.8%)	26 (21.1%)	36 (29.0%)	29 (23.4%)	1.13 (0.69, 1.87)	1.10 (0.73, 1.65)
at least 1 <u>brown rice prepared dishes</u>	9 (7.3%)	14 (11.4%)	11 (8.9%)	19 (15.3%)	1.43 (0.71, 2.89)	1.30 (0.57, 2.93)
at least 1 <u>lower-sodium salt prepared dishes</u>	0 (0.0%)	11 (8.9%)	0 (0.0%)	36 (29.0%)	4.36 (1.64, 11.58) \diamond	4.37 (1.68, 11.38) \diamond
Dietary intake based on out-of-home food consumption	Median (IQR)				Linear regression coefficients [¶]	
P:S ratio	1.38 (1.22, 1.52)	1.40 (1.21, 1.53)	1.33 (1.18, 1.51)	1.39 (1.24, 1.52)	0.004 (-0.05, 0.05)	0.006 (-0.05, 0.07)
Energy (kcal/day)	841 (698, 1087)	922 (732, 1176)	953 (714, 1210)	969 (762, 1165)		
Protein (g/1000 kcal)	41.18 (37.19, 47.09)	42.32 (38.40, 46.72)	40.75 (37.32, 45.39)	42.95 (38.92, 46.83)		
Carbohydrate (g/1000 kcal)	111 (104, 118)	108 (98, 119)	112 (99, 119)	110 (101, 118)		
Total fat (g/1000 kcal)	42.75 (39.52, 45.37)	43.47 (39.59, 47.74)	43.31 (38.61, 46.79)	42.79 (38.81, 45.95)	-1.27 (-2.48, -0.06) \diamond	-1.40 (-2.53, -0.26) \diamond
Saturated fat (g/1000 kcal)	16.75 (14.32, 18.63)	17.01 (14.86, 19.58)	17.09 (15.19, 19.25)	16.90 (14.79, 18.48)	-0.38 (-1.01, 0.24)	-0.51 (-1.12, 0.09)
Mono-unsaturated fat (g/1000 kcal)	16.08 (14.19, 17.60)	15.75 (13.99, 17.76)	16.38 (13.94, 18.15)	15.38 (13.59, 17.64)	-0.50 (-0.94, -0.06) \diamond	-0.60 (-1.07, -0.12) \diamond
Poly-unsaturated fat (g/1000 kcal)	6.35 (5.66, 7.71)	6.97 (5.77, 7.99)	6.25 (5.32, 7.27)	6.98 (6.12, 7.89)	0.03 (-0.24, 0.29)	0.08 (-0.26, 0.41)

Dietary fibre (g/1000 kcal)	6.76 (6.08, 8.20)	6.93 (5.74, 8.21)	6.46 (5.62, 7.79)	7.04 (6.03, 8.08)	-0.14 (-0.59, 0.31)	0.21 (0.07, 0.36) \diamond
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dish preparation by the food vendors. Decals stating the use of healthier oil were displayed at point-of-purchase. The intervention did not significantly change the consumption of the other two types of healthier dishes, the lower-calorie- and brown rice-dishes. Both lower-calorie dishes and brown rice were highlighted by decals at the point-of-purchase and stall directories, but were not the default option (except for two stalls which had 20% or less brown rice incorporated in all chicken rice dishes). This finding suggests that environmental dietary interventions are more likely to be successful when the healthier ingredients are used by default. This supports the theory that habitual human behaviour tends to be automatically cued by the environment without much conscious awareness or deliberation (43). This strong disposition to go with default options during decision making, can therefore be capitalized to promote healthier eating behaviours (44). Conventionally, a default is viewed as ‘the option provided to the consumer if they do not explicitly state their preference’ (45). In this study, with the default being oil used in food preparation, participants did not have alternatives (e.g. foods cooked with high saturated-fat oil) to choose from at the food centre. Our finding is consistent with the results of an experiment conducted in a Dutch university on the choice of bread and topping combinations by students and staff (46). A strong default effect was observed in the study when the majority of the participants chose to go with the default option (whole wheat, brown or white bread) and deemed it to be attractive, regardless of the type of topping offered.

Although the intervention resulted in a higher proportion of participants consuming dishes cooked with healthier oil blends (35–37% substitution of palm oil with soy bean oil), the saturated fat and poly-unsaturated fat intakes were comparable between arms, and the mono-unsaturated fat intake from out-of-home foods was reduced in the intervention arm. The decreased total fat intake in the intervention arm may partly explain the decreased mono-unsaturated fat intake. However, in sensitivity analyses (Supplementary Table 3), when fatty acid intakes were expressed as a percentage of energy from total fat, the mono-unsaturated fat intake reduction in the intervention arm was not statistically significant while increases in polyunsaturated fat intake in the intervention arm were. These changes in relative intake of fatty acids may be due to the fatty acid composition of the healthier oil relative to palm oil. Specifically, the healthier oil blend had lower mono-unsaturated fatty acid percent (6%), lower saturated fatty acid percent (10%) and higher poly-unsaturated fatty acid percent (20%) compared with the default palm oil used in control centers and during pre-intervention. The healthier oil blend was still relatively high in saturated fat. Ten intervention cooked food stalls (32%) were observed to have used additional one or more cooking oil/fat (e.g. margarine and/or butter). These findings highlight the need to consider increasing percentages of palm oil substitution with healthier oils and encouraging the use of healthier cooking fats and unblended oils like soy bean or canola oil.

We also observed a modest increase in dietary fibre consumption from out-of-home dishes in the intervention group after adjusting for pre-intervention dietary fibre and energy intakes. However, this exploratory finding may be due to chance. Further trials may be warranted to establish this finding.

Our finding that offering brown rice, and promoting brown-rice and lower-calorie dishes did not significantly increase their consumption is consistent with similar interventions in other countries. A worksite cafeterias trial conducted in the Netherlands which displayed a “Choices” logo, did not improve lunchtime food choices (47). The authors suggested that menu labelling might be more salient to consumers who are already in the preparation and action phase in the Transtheoretical Model of Behavior Change (48) with regard to healthier eating. Likewise, point-of-purchase prompts did not result in a significant change in choice of lower-salt instead of regular soup or lower-fat instead of regular croissants in a Dutch hospital (49). In Belgian university canteens, posting of nutrition information using a 3-star rating system with a descriptor of unhealthy nutrient contents also did not significantly improve meal choices or nutrient intakes (15). Contrary to these findings, when a traffic-light food labelling program was implemented at a worksite canteen in Taiwan the availability of healthier main dishes and the proportion of consumers utilising the traffic-light food label to select food increased significantly (28).

Unlike the use of healthier oils, dishes prepared with lower-sodium salt were not highlighted to consumers in the HDP. There is evidence to suggest that signalling changes in salt content to consumers can be counter-productive. Reduced-salt labels have been suggested to induce negative taste expectations of soups and compensatory actions such as adding more salt (50). As sodium content can be gradually reduced without consumers noticing a difference, and as people adapt to lower sodium content of dishes over time, using covert, rather than overt approaches to reduce sodium consumption has been suggested (50). When product reformulation was compared to an information provision campaign in the United Kingdom government’s salt reduction programme, the observed decline in dietary salt intake was largely attributed to product reformulation (51). Food labelling might be less effective due to its reliance on consumers’ attention, ability to interpret the labels and willingness to choose the healthier option (51).

Policies that restrict the availability of unhealthier food options are sometimes viewed as an infringement of personal choices (15). However, this is less likely to be a concern for changes such as the type of fat that may not considerably alter the sensory properties of food. Similar approaches such as restricting the use of trans-fat containing oils has successfully removed trans-fat from the food supply with little consumer objection (52). A more salient consideration for such interventions is the willingness of food vendors to use healthier oils. Apart from removing the price barrier by subsidising healthier oils, the implementation of this intervention was led by facilities management and received strong institutional support. This finding is aligned with other studies which show that institutional support is a key determinant of intervention success (53). Oil substitution in menu reformulation is more covert as compared to substituting white rice with brown rice (54) and offering brown rice as the default may pose other challenges. Nevertheless, taken together, findings from our study and previous studies suggest that menu reformulation should be prioritized before menu labelling to improve dietary quality of out-of-home dishes as it is less dependent on consumers’ utilization of information provided (55,56).

The strength of our study lies in evaluation of the program in a real-world setting using a rigorous cluster-randomized design study. The use of food diaries enabled the collection of detailed dietary information. Our study also had several limitations. While we planned for a systematic sampling approach to recruit

participants, a convenience sampling was employed for feasibility reasons. Participants who were willing to participate may have been more interested in healthy eating as compared to those who did not participate. However, this is likely to be applicable to both the intervention and the control centers and hence may not affect internal validity. Our study results may be more generalizable to other IHLs and workplaces where there is likely to be greater institutional control over the implementation of the intervention. The higher than expected dropout rate (39%) in our study was also observed in other dietary worksite interventions (53). Post-intervention data were collected near exam period which may have contributed to participants not returning food diaries. In addition, similar to other dietary interventions, the study was conducted as an open trial due to the difficulty in blinding both researchers and participants to the changes introduced from the intervention. The 10-weeks intervention duration may have been insufficient to capture dietary habits such as replacing white rice with wholegrain rice which may require a longer duration to develop. Our outcomes evaluation had to end at 10 weeks as the semester was going into vacation period and it was logistically more feasible for OCA to start implementing the HDP at control centers during the vacation period.

The outcome data may be influenced by social desirability biases as the food diaries were self-reported. Post-intervention total energy intake per day reported by both intervention arms were higher than pre-intervention intakes reported. This could have been due to more frequent reminders sent from our study team to participants to report all foods consumed out-of-home during post-intervention. We assessed the uptake of lower-sodium salt-prepared dishes but did not examine the impact of these dishes on the participants' sodium intake as we were uncertain about the precise amounts used by the vendors. A large increase in proportion of consumers having at least one healthier oil blend prepared dish in the control arm was observed post-intervention. This observation might have been due to contamination. Although we tried to limit contamination by selecting participants who were frequent diners at a given food centre, it is possible that motivated participants from control centers may have switched to eating at the intervention centers due to availability of healthier food options. However, this would result in an underestimation of the intervention effects. As with other dietary worksite interventions (53), we did not assess the change in frequency of healthier dishes or quality of dishes taken at home for comparison with the dietary behaviour at school/work. As during pilot testing, we found that respondent burden for recording all foods consumed was high which could potentially increase drop-out. Hence any compensatory actions taken at home (e.g. preparation of healthier home-made dishes) could not be assessed.

5.0 Conclusions

Evidence from our trial suggests that implementing policies to use healthier ingredient options (oil blends and lower-sodium salt) as the default during food preparation are more effective to improve healthier out-of-home food intakes compared with labelling of healthier choices in an Asian university setting. Our study adds to international evidence that the default type interventions in food environments are generally more effective than those relying on information-based choices of consumers. As one of the few studies to evaluate the impact of ingredient subsidies on out-of-home dietary intake, these findings

are promising. However, only modest improvements in nutrient intakes from out-of-home dishes were observed. Careful consideration of implementation design features including the use of robust minimum criteria cut-offs for deeming an ingredient as being healthier and extending subsidies to ingredients with the healthiest profile may help further improve nutrient intakes.

Abbreviations

The following abbreviations are used in this manuscript:

ANOVA: Analysis of Variance;

BMI: Body Mass Index;

CI: Confidence intervals;

GEE: Generalized estimating equation;

HDP: Healthier Dining Programme;

HPB: Health Promotion Board;

IHL: Institutes of higher learning;

IQR: Interquartile Range;

NIP: Nutrition Information Panel;

NUS: National University of Singapore;

OCA: Office of Campus Amenities;

SD: Standard deviations;

USDA: U.S. Department of Agriculture;

Declarations

Ethics approval and consent to participate

The study was approved by the National University of Singapore Institutional Review Board (approval number: 11–137). Verbal informed consent was obtained from all participants prior to study enrolment and participant information sheet was provided to consented participants.

Consent for publication

Not applicable

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Availability of data materials

We cannot share the dataset for this study with external researchers due to institutional review board guidelines.

Conflicts of Interest

None

Author Contributions

S. S. Y.S was responsible for coordinating with interview vendors, food vendors and National University of Singapore Office of Campus Amenities, managing logistics, collecting and managing data, participating in discussions about the results, drafting the first manuscript and revising the submitted manuscript.

R. M. V. D. co-conceived and designed the study, co-supervised the study, contributed to discussions about the results and revising the manuscripts.

B.C. T. generated the random assignment of intervention, provided guidance on the design, analysis and interpretation of the data, and contributed to discussions about the results and revising the submitted manuscript.

Z. T. helped with coordinating with interview vendors, food vendors and National University of Singapore Office of Campus Amenities, managing logistics, collecting and cleaning the data and revising submitted manuscript.

M. C. W. co-conceived and designed the study, contributed to discussions about the results and revising the manuscripts.

S. A. R. co-conceived and designed the study, co-supervised the study, co-coordinated with the vendors and National University of Singapore Office of Campus Amenities, and contributed to discussions about the results and revising the submitted manuscript.

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Additional File Descriptions

Supplementary Table 1: Criteria for classification of different types of 'healthier dishes' (DOC)

Supplementary Table 2: Baseline demographics of all participants (enrolled) by randomised arms (DOC)

Supplementary Table 3: Sensitivity analysis for fatty acids intake expressed as percent fat calorie intake (DOC)

Supplementary Figure 1: One of the posters created for targeting social norm for brown rice consumption (DOC)

Supplementary Figure 2: Healthier Choice Symbol decals placed on point-of-purchase standees featuring the lower-calorie dish(s) at intervention stall (DOC)

Supplementary Figure 3: Example of posters and stall directory placement at one of the intervention centers (DOC)

Supplementary Figure 4: Decision tree to determine if a food item is considered an outside-prepared food for inclusion (DOC)

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Figures

Legend:

- > - Healthier Ingredient Scheme activities
- > - Healthier Dining Programme

- ⚙️ - Incorporated by default
- ⚡ - Mixed (incorporated by default in some stalls and left optional in others)
- ⬆️ - Left optional as a healthier alternative

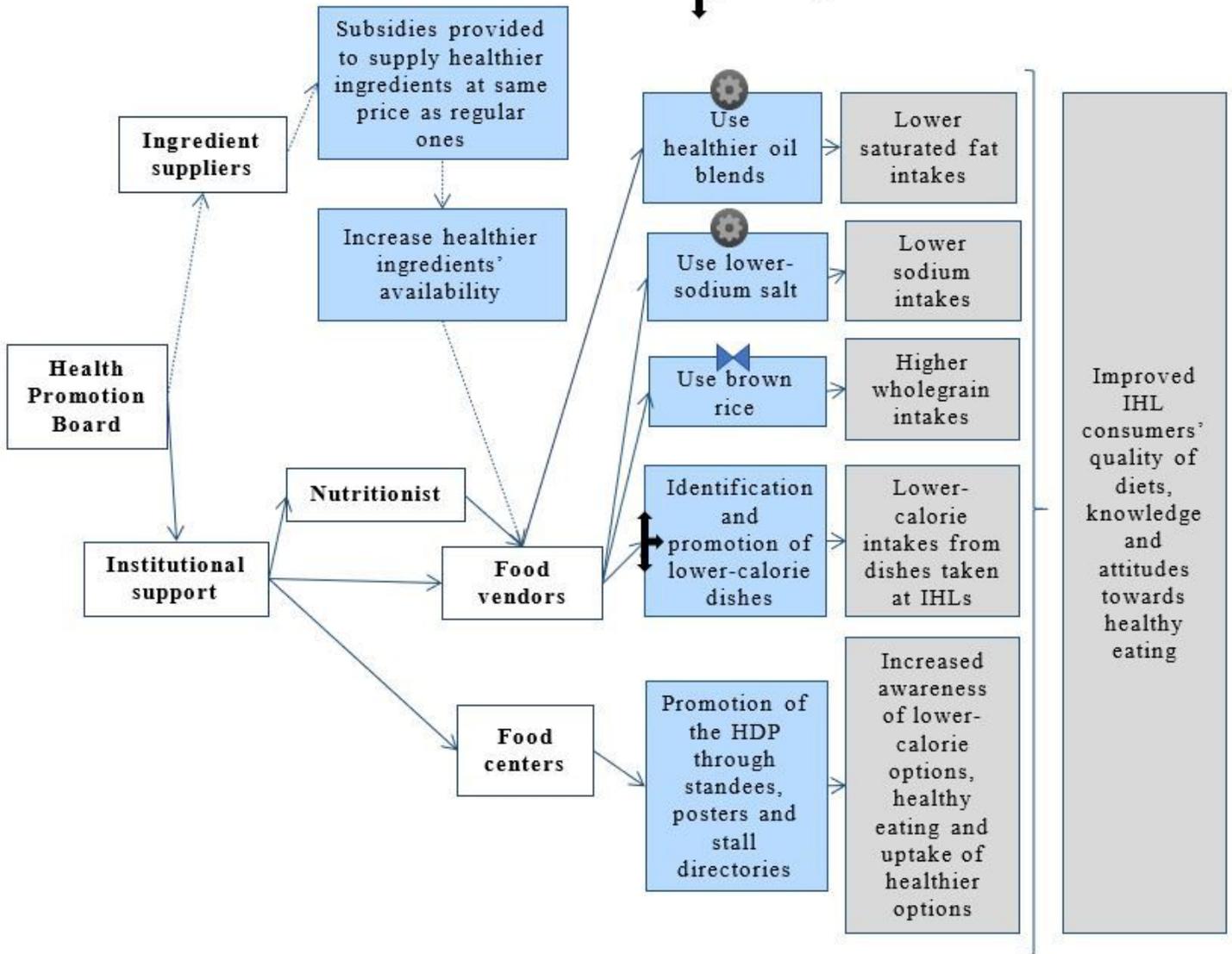


Figure 1

Visual representation of the Healthier Dining Programme conducted at NUS and its intended effects[^]
[^]Default is defined as the incorporation of healthier ingredients during cooking by the food vendors instead of providing it as an option to consumers. IHL, institution of higher learning

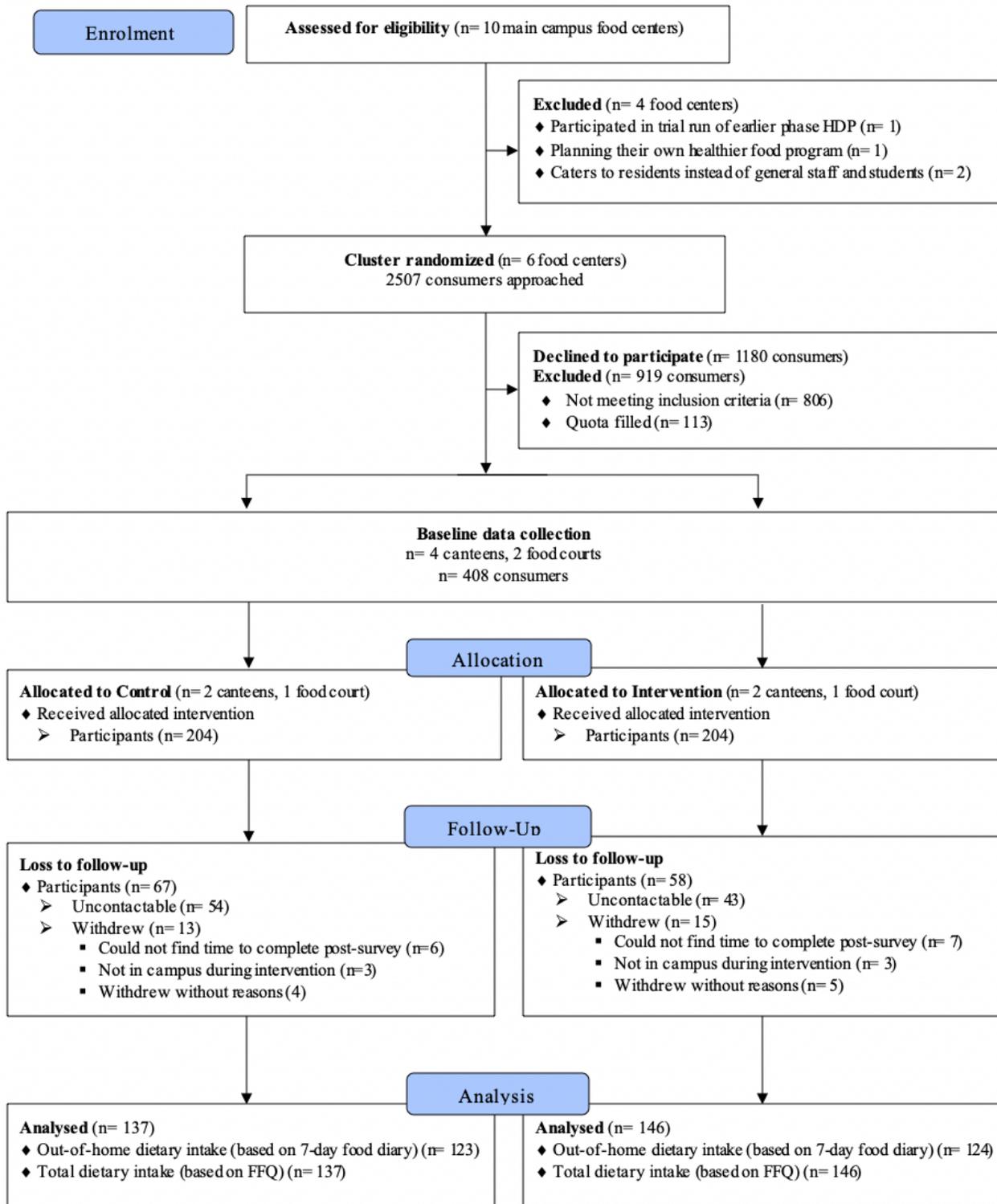


Figure 2

Participants' flow in the outcomes evaluation of the Healthier Dining Programme

Supplementary Files

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