Investigation of Causes and Evaluation of Programs: three applications of Health Economics

Yu Sun

Dissertation submitted to the faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the
degree of

Doctor of Philosophy
in
Economics

Wen You, Chair
George C. Davis, Co-Chair
Brenda Davy
Suqin Ge

May 10th, 2017
Blacksburg, Virginia

Keywords: Nutrition education, Type 2 diabetes, Relative deprivation, Process benefits, Household production framework

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ACADEMIC ABSTRACT

In chapter 1, a comprehensive meta-analysis is conducted to synthesize the effectiveness, cost, and cost-effectiveness of lifestyle diabetes prevention interventions and compare effects by intervention delivery agent and channel. Sixty-nine studies meet inclusion criteria. The results show that participants receiving intervention with nutrition education experienced a reduction of 2.07 kg (95% CI: 1.52 to 2.62; $p<0.001$; 95% CI: 88.61% to 92.87%) in weight at 12 months with effect sizes over time ranging from small (0.17, 95% CI: 0.04 to 0.30; $p=0.012$; 95% CI: 80.42% to 91.14%) to medium (0.65, 95% CI: 0.49 to 0.82; $p<0.001$; 95% CI: 98.52% to 98.94). In sum, lifestyle interventions are effective in reducing body weight and glucose-related outcomes. Dietitian-delivered interventions achieve greater weight reduction compared to those delivered by other personnel.

In chapter 2, this study attempts to examine the effects of household relative deprivation on children's health outcomes. A modified household production model is developed with energy intake, energy expenditure and a composite good as main inputs in the health production. A two-stage Stackelberg game facilitates the need to model the parent-child interaction which follows similar structure as You and Davis (2011). We use three measurements of relative deprivation based on per capita household income and four reference groups based on combinations of geographic and demographic characteristics. The results show that relative deprivation is negatively associated with child health.

In chapter 3, we define "process benefits" as the direct effect on utility from engaging in an activity and examine how "process benefits" associated with food activities, both uptake and duration, are related to factors such as socio-economic status and demographics. A household production model is utilized to demonstrate the vital role of process benefits in home food production and the implications it will have for nutrition based policies targeting resources. The results display that the process benefits are associated with some demographic characteristics. This implies that shortfalls in food activities are not simply a matter of technology or resource

shortfalls, but also reflect disutility associated from these activities which in turn will attenuate the impact of policies design to merely address resource shortfalls.

GENERAL AUDIENCE ABSTRACT

Evaluation of programs is a vital part in health economics for it is important in understanding the effect and limitation of a program from an economic perspective. Three applications are included in this dissertation. The first application is to synthesize the overall effectiveness of diabetes prevention program including nutrition education; the second application is to evaluate if there is a negative association between relative deprivation and children's health outcomes; the third one is to explain the small effect of nutrition policy, such as SNAP.

Type 2 diabetes (T2D) has increased significantly worldwide, leading to substantial increases in total economic costs in the US. A proliferation of studies have attempted to translate lifestyle interventions into clinical and community practice in an attempt to halt this growing public health epidemic. Therefore, there is a need to investigate the effectiveness of interventions including nutrition education for diabetes prevention. The results show that diabetes prevention program with nutrition education is effective in reducing body weight and glucose-related outcomes.

China has reached the fastest rate of growth in economy since the implementation of reform and become the world's second largest economy. However, improvement in health fails to accompany the massive growth in material living standards for the Chinese population. This observation prompts us to investigate the relative deprivation hypothesis. The results show that children who are more relatively deprived have poor health outcomes.

Food assistance programs, e.g., Supplemental Nutrition Assistance Program (SNAP), have been developed to improve people's health. However, the nutrition level recommended by those programs are still not met for the targeted population. The results show that respondents who enjoy cooking spend more time on activities related to food production, such as food preparation, presentation and clean up. And the small effect of nutrition policies is due to the disutility from the process of food production.

To Enji and Our Parents for Their Unconditional Love and Support.

Contents

ACKNOWLEDGMENTS

It is truly a life-changing experience for me to pursue a doctoral degree at Virginia Tech and I would not have been able to make it without the support and guidance that I receive from many people. I must first thank my committee chairs Dr. You and Dr. Davis for their constant guidance throughout my academic journey. They always show their patience and inspire me to figure out the research question in a rigorous way. I have benefited substantially from many insightful discussions with them and advices. I especially want to thank Dr. You who has always been considerate and provided opportunities for me to take part in different projects. I would also like to thank my dissertation committee members, Dr. Davy and Dr. Ge for their invaluable suggestions. Collaboration with Dr. Davy is a great opportunity for me to learn methods for systematic review and meta-analysis. It is joyful to work with her and I really appreciate her encouragement during the process of manuscript improvement. I am also indebted to Dr. Almeida and Dr. Estabrooks for their crucial supports.

In addition, I am grateful to my friends, Jangfeng Gao, Chaoping Xie, Ming Ma and Binbin Lin, who have given me a lot of help and inspiration at difficult times in my life. In addition, I would like to thank my fellow students from lab meetings for their intriguing questions about my paper presentations.

Finally and most importantly, great gratitude to my husband, Enji, and our parents. They always encourage me to continue this journey with their firm belief and powerful words. Without their love and support, I would never have been able to finish my work and dissertation.

CHAPTER 1.

The Effectiveness and Cost of Lifestyle Intervention Including Nutrition Education for Diabetes Prevention: A Systematic Review and Meta-analysis

Chapter 1.

1.1. Introduction

Type 2 diabetes (T2D) has increased significantly worldwide. Among adults aged 20-79 worldwide, 8.8% were estimated to have diabetes in 2015, and the prevalence of diabetes is estimated to increase to one in ten adults by 2040.[1] Among adults in the United States (US), the estimated lifetime risk of developing T2D is 40%.[2] Type 2 diabetes is a challenging public health problem, with serious consequences on health and health care costs. [3,4] This condition greatly reduces life expectancy and leads to numerous medical complications, such as renal disease, diabetic neuropathy, and macrovascular disease.[5] This condition has contributed to substantial increases in total economic costs in the US- from $174 billion in 2007 to $245 billion in 2012, and shows no signs of slowing down. [6]

Since the completion of the Diabetes Prevention Program, there has been a proliferation of studies attempting to translate lifestyle interventions into clinical and community practice in an attempt to halt this growing public health epidemic.[7-9] Lifestyle intervention, specifically intensive diet and physical activity behavioral counseling programs, are recommended for the prevention of T2D.[10] Dietitians, who are trained to deliver medical nutrition therapy, play an important role in diabetes prevention counseling.[8,9,11] However, given limited access to dietitians and possibly higher program costs relative to other types of intervention delivery agents, nutrition education is sometimes provided by other types of delivery agents such as healthcare professionals, community health workers, or others (e.g. average salary for a community health worker is $37,490, vs. the average salary for a dietitian is $56,300).[12,13] While understanding the appropriate personnel to deliver diabetes prevention intervention content has significant cost implications for clinical and community organizations, the relative effectiveness and cost-effectiveness of dietitian-delivered nutrition education compared to nutrition education delivered by other agents has yet to be examined.

As reported by Sherwood et.al, consumers desire interventions with less person-to-person contact. Technology-based programs represent an alternative approach to minimize in-person interactions.[14] Technology-based lifestyle interventions have been broadly defined as those which utilize web-based platforms, mobile applications, telecommunication technology and phone counseling sessions such as interactive voice response calls, or text messaging. These technologies may be used alone or in combination with in-person intervention contacts. Technology-based approaches also have the potential advantage of reducing personnel resource demand, and can overcome transportation barriers to reach geographically disparate population groups.[1] Therefore, there is a need to investigate the relative effectiveness of technology-based interventions, compared to traditional in-person interventions. Having these data available could inform decision-making related to organizational selection, adaptation, and implementation of diabetes preventions programs.[2,3]

Seven meta-analyses that evaluated nutrition education in diabetes prevention programs were identified. They reported non-standardized mean differences in weight and glucose tolerance or economic evaluation ratio,[13,15-20] and four analyses focused on changes in health outcomes at 12 months.[13,15-17] Two meta-analyses reported the effectiveness of prevention programs at multiple time points.[18,20] Those that limited the review to only randomized controlled trials (RCT) reported a reduction in 2-h blood glucose (BG).[16] Those focused on clinical care settings reported change in weight,[17] and those conducted in “real-world” settings reported the percentage of body weight change.[15] Meta-analyses focused on routine clinical settings examined the effectiveness of adherence to guidelines,[13] and others did not describe the study setting in their inclusion criteria. Only two meta-analyses included a summary of costs; the reported median program cost per participant was $653 (2013 U.S. dollars) [19] and it was suggested that nonmedical personnel may reduce program costs without sacrificing effectiveness.[15] Overall, these meta-analyses have demonstrated that lifestyle-based diabetes intervention programs are effective in reducing risk for developing T2D in adults.

While the findings across these meta-analyses are promising there still is an absence in evidence synthesis that examines the effectiveness, costs, and cost-effectiveness of diabetes prevention interventions across delivery personnel, delivery channel, setting, and populations. The paucity of these data makes it difficult for typical clinical or community organizations to determine if: (1) intervention delivery is affordable, (2) program delivery personnel are available, or (3) the intervention content is adaptable to fit the context.[21] The purpose of this systematic review was to conduct a comprehensive meta-analysis to synthesize the effectiveness, cost, and cost-effectiveness reported across studies testing diabetes prevention interventions. We also examined, with subgroup analyses, if differences in these outcomes existed between interventions that were delivered by dietitians compared to non-dietitians, or if differences existed based on technology versus in-person intervention delivery.

Non-dietitians included intervention delivery agents such as wellness instructors, lay leaders, community health workers (CHW), health department counselors, lifestyle coaches, healthcare professionals, group leaders, diabetes educators, health educators, community residents, research staff, nutritional scientists, physiotherapists, general practitioners, study physician, nurses, facilitators and pharmacists. Subgroup analyses were performed to explore the average effect size differences in intervention effects across those subgroup dimensions including US versus non-US study locations, RCT versus studies using a quasi-experimental design (QED), and length of study follow-up (3, 6, and 12 months, and up to 60 months).

1.2. Materials and Methods

This review was conducted according to the PRISMA guidelines [22] and was registered with the PROSPERO International register of systematic reviews (registration number CRD42014013817).

1.2.1 Eligibility Criteria

Studies that focused on diabetes prevention for high-risk adults through lifestyle interventions, used RCT or QED (with and without control groups), and reported relevant clinical outcomes within five years (e.g., body weight, fasting BG [FBG], or glucose tolerance) were included. Risk criteria for T2D included the following: overweight or obesity status (BMI≥24, BMI ≥ 23 for Asian adults), prediabetes (FBG ranging from 95-125 mg/dl), impaired fasting glucose (Fasting blood glucose measurement of 101- 108 mg/dl [5.61-6.00 mmol/l] or fasting venous plasma glucose measurement of 110 – 124 mg/dl [6.11-6.88 mmol/l] or fasting glucose measurements of 100 - 125 mg/dl [5.55-6.94 mmol/]) , impaired glucose tolerance and diabetes risk score reflecting increased risk for T2D (American Diabetes Association (ADA)-score ≥10, Finnish Diabetes Risk score (FINDRISC) score≥9, Australian diabetes risk (AUSDRISK) score ≥ 12). Only studies with interventions lasting more than four weeks were included, as shorter-term lifestyle programs are not likely to produce sustained changes.[23] Studies published before July 2015 in the English language were included. Studies that aimed to improve dietary knowledge among health care workers or medical students were excluded, as were studies focused solely on weight loss which were unrelated to diabetes prevention.

1.2.2 Search Strategy

A systematic literature search was conducted using the following databases: the Cochrane Library, PubMed, ERIC, CAB Direct, Science Direct and Google Scholar.

The search terms used combinations of ‘nutrition education’, ‘lifestyle intervention’, ‘behavioral intervention’, ‘nutritionist’, ‘registered dietitian/dietician’, ‘dietary intake’, ‘nutrition’, ‘prediabetes’, ‘dietary education’, ‘diabetes prevention’, ‘glucose tolerance’, ‘glucose homeostasis’, ‘fasting glucose’, ‘cost-effectiveness’. Citations and abstracts of all retrieved studies were imported into ENDNOTE X7 citation management software. Duplicates were removed and the remaining studies were assessed for eligibility criteria by two researchers. Supplementary Table 1.1 and 1.2 present examples of the complete search strategy used in the electronic databases CAB Direct and PubMed. Reference lists of identified studies and related reviews were also hand-searched for relevant articles.

1.2.3 Data Extraction and Quality Evaluation

Based on the Cochrane template a data extraction form was developed (available from the authors upon request).[24] The following information from each article was extracted: study details (authors, year, and county of publication), sample size and participant characteristics (age, sex, weight measurements at baseline), risk criteria for T2D (such as overweight /obese/ prediabetic/diabetes risk score), duration of the intervention (from baseline to the end of intervention), active and maintenance phases, details of intervention procedures, outcome measurements (method, body mass index [BMI], body weight loss, blood glucose outcomes, and incidence of diabetes), author’s conclusions and study limitations.

The quality of selected research articles was evaluated according to Academy of Nutrition and Dietetics Evidence Analysis Library quality rating worksheet.[25] This checklist includes criteria for evaluating the relevance and validity of included studies. Each study was assessed for quality independently by at least two reviewers and assigned an overall quality grade (categories: +, -, or 0). When present, differences in ratings between reviewers were discussed in order to reach a consensus. If agreement could not be established, a third reviewer was included to resolve differences.

1.2.4 Data Analysis

This review included the following outcome measurements: body weight, BMI, fasting blood glucose (FBG), 2-hour plasma glucose (2-h BG), and glycated hemoglobin (HbA1c). Reported imperial values were converted into metric units except for BG concentration, which was reported in mg/dl. Analyses were carried out using statistical analysis software [26]. Mean change was obtained by subtracting the

1.baseline mean value from the mean at a subsequent measurement period (e.g., months 6 or 12). Separate analyses were conducted for active intervention phase changes, and for the overall intervention phase (i.e. active and maintenance phases) changes. Some of the missing mean standard deviations (SD) for the outcomes of interest were obtained by contacting authors. The rest of the missing values were calculated from correlation coefficients, confidence intervals or standard errors according to calculations outlined in the Cochrane handbook for systematic reviews of interventions (Section16.1).[27] Furthermore, both effect size (ES) and the non-standardized mean difference (NSMD) of primary outcomes (e.g., weight) were estimated and compared. An advantage of standardized effect sizes is that they can be used to compare magnitude of change across studies.[28] Non-standardized mean difference allows the present results to be compared with related meta-analyses since they report NSMD.

To facilitate the model selection in this meta-analysis, statistical heterogeneity tests, I^2 index were used to determine the magnitude of heterogeneity. [29] A random-effects model with DerSimonian and Laird's technique was used when heterogeneity was confirmed.[30,31] Meta-regression analyses were performed to explore heterogeneity and assess the relationship between relative weight loss, FBG reduction, change in 2-h BG and HbA1c (i.e., intervention group relative to control group) at 12 months and study characteristics, such as delivery agent (dietitian or non-dietitian), delivery channel (In-person or Technology-delivered), study design (RCT or QED), study location (US or non-US), percentage of female participants, mean age of the study sample, baseline average BMI, study setting (in primary setting or others), and group session (group-based or not). Furthermore, the existence of publication bias was assessed by a visual examination of funnel plots and test statistics from Begg's and Egg's tests.[32]

The average cost-effectiveness ratio (ACER), which refers to the average cost of an intervention per unit of output, was used to estimate average cost spent per effect (i.e., per kg weight lost). When sufficient information was available from the included studies, ACER was calculated to provide the average cost for 1 kg weight loss.

1.3. Results

1.3.1 Characteristics of Studies

The database search resulted in a total of 10,840 abstracts. After removing duplicates (3,404 in total), a total of 7,436 abstracts went through the initial screening (See *Eligibility Criteria*). The initial screening resulted in 118 abstracts eligible for full-text article assessment. The full-text assessment resulted in the final sample of 69 studies included in our meta-analysis. Figure 1.1 depicts the complete search process.

The key characteristics of included studies are presented in Supplementary Table 1.3.[1,23,24,33-98] Among included studies, there were 32 conducted in the US and 37 conducted in other countries. Study designs included RCT (n=41), pre-post (n=25), matched-cohort design (n=2), and non-randomized comparison (n=1). Most interventions included both dietary and physical activity lifestyle components, with four studies focusing solely on dietary changes.[64,66,79,85] Intervention delivery agents included registered dietitians (n=33), or non-dietitian agents such as other health professionals, lay leaders, and community health workers (n=36). Active intervention phase ranged from two months (n=3) to 12 months (n=13), and maintenance phase ranged from 5 months (n=1) to 51 months (n=1). This analysis included a total of 22,009 participants with mean age of 52.7 years. Approximately 65.4% of participants were women. Participant's race and ethnicity were mostly white and Hispanic or Latino.

The I^2 index demonstrated that most of the overall effect sizes in weight, FBG, 2-h BG and HbA1c change at different durations were heterogeneous. When there was statistical evidence of heterogeneity at one or more time points, random effects models were used in the analysis. Otherwise, fixed effects models were used to calculate the average effect sizes. Results of change in BMI were similar to that of weight, so we chose to present the results of weight change [the results of BMI change are available from the authors upon request]. Negative effect sizes reflected a reduction in the variable of interest.

1.3.2 Main findings

The comparison of delivery agents and channels are the main focus of this review, however we will first briefly discuss the overall results (i.e., pooled comparison). The effect size and mean difference for weight at 12 months are presented as forest plots in Supplemental Figure 1.1 and 1.2, and the remaining overall results are available from authors upon request.

<u>Weight:</u> A total of 64 studies reported results related to change in weight. The overall effect sizes for weight change were all negative, reflecting a reduction in body

weight, and the magnitudes ranged from 0.17 (95% CI: 0.04 to 0.30; p=0.012; I^2= 86.83%, 95% CI: 80.42% to 91.14%) to 0.65 (95% CI: 0.49 to 0.82; p<0.001; I^2= 98.75%, 95% CI: 98.52% to 98.94). The effect sizes over time showed curvilinear trends, with a peak value at six months for weight loss, although the trends were not statistically significant (p>0.05). Non-standardized mean differences in weight loss for intervention groups relative to control groups showed a decreasing trend over time. Changes in weight were negative, indicating a reduction in body weight, and the magnitude of change ranged from 1.17 kg (95% CI: 0.50 to 1.83; p= 0.001; I^2= 73.02%, 95% CI: 56.29% to 83.34%) to 3.15 kg (95% CI: 2.08 to 4.22; p<0.001; I^2= 97.61%, 95% CI: 97.11% to 98.02%). On average, participants receiving intervention including nutrition education experienced a reduction of 2.07 kg (95% CI: 1.52 to 2.62; p<0.001; I^2=90.99%, 95% CI: 88.61% to 92.87%) in weight at 12 months.

Fasting blood glucose (FBG): Forty-one studies reported FBG results. The average effect size of FBG change was negative, indicating a reduction, and the magnitude showed an increasing trend to 0.33 (95% CI: 0.14 to 0.52; p=0.00; I^2= 94.38, 95% CI: 92.87% to 95.57%) at 12 months, followed by a decrease to 0.11 (95% CI: 0.04 to 0.18; p= 0.002; I^2= 47.64%, 95% CI: 0.00% to 75.67%) at longer durations, but the trend was not statistically significant. Relative mean differences in FBG were all negative and the sizes of change range from 1.65 mg/dl [0.09 mmol/L] (95% CI: 0.14 to 3.17; p=0.03; I^2=56.83%, 95% CI: 9.21% to 79.46%) at 12 months and beyond to 3.84 mg/dl [0.21 mmol/L] (95% CI: 1.35 to 6.33; p= 0.003; I^2=99.18%, 95% CI: 98.99% to 99.34) at 6 months, with the greatest difference at 6 months.

2-h blood glucose (2-h BG) and Hemoglobin A1c (HbA1c): Nineteen studies reported 2-h BG and 15 studies reported HbA1c. The overall effect size for 2-h BG was negative and the magnitude increased to 0.65 (95% CI: 0.03 to 1.27; p= 0.04; I^2= 99.41%, 95% CI: 99.30% to 99.49%) at 12 months, but decreased to 0.06 (95% CI: 0.01 to 0.14; p= 0.078; I^2= 38.40%, 95% CI: 0.00% to 74.08%) at longer durations. For HbA1c, the effect sizes were negative and the greatest magnitude was 0.34 (95% CI: 0.17 to 0.51; p<0.001; I^2= 72.32%, 95% CI: 47.58% to 85.39%) at 12 months, but a smaller effect size of 0.29 (95% CI: 0.01 to 0.59; p=0.059; I^2= 68.00%, 95% CI: 0.00% to 90.72%) was evident at longer durations. Relative mean differences were negative and showed a similar trend as that of effect size, with the largest difference of 7.21 mg/dl [0.40 mmol/L] (95% CI: 1.95 to 16.36; p=0.123; I^2= 97.7%, 95% CI: 97.04% to 98.20%) for 2-h PG at 12 months.

1.3.3 Intervention Cost

Among 69 studies, cost information was reported by only eight studies.[34,35,43-45,92,97,99] Intervention costs primarily included material costs, intervention staff salaries, and others (i.e., cost for using pedometers and facilitator calls, cost relating to physical activity and cost for food shopping and preparation). The material cost was reported in only one study and was $1,075.09, including food, scales, and items distributed to 11 participants and paper handouts to 28 participants.[34] Intervention labor cost varied by the delivery agent and by the intensity of counseling. In the two studies that reported these costs, diabetes educators were compensated by $275/year per participant while dietitians were compensated by $528/year per participant (at annual average exchange rate in 2014) for the intervention delivery.[44,92] Dawes et al. reported that the cost for pedometers and facilitator calls per participant was C$35 and C$58 (Canadian dollars) respectively.[97]

Five of these studies provided intervention cost per participant.[43-45,92,99] The average intervention cost per person was $385. Three of them were delivered by dietitians with a lower average cost per person of $314, compared to that of $491 delivered by health educators and community leaders. Vadheim et al. reported that the per-participant cost of a tele-health intervention was $90.17 less than an in-person intervention, because this approach could allow more individuals to participate.[43]

The absence of complete information made it challenging to compute the unit cost for direct comparison. However, four studies reported sufficient information to calculate the average cost effectiveness ratios (ACER). Table 1.1 presents cost information for the above studies with ACER. The lowest average cost for 1-kg weight loss over two months was $53.87. The highest average cost for 1 kg weight loss was $1,005.36 over 12 months in a study that assessed an intervention including weight control and physical activity aimed at south Asian individuals in the UK.[92]

Subgroup Findings

Subgroup analyses for overall effect sizes for both active intervention phase and overall (active + maintenance) study phase by delivery agent and channel are presented in Table 1.2 and summarized below. For each outcome, the first row reports the effect sizes with the confidence intervals; the second row reports the I^2 index and the confidence interval. Results of similar subgroup analyses by study design and location (US vs non-US), and for relative effect size (intervention group compared to control group) for delivery agent and channel, and study design and location are presented in Supplemental Tables 1.4, 1.5, and 1.6 respectively.

Delivery agent

Weight: On average, dietitian-delivered interventions achieved the largest and statistically significant average effect size on weight reduction for the active phase of interventions at three months (Hedge's g: -0.27, 95% CI: -0.36 to -0.19; $p<0.001$; I^2= 96.68%, 95% CI: 95.38 % to 97.61%) and for the overall intervention phase at 12 months (Hedge's g: -0.30, 95% CI: -0.40 to -0.21; p=0.025; I^2= 91.72%, 95% CI: 88.29% to 94.14%) as compared to other durations (Table 1.2). Within the 12-month duration, the intervention phase and overall phase did not show statistically significant differences in effect sizes between dietitian-delivery and non-dietitian-delivery agents. As shown in the Figure 1.2 forest plot, there were relatively larger variations in effect sizes among non-dietitian delivered interventions (I^2=94.71% 95% CI: 93.06% to 95.96%) as compared to dietitian-delivered ones (I^2=91.72% 95% CI: 93.06% to 95.96%). For overall intervention phases lasting longer than 12 months, dietitian-delivered interventions demonstrated a greater effect size for weight reduction (Hedge's g: -0.24, 95% CI: -0.44 to -0.04; p=0.019; I^2= 88.13%, 95% CI: 81.51% to 92.38%)than non-dietitians (Hedge's g: -0.04, 95% CI: -0.08 to -0.01; p=0.009; I^2= 56.71%, 95% CI: 0.00 % to 85.64%) but the difference was not statistically significant due to the wider variations of effect sizes within dietitian-delivered intervention studies. Similar to overall effect sizes, all interventions across delivery agent type showed consistent significant effects on weight reduction across all program durations except for weight reduction at 6 months; no statistically significant differences across delivery agent types were noted (Supplementary Table 1.4). Mean reductions in weight of dietitian-delivery programs were larger than non-dietitian programs except for the 12 month duration (-1.90 kg, 95% CI: -2.73 to -1.06; $p<0.001$; I^2= 91.14%, 95% CI: 87.38% to 93.78% for dietitian-delivery programs and -2.23 kg, 95% CI: -2.99 to -1.46; $p<0.001$; I^2= 91.28%, 95% CI: 88.04% to 93.63% for non-dietitian-delivery programs) (Supplementary Table 1.4).

FBG: Programs delivered by non-dietitians produced significant effect sizes for active intervention phases lasting three and six months (Hedge's g: -0.30, 95% CI: -0.51 to -0.10; p=0.001; I^2= 53.46%, 95% CI: 1.17% to 78.09% for those delivered by non-dietitians at six months), which was similar to the effect sizes at those time points for overall intervention phases (Table 1.2). For overall intervention phases lasting 12 months or longer, dietitian-delivered interventions produced significant average effect sizes (Hedge's g: -0.21, 95% CI: -0.29 to -0.12; p<0.001; I^2= 0.00%, 95% CI: 0.00% to 74.62% for programs delivered by dietitian and 0.04, 95% CI: -0.07 to 0.15; p=0.507; I^2= 0.00%, 95% CI: 0.00% to 89.60% for those delivered by non-dietitians at 12 months and beyond) and the difference was statistically significant (p=0.0002).

2-h BG and HbA1c: A statistically significant effect size for 2-h BG for non-dietitian-delivered programs for active intervention phase was observed at 6 months (Hedge's g: -0.22, 95% CI: -0.42 to -0.01; p=0.036; I^2= 0.00%). Dietitian-delivered programs demonstrated significant effects for both outcomes at the longer durations No statistically significant effect for HbA1c for active intervention phase was present (Table 1.2). The subgroup comparison for HbA1c was only possible at 12 months for overall intervention phases, due to limited sample sizes (Table 1.2). Dietitian-delivered programs produced greater effect size for HbA1c than non-dietitian-delivered programs at 12 months (Hedge's g:-0.43, 95% CI: -0.70 to -0.16; p=0.002; I^2= 62.30%, 95% CI: 0.00% to 87.33% for programs delivered by dietitian and -0.26, 95% CI: -0.55 to 0.03; p=0.079; I^2= 74.29%, 95% CI: 41.49% to 88.71% for those delivered by non-dietitians) (Table 1.2).

Delivery channel

Weight: Effect sizes were generally larger for weight loss in technology-delivered interventions than in-person interventions in the active intervention phase, across all durations (Table 1.2). Similar comparison results were observed at 3, 12, and 13-60 months in the analysis of overall intervention phases. The largest effect sizes for both delivery channels were present at 6 months for overall intervention phases (Hedge's g: -0.62, 95% CI: -1.02 to -0.22; p=0.002; I^2= 89.18%, 95% CI: 77.50% to 94.80% for technology group and -0.67, 95% CI: -0.86 to -0.48; p<0.001; I^2= 99.0%, 95% CI: 98.83% to 99.18% for in-person group). The only statistically significant larger weight loss the technology-delivered interventions produced as compared to in-person delivery interventions was at 12-month for the active intervention phase (Hedge's g: -0.63, 95% CI: -0.97 to -0.29; p<0.001; I^2= 61.1% for technology group and -0.15, 95% CI: -0.22 to -0.08; p<0.001; I^2= 88.8%, 95% CI: 82.36% to 92.90% for in-person group). As depicted in the Figure 1.3 forest plot, there were many more studies using in-person delivered interventions, and they demonstrated a wider variation in effect size compared to technology-delivered interventions.

FBG: For active intervention phases, only 3-month interventions showed statistically significant effect sizes for FBG changes for in-person delivery interventions (Hedge's g:
-0.25, 95% CI: -0.42 to -0.07; p=0.007; I^2= 88.01%, 95% CI: 80.01% to 92.81%). The two delivery channels did not show statistical significance in effect sizes difference. For the overall intervention phase, the largest effect size for both delivery channels were noted as the same at 12 months (Hedge's g: -0.33, 95% CI: -0.58 to-0.08; p=0.011; I^2= 80.33%, 95% CI: 48.12% to 92.54% for technology group and -0.33, 95% CI: -0.55 to -0.12; p=0.003; I^2= 94.46%, 95% CI: 93.53% to 96.07% for in-person group). Significant effect sizes were evident with reductions in FBG at durations longer than 12 months for in-person-delivered interventions (Hedge's g: -0.13, 95% CI: -0.20 to-0.06; p<0.001; I^2= 40.58%, 95% CI: 0.00% to 73.76%) (Table 1.2).

2-h BG and HbA1c: Comparisons of in-person and technology-delivered interventions were not possible for active intervention phases due to insufficient data (Table 1.2). A significant effect size was only detected for 2-h BG at 12 months for technology-delivered interventions for the overall intervention phase (Hedge's g: -0.27, 95% CI: -0.41 to-0.13; p<0.001; I^2= 0.00%).

Other factors

Weight: Interventions tested in RCT showed statistically significantly larger effect sizes for weight loss for programs with 6 month and 12 months as compared to interventions tested using QED for both active and overall phases (Supplementary Table 1.5). Both active and overall program effect sizes for weight loss were statistically significantly larger in US than in non-US studies except effect size at 12 months for active intervention (Supplementary Table 1.5).

FBG: Interventions using different study designs produced mixed effect sizes across different study durations, with no consistent trend (Supplementary Table 1.5). At 3 months and 12 months, interventions tested in RCT showed larger effect sizes for FBG than interventions using QED for both active and overall interventions. For example, the effect size at 12 month for overall programs was -0.53 (95% CI: -0.89 to -0.17; p=0.004; I^2= 95.75%, 95% CI: 94.12% to 96.94%) for interventions tested in RCT and -0.11 (95% CI: -0.29 to 0.062; p=0.203; I^2= 89.23%, 95% CI: 83.93% to 92.78%) for interventions using QED. US studies demonstrated statistically larger effect sizes for FBG change as compared to non-US studies for programs at 3 months for active interventions and at 3 and 12 months for overall interventions.

2-h BG and HbA1c: Only interventions tested in RCT showed a statistically significant effect size for 2-h BG at durations of 12 months and beyond (Hedge's g: -0.13, 95% CI: -0.22 to -0.04; p=0.004; I^2= 0.00%, 95% CI: 0.00% to 74.62%) (Supplementary Table 1.5) for overall intervention phases (active + maintenance). Non-US interventions demonstrated significant effect sizes for 2-h BG change at 12 months for non-US studies for overall interventions (Hedge's g: -0.68, 95% CI: -1.32 to -0.04; p=0.039; I^2= 99.45%, 95% CI: 99.35% to 99.53%). Non-US studies showed greater effect sizes for HbA1c compared to US studies at 12 months (Hedge's g: -0.15, 95% CI: -0.20 to-0.10; p=0.027; I^2= 56.43%, 95% CI: 0.00% to 83.86% for US studies and -0.44, 95% CI: -0.74 to -0.13; p=0.005; I^2= 79.12%, 95% CI: 50.36% to 91.22% for non-US studies). No statistical difference was noted in the comparison between US and non-US studies on those outcomes.

Mean difference in outcomes showed similar results to effect sizes for overall interventions except the comparison result for weight. Interventions tested in RCT showed greater effect only at 6 months compared to interventions using QED (Supplementary Table 1.6).

Sources of heterogeneity: meta-regression

To provide insight as to which study characteristics were independent predictors of intervention effectiveness, meta-regressions on weight and FBG were conducted (Table 1.3 and Table 1.4). A meta-regression was performed in the full sample for 2-hr BG and HbA1c, which is presented in Table 1.5. There was not sufficient data available for a subsample analysis for 2-hr BG and HbA1C.

Weight reduction (at 12 months) was chosen to be the outcome of interest, since it is the primary outcome of most diabetes prevention interventions in adults [7,23]. Beyond the full sample meta-analysis, we also conducted a subsample meta-analysis by study location (US, Non-US) to further isolate location-specific contextual differences from the intervention effects. Studies included an average of 300 individuals, and 51% were conducted in a primary care setting. 52% of the studies also utilized dietitians for intervention delivery. Most studies (79%) were delivered in person, and most (70%) used a group-based intervention format. Mean baseline BMI was in the obese range (31.21 kg/m^2).

Dietitian-delivered interventions demonstrated a larger relative weight loss (i.e., intervention group relative to control group) than programs delivered by non-dietitians in all groups (the full sample: -1.0 kg; the US subsample:-2.4 kg; the non-US subsample: -1 kg). Delivery channel was shown to be a statistically significant independent predictor of weight loss in the non-US subsample (Table 1.3).

Other independent predictors of weight change at 12 months included the study setting, as less relative weight reduction was noted in programs delivered in primary care settings in the full sample and in the US subsample. We observed lower relative weight loss in the full sample and in US studies using a group-based intervention format. Interventions conducted in the US demonstrated greater relative weight loss compared to non-US interventions (-1.2 kg). A longer study duration resulted in less weight loss, for non-US studies.

FBG reduction (at 12 months) is a predictor of future diabetes and is commonly used as an enrollment criteria for diabetes prevention trials.[100] We also conducted meta-regression for the full sample and for subsamples of US and non-US studies. The average sample size for the full sample is smaller than that of the meta-regression on weight (198), and 45% of these studies were conducted in a primary care setting. About a half (49%) of the studies employed dietitians for intervention delivery. Most (85%) studies were delivered in person and most (82%) used a group-based intervention. Mean baseline BMI was in obese range (31.10kg/m2). Only study type was shown to be a statistically significant independent predictor of FBG reduction in the non-US subsample (-5.2 mg/dl) [-0.289 mmol/L] (Table 1.4).

c) Meta-regression on 2-h BG and HbA1c

There was insufficient data for a meta-regression for subsamples of US and non-US studies, for the outcomes of 2-h BG and HbA1c. Table 1.5 presents the results of meta-regression for the full sample of those outcomes. The data summary was similar to those of weight and FBG. Only 4% of the studies with 2-h BG were conducted in the U.S. No statistically significant independent predictor was observed for 2-h BG or HbA1c.

Sensitivity Analysis and Publication Bias

A sensitivity analysis was performed to evaluate the robustness of the results. The sensitivity analysis, first restricted to studies with a positive rating and then to studies published within the past 10 years. The effect sizes of both sensitivity analyses did not substantially change from the primary results. For example, effect sizes of weight achieved the greatest magnitude at 6 months for both sensitivity analysis (High quality studies: -0.80, 95% CI: -1.12 to -0.48; p<0.001; I2= 98.94%, 95% CI: 98.74% to 99.11% and recent 10-year studies: -0.65, 95% CI: -0.82 to -0.49; p<0.001; I2= 98.85%, 95% CI: 98.52% to98.94 %), which is similar to the trend of overall interventions (-0.65, 95% CI: 0.17 to 0.28; p<0.001 ;I2= 98.75%, 95% CI: 98.52% to 98.94). Similar trends of effect sizes for all outcomes were observed in these two sensitivity analyses except for the greatest magnitude of effect size for 2-h BG occurred at 13 months for recent 10-year studies.

We included outcomes at 12 months for publication bias tests since it is only relevant if the number of studies is larger than 10.[101] According to Egger's test and funnel plots (Supplementary Figure 1.3), no statistically significant publication bias was observed for change in weight or FBG in the case of non-standardized mean differences.[102-104] However, the Egger's test showed evidence of publication bias for mean difference in 2-h BG (p=0.013) and HbA1c (p=0.004).

In terms of effect sizes, significant publication bias was evident for outcomes of weight (p=0.001) and HbA1c (p=0.043) (Supplementary Figure 1.4). One possible reason may be that only English language publications were included. Studies with positive results may be more likely to be published in international and English-language journals, whereas studies with negative findings tend to be published in local and regional journals in their native language.[105]

1.3.4 Study Quality

Supplementary Table 1.7 presents the results of study quality assessment. The two raters agreed that all the studies were eligible for plus (+) designation in the quality section. The second aspect was to examine the validity of the included studies; most were assigned a plus (+) in this section. Among all studies, 12 studies were rated as neutral quality and 57 studies were rated as high quality (Supplementary Table 1.7). The following aspects were sometimes not reported: blinding, representativeness of the population, number and reasons for withdrawals, and the validity of study measurements. Several studies did not clearly report their limitations or the funding sources. Discrepancies between the reviewers' initial quality assessment focused on questions related to the comparableness of the study groups, and appropriateness of the statistical analysis.

1.4. Discussion

The overarching goal of this meta-analysis was to determine the effectiveness, costs, and cost-effectiveness of lifestyle interventions focused on diabetes prevention with a comparison of outcomes by delivery personnel (i.e., dietitian versus non-dietitian) and by delivery channel (i.e., technology versus in-person intervention delivery). Overall, we were able to replicate other systematic reviews that point towards the promise of these interventions to prevent diabetes.[21] Specifically, small to medium effect sizes[106] were documented across most outcomes (i.e., weight, 2-h BG and HbA1c) and varying intervention duration, indicating that lifestyle interventions were effective at reducing body weight, 2-h BG, and HbA1c. The observed effects on weight and blood glucose were clinically meaningful because sustained weight loss of 3-5% is likely to result in clinically meaningful reductions in blood triglycerides, blood glucose, and glycated hemoglobin and in the risk of developing T2D.[107] Significant reductions in glycemic outcomes were also detected (e.g., reduction in FBG of 3.84 mg/dl [0.213 mmol/L] at 6 months), which is a positive finding given that not all individuals participating in the reviewed studies met prediabetes diagnostic criteria (i.e., some were recruited based upon weight status or ADA risk screener scores). We also demonstrated in the meta-regression analysis that dietitian-delivered interventions may be more effective than those delivered by non-dietitian delivery agents, particularly for interventions carried out in the US. To further support this statement, we conducted a meta-regression analysis with the location dummy variable interacting with all variables and tested the interaction of the location dummy variable with the delivery agent dummy variable. The p-value for this interaction term is 0.061, indicating that interventions delivered by dietitians in the US studies have statistically significant greater reduction in weight change at the 10% level. However, this analysis did not indicate that delivery channel was a significant independent predictor of weight reduction. Unfortunately, we also document, as in other reviews of lifestyle interventions,[108] that cost information is not regularly reported and that cost-reporting components varied across studies. For example, the total costs in one analysis consisted of three parts: cost for diabetes educators, program materials, and cost for a tool box; Bhopal et.al. also added indirect costs to the total cost. Hence, it is possible that the differences in ACER may be due to the lack of a standardized approach studies to complete cost analyses across studies rather than a true difference.[92] Only eight of 69 studies reported intervention costs and only four provided the information necessary to determine ACERs—leaving these data tenuous to interpret with a high degree of confidence.

Our findings are consistent with those reported by Balk et al—combined diet and physical activity programs are effective at helping individuals at risk for T2D to reduce body weight and FBG.[18] Schellenberg et al. conducted a meta-analysis of lifestyle interventions and reported that lifestyle interventions had an important impact on body weight and BMI for high-risk patients.[109] Our analysis found that mean weight loss was 2.1 kg, which is similar to the 1.8 kg reported by Cardona-Morrell in 2010.[17] According to the 2013 Guidelines for the Management of Overweight and Obesity in Adults,[107] a sustained weight loss of 3-5% is likely to results in clinical meaningful reductions in blood glucose and in risk of developing T2D. This magnitude of weight loss reported overall for the studies reviewed was likely consistent with the 3% weight loss benchmark (e.g., 2.7 kg for an individual weighing 91 kg [200 lbs.]), therefore this magnitude of weight reduction appears to be clinically meaningful particularly for individuals who are at risk for T2D. Our study adds to the literature by summarizing the effect size across a number of relevant outcomes. We found that the effect size for different outcomes ranged from small (2-h BG and HbA1c within 6 months) to medium (weight and FBG at 12 months). [106,110] As such, our meta-analysis provides further evidence that when lifestyle interventions are implemented, practitioners and patients can expect modest improvements which translates into clinically meaningful change and reduced risk.

It is noteworthy that dietitian-delivered interventions were more effective at producing weight loss compared to other intervention delivery agents in the full sample, and particularly for interventions conducted in the US (Table 1.3). The US credentialing agency for Registered Dietitians (RD/RDN), the Commission on Dietetics Registration, has reciprocity agreements with only a limited number of countries who have similar dietetics education and credentialing as in the US: Dietitians of Canada; Dutch Association of Dieticians and Ministry of Welfare, Public Health and Culture; the Philippine Professional Regulation Commission; and the Irish Nutrition and Dietetic Institute [111]. Thus, it is possible that dietitians practicing in other countries have received a different type of training than those in the US. This difference in training could explain the greater effectiveness (i.e., greater weight loss) of dietitian-led interventions in US studies. This issue warrants additional research. For example, it could be hypothesized that registered dietitians have training that allows them to more effectively communicate nutrition information, facilitate skill development, and develop strategies for implementation with their patients [112]. It could also be that the training process associated with dietetics provides dietitians with tacit knowledge that aids in providing participants with the right services at the right time. From an organizational decision making perspective, this meta-analysis suggests that healthcare and community settings considering implementing a diabetes prevention program should utilize available dietitian resources.

We initially hypothesized that technology-delivered interventions would have equitable or smaller effects than in-person interventions. This hypothesis was based on the similar outcomes reported between technology-assisted interventions and in-person interventions at 12 months in a review conducted by Ali et al.[15] We extended these findings to document no independent effects of delivery channel after controlling for other study factors. This, again, has implications for both practice and future research. Specifically, technology-support may be best delivered early in an intervention with in-person strategies used to support maintenance of changes. Alternatively, a fruitful area of research may examine the different technology-based strategies that are necessary for longer-term maintenance.

Additional findings of interest arose from our subgroup analysis. We found that study design was related to intervention outcomes, but in a complex way. We found in our univariate analyses that studies that used QED resulted in smaller effects than those that used RCT, however, when considered in our meta-regression, while accounting for a number of other factors, differences in study type was not associated with weight loss. This finding suggest that other factors beyond study design are likely the drivers of differential effect sizes. Furthermore, US studies on average documented larger weight loss as compared to those non-US studies which can be partially due to the heavier baseline samples in US (90.36 kg vs. 82.90 kg, respectively).

Related to design issues, our quality assessment of this body of literature was positive, but reporting could be improved by describing the method of handling withdrawals and missing values, whether blinding was used to prevent bias, or whether "intent to treat" was used in the analysis.

It is unfortunate that there was limited cost information provided across these studies. With some notable exceptions, [34,35,43-45,92,97,99]this body of literature does not include the information necessary to support clinical or community decision making relative to program uptake and implementation. [113] These preliminary data were, however, contrary to our hypothesis that dietitian-delivered interventions would be more expensive than those provided by non-dietitian delivery agents. The studies that did complete comparisons found that dietitian-delivered interventions are less expensive when considered by the amount of participant weight lost. This information underscores the need for community and clinical organizations to look beyond the simple cost of materials and delivery staff expertise and focus on the cost relative to intervention outcomes over time. Clearly, more evidence is needed to support that dietitian-delivered interventions and electronic-technology-interventions have a lower cost on average relative to changes in outcomes.

There are some limitations to this meta-analysis which should be acknowledged. Despite the large total number of papers included in this review, the number of studies available for some outcomes was limited, leading to insufficient studies available for some of the subgroup analyses. For example, there were insufficient data to analyze effect of 2-h BG and HbA1c beyond 12 months. In addition, a common limitation of meta-regression is that the analysis is often underpowered due to the limited number of available studies. We acknowledge this as a limitation of our investigation. The study selection was limited to English articles, which could be a source of the identified publication bias. Most of the studies using QED included in this review are before-and-after studies. Some of these studies did not report confounder-adjusted outcomes. It is possible that pre-post differences may result in potential bias. However, as mentioned previously, the overall quality of studies included was rated as positive. It is also possible that intervention design, as opposed to delivery agent (i.e., dietitian vs non-dietitian), could have explained differences in program effectiveness. Information about cost and cost-effectiveness information is quite limited in our body of literature and may lead to uncontrolled differences between available studies with cost information. Formal cost-reporting methods are needed in future studies to support a complete analysis of cost and cost-effectiveness of lifestyle interventions including nutrition education for prevention of diabetes.

1.5. Conclusions

This systematic review and meta-analysis indicated that diabetes prevention programs including nutrition education were associated with a reduced risk of diabetes, assessed by weight, FBG, 2-h BG and HbA1c. Dietitian-delivered intervention programs demonstrated greater effectiveness than those delivered by non-dietitian delivery agents. Technology-delivered interventions sometimes showed greater effectiveness compared to in-person delivered programs. These findings provide support for role of dietitians in diabetes prevention programs. However, our meta-analysis is limited in that it included only English language publications, and publication bias was present for some outcomes. Hence, the results should be interpreted with caution. We are unable to provide conclusive cost information due to the limited cost-reporting and inconsistent cost estimate approaches. Future research should include information about program costs, in order to better determine the cost-effectiveness of specific intervention features.

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Table 1.1. The effectiveness of lifestyle intervention including nutrition education for diabetes prevention: Average cost effectiveness ratios (ACER), weight loss in kg

Reference	Duration (months)	Delivery Agent	Effectiveness Mean (kg)	Cost per person ($)	ACER ($) Mean
Davis-Smith, Boltri et al., 2007	12	Volunteer healthcare professionals	-4.80	-	-
Ackermann, Finch et al., 2008	12-14	Wellness instructor	IG[a]: -5.67 CG[b]: -1.63	-	-
Vadheim, McPherson et al., 2010	4	Dietitian	On-site: -6.50 Telehealth: -6.70	On-site: 560.17 Telehealth: 470.00	On-site: 86.18 Telehealth: 70.15
Katula, Vitolins et al, 2011	12	Dietitian	-5.70	-	-
Kramer, McWilliams et al., 2011	12	Health educators	-5.94	320.00	53.87
Ockene, Tellez et al., 2012	12	Community individuals	-2.50	661.00	264.40
Bhopal, Douglas et al., 2014	36	Dietitian	IG: -1.01 CG: -0.31	IG: 328.35[c] CG: 311.66[c]	IG: 325.10 CG: 1005.36
Dawes, Ashe et al., 2015	6	RD	-6.2 ±5.20	109.00[d, e]	17.60

[a] IG=intervention group
[b] CG=control group
[c] Conversion of English pound to US dollars, according to the current exchange rates (on 9 Sep, 2015).
[d] Conversion of Canadian dollar to US dollar according to the current exchange rates (on 9 Sep, 2015).
[e] Only intervention delivery cost was reported.
- Insufficient data for calculating ACER.

Table 1.2. The effectiveness of lifestyle intervention including nutrition education for diabetes prevention: effect size according to delivery agent (dietitian vs non-dietitian) and delivery channel (in-person vs technology-delivered) over time, in the active intervention and overall (active + maintenance study phases)

Outcome	3 months		6 months		12 months		13-60 months	
Active Intervention Phase								
Delivery Agent								
	Dietitian	Non-dietitian	Dietitian	Non-dietitian	Dietitian	Non-dietitian	Dietitian	Non-dietitian
Weight	-0.27***	-0.20***	-1.40	-0.44***	-0.16***	-0.27***	-	-
	(-0.36, -0.19)[a]	(-0.28, -0.12)[a]	(-4.05, 1.24)[a]	(-0.56, -0.31)[a]	(-0.24, -0.07)[a]	(-0.45, -0.08)[a]		
	96.68[b]	90.61[b]	99.72[b]	90.38[b]	84.75[b]	95.62[b]	-	-
	(95.38, 97.61)[c]	(86.02, 93.70)[c]	(99.64, 99.79)[c]	(84.82, 93.90)[c]	(71.74, 91.77)[c]	(92.73, 97.36)[c]		
FBG[d]	-0.18	-0.30***	-1.81	-0.35**	-0.49	0.01	-	-
	(-0.44, 0.07)[a]	(-0.51, -0.10)[a]	(-5.78, 2.16)[a]	(-0.66, -0.04)[a]	(-1.15, 0.16)[a]	(-0.41, 0.43)[a]		
	94.18[b]	52.11[b]	99.87[b]	69.70[b]	97.39[b]	93.85[b]	-	-
	(89.26, 96.85)[c]	(0.00, 78.51)[c]	(99.84, 99.90)[c]	(28.92, 87.08)[c]	(96.24, 98.19)[c]	(85.43, 97.41)[c]		
2-h BG[e]	-	-	0.06[f,g]	-0.22**[f,g]	-1.38	-0.08[f]	-	-
			(-0.08, 0.20)[a]	(-0.42, -0.01)[a]	(-3.43, 0.68)[a]	(-0.28, 0.12)[a]		
	-	-	0[b]	0[b]	99.77[b]	78.46[b]	-	-
			(-)[c]	(-)[c]	(99.72, 99.81)[c]	(30.76, 93.30)[c]		
HbA1c[h]	-	-0.10[f, g]	-	-0.16[f, g]	-0.69[g]		-	-
		(-1.43, 1.23)[a]		(-0.37, 0.04)[a]	(-1.52, 0.14)[a]			
	-	95.12[b]	-	30.99[b]	99.77[b]		-	-
				(0.00, 75.12)[c]	(99.72, 99.81)[c]			
Delivery Channel								
	IP[i]	TECH[j]	IP	TECH	IP	TECH	IP	TECH

Outcome	3 months		6 months		12 months		13-60 months	
Weight	-0.22*** (-0.28, -0.15)[a] 96.26[b] (95.10, 97.15)[c]	-0.32*** (-0.50, -0.13)[a] 85.59[b] (73.55,92.15)[c]	-0.88*** (-1.21, -0.55)[a] 99.31[b] (99.16, 99.43)[c]	-0.92** (-1.68, -0.15)[a] 89.64[b] (72.08, 96.16)[c]	-0.15*** (-0.22, -0.08)[a] 88.80[b] (82.36, 92.90)[c]	-0.63***g (-0.97, -0.29)[a] -	- -	- -
	IP	TECH	IP	TECH	IP	TECH	IP	TECH
FBG	-0.25*** (-0.42, -0.07)[a] 88.01[b] (80.01, 92.81)[c]	-0.27[g, g] (-0.87, 0.34)[a] 78.61[b] (31.37, 93.34)[c]	-0.95 (-2.71, 0.80)[a] 99.58[b] (99.49, 99.65)[c]	- -	-0.34 (-0.84, 0.15)[a] 97.35[b] (96.34, 98.09)[c]	- -	- -	- -
2-h BG	- -	- -	-0.03[f] (-0.14, 0.09)[a] 40.72[b] (0.00, 79.95)[c]	- -	-1.03 (-2.32, 0.26)[a] 99.70[b] (99.64, 99.74)[c]	- -	- -	- -
HbA1c	- -	-0.10[f] (-1.43, 1.23)[a] 95.12[b] (-)[c]	-0.11[f, g] (-0.33, 0.11)[a] 34.70[b] (0.00, 78.75)[c]	- -	-0.69[f] (-1.52, 0.14)[a] 88.13[b] (-)[c]	- -	- -	- -
Overall Intervention Phase								
Delivery Agent								
	Dietitian	Non-dietitian	Dietitian	Non-dietitian	Dietitian	Non-dietitian	Dietitian	Non-dietitian
Weight	-0.26*** (-0.34, -0.18)[a] 96.44[b] (95.09, 97.42)[c]	-0.20*** (-0.28, -0.12)[a] 90.61[b] (86.02, 93.70)[c]	-0.99 (-2.11, 0.12)[a] 99.60[b] (99.50, 99.67)[c]	-0.28** (-0.36, -0.19)[a] 88.51[b] (82.73, 92.35)[c]	-0.30*** (-0.40, -0.21)[a] 91.72[b] (88.29, 94.14)[c]	-0.26*** (-0.34, -0.18)[a] 94.71[b] (93.06, 95.96)[c]	-0.24** (-0.44, -0.04)[a] 88.13[b] (81.51, 92.38)[c]	-0.04**f (-0.08, -0.01)[a] 56.71[b] (0.00 85.64)[c]

Outcome	3 months		6 months		12 months		13-60 months	
FBG	-0.18 (-0.44, 0.07)[a] 94.18[b] (89.26, 96.85)[c]	-0.34*** (-0.54, -0.14)[a] 53.46[b] (1.17, 78.09)[c]	-1.81[f] (-5.78, 2.16)[a] 99.87[b] (99.84, 99.90)[c]	-0.47**[g] (-0.78, -0.15)[a] 69.28[b] (35.91, 85.28)[c]	-0.42*** (-0.70, -0.14)[a] 95.68[b] (94.14, 96.81)[c]	-0.17 (-0.37, 0.04)[a] 87.61[b] (80.60, 92.09)[c]	-0.21***[f, g] (-0.29, -0.12)[a] 0.00[b] (0.00, 74.62)[c]	0.04[g] (-0.07, 0.15)[a] 0.00[b] (0.00, 89.60)[c]
2-h BG	- -	- -	0.06 (-0.08, 0.20)[a] -	-0.22*** (-0.42, -0.01)[a] -	-0.44*** (-0.51, -0.38)[a] 99.65[b] (99.58, 99.70)[c]	-0.09 (-0.22, 0.05)[a] 70.10[b] (30.02, 87.22)[c]	-0.13**[g] (-0.23, -0.04)[a] 0.00[b] (0.00, 79.20)[c]	0.02[f, g] (-0.09, 0.12)[a] -
	Dietitian	Non-dietitian	Dietitian	Non-dietitian	Dietitian	Non-dietitian	Dietitian	Non-dietitian
HbA1c	-0.10[f] (-1.43, 1.23)[a] 95.12[b] (-)[c]	- -	- -	-0.16[g] (-0.37, 0.04)[a] 30.99[b] (0.00, 75.12)[c]	-0.43*** (-0.70, -0.16)[a] 62.30[b] (0.00, 87.33)[c]	-0.26* (-0.55, 0.03)[a] 74.29[b] (41.49, 88.71)[c]	-0.38***[f, g] (-0.55, -0.20)[a] 30.80[b] (-)[c]	- -
Delivery Channel								
	IP	TECH	IP	TECH	IP	TECH	IP	TECH
Weight	-0.21*** (-0.27, -0.15)[a] 96.09[b] (94.89, 97.01)[c]	-0.32*** (-0.50, -0.13)[a] 85.59[b] (73.55, 92.15)[c]	-0.67*** (-0.86, -0.48)[a] 99.02[b] (98.83, 99.18)[c]	-0.62*** (-1.02, -0.22)[a] 89.18[b] (77.50, 94.80)[c]	-0.24*** (-0.30, -0.18)[a] 92.81[b] (90.83, 94.36)[c]	-0.41*** (-0.68, -0.14)[a] 93.66[b] (89.35, 96.22)[c]	-0.16*** (-0.31, -0.01)[a] 89.01[b] (83.33, 92.76)[c]	-0.21**[g] (-0.27, -0.15)[a] 96.09[b] (94.89, 97.01)[c]
FBG	-0.27*** (-0.45, -0.10)[a] 87.25[b] (79.10, 92.22)[c]	-0.27[f, g] (-0.87, 0.34)[a] 78.61[b] (31.37, 93.34)[c]	-1.02 (-2.58, 0.53)[a] 99.46[b] (99.34, 99.55)[c]	- -	-0.33*** (-0.55, -0.12)[a] 94.96[b] (93.53, 96.07)[c]	-0.33** (-0.58, -0.08)[a] 80.32[b] (48.11, 92.54)[c]	-0.13***[g] (-0.20, -0.06)[a] 40.58[b] (0.00, 73.76)[c]	- -

Outcome	3 months		6 months		12 months		13-60 months	
2-h BG	-	-	-0.03[f, g] (-0.14, 0.09)[a]	-	-0.71* (-1.42, 0.00)[a]	-0.27**[f, g] (-0.41, -0.13)[a]	-0.06[g] (-0.13, 0.02)[a]	-
	-	-	40.72[b] (0.00, 79.95)[c]	-	99.49[b] (99.40, 99.57)[c]	0[b] (-)[c]	46.63[b] (0.00, 78.87)	-
HbA1c	-	-0.10[f] (-1.43, 1.23)[a]	-0.11[g] (-0.33, 0.11)[a]	-	-0.40[f, g] (-0.62, -0.18)[a]	-	-0.29 (-0.59, 0.01)[a]	-
	-	95.12[b] (-)[c]	34.70[b] (0.00, 78.75)[c]	-	68.90 [b] (37.78, 84.46)[c]	-	67.99 [b] (0.00, 91.72)[c]	-

[a] The 95% confidence intervals of effect size are in the parenthesis.
[b.] I square in heterogeneity test
[c] The 95% confidence intervals of I square
[d] FBG=fasting blood glucose
[e] 2-h BG=2-hour blood glucose
[f] The number of studies is less than 4.
[g] Indicates that fixed-effect model was used to calculate the summary mean difference in outcomes.
[h] HbA1c=hemoglobin A1c
[i] IP=in-person intervention
[j] TECH=technology-delivered intervention with/without in-person contact
*Statistical significance at 10% level
**Statistical significance at 5% level.
***Statistical significance at 1% level.
- Insufficient data for meta-analysis

Table 1.3. Meta-regression results: Effects of study features and participant characteristics on 12-month mean body weight change. Dependent variable: relative mean weight loss (intervention groups vs. control groups).

Variable Name	Description	Data Summary Mean [a] (SD)[b]	All data Coefficient (SE) [c]	US Studies Coefficient (SE) [c]	Non-US Studies Coefficient (SE) [c]
Length	Duration of the nutrition education intervention (months)	11.37 (9.56)	0.02 (0.02)	0.04 (0.04)	0.04** (0.01)
Sample size	Sample size of the study	299.64 (499.03)	-0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)
Percentage of women	Percentage of women	62.90 (19.97)	0.00 (0.01)	0.05* (0.02)	-0.01 (0.01)
Setting	=1, if studies are conducted in primary care setting	0.51 (0.50)	1.08* (0.45)	3.67*** (0.83)	-0.12 (0.38)
Delivery Agent	=1, if intervention is delivered by a dietitian	0.52 (0.50)	-0.96* (0.39)	-2.44** (0.68)	-1.04* (0.40)
Study type	=1, if studies are RCT	0.66 (0.48)	0.92 (0.58)	3.42** (1.03)	-0.47 (0.47)
Location	=1, if studies are conducted in United States	0.53 (0.50)	-1.18* (0.49)		
Delivery channel	=1, if intervention employs in-person delivery	0.79 (0.41)	0.17 (0.49)	-0.55 (0.60)	1.60* (0.62)
Mean age	Average age of sample	53.25 (6.99)	-0.04 (0.03)	-0.07 (0.05)	-0.06* (0.03)
Group-based	=1, if intervention is delivered in groups	0.70 (0.46)	1.01* (0.47)	2.95*** (0.78)	0.45 (0.37)
Baseline BMI	Average BMI at baseline	31.21 (3.27)	-0.17* (0.08)	-0.08 (0.11)	-0.16* (0.08)
Constant	-	-	3.82 (2.83)	-4.97 (4.87)	6.28* (2.53)

Adjusted R-squared: 53.94%

[a] Mean=Mean value
[b] SD=Standard deviation of included variables.
[c] SE= Standard errors
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

Table 1.4. Meta-regression results: Effects of study features and participant characteristics on 12-month mean FPG change. Dependent variable: relative mean FPG reduction (intervention groups vs. control groups).

Variable Name	Description	Data Summary Mean [a] (SD)[b]	All data Coefficient (SE) [c]	US Studies Coefficient (SE) [c]	Non-US Studies Coefficient (SE) [c]
Length	Duration of the nutrition education intervention (months)	12.00 (9.98)	0.04 (0.06)	0.01 (0.15)	-0.02 (0.07)
Sample size	Sample size of the study	197.95 (147.08)	0.00 (0.00)	0.00 (0.02)	0.00 (0.01)
Percentage of women	Percentage of women	65.29 (19.14)	-0.03 (0.03)	0.08 (0.13)	-0.05 (0.03)
Setting	=1, if studies are conducted in primary care setting	0.45 (0.50)	-0.21 (1.85)	-4.47 (5.69)	0.61 (1.86)
Delivery Agent	=1, if intervention is delivered by a dietitian	0.49 (0.50)	-1.60 (1.26)	-1.30 (5.63)	-2.77 (1.87)
Study type	=1, if studies are RCT	0.58 (0.50)	-1.73 (1.51)	-0.10 (2.56)	-5.18* (1.89)
Location	=1, if studies are conducted in United States	0.45 (0.50)	-1.45 (2.02)		
Delivery channel	=1, if intervention employs in-person delivery	0.85 (0.36)	0.17 (1.58)	-1.27 (3.03)	3.21 (2.60)
Mean age	Average age of sample	53.94 (5.44)	0.03 (0.11)	0.14 (0.25)	-0.31 (0.16)
Group-based	=1, if intervention is delivered in groups	0.82 (0.39)	0.65 (1.55)	3.02 (5.08)	-1.19 (1.80)
Baseline BMI	Average BMI at baseline	31.10 (3.55)	0.04 (0.22)	-0.32 (0.45)	0.07 (0.29)
Constant	-	-	-2.83 (9.01)	-7.55 (18.68)	17.50 (13.42)

Adjusted R-squared	= 35.55%

[a] Mean=Mean value
[b] SD=Standard deviation of included variables.
[c] SE= Standard errors
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

Table 1.5. Meta-regression results: Effects of study features and participant characteristics on 12-month mean 2-PG and HbA1c change. Dependent variable: relative mean 2-PG and HbA1c reduction (intervention groups vs. control groups).

Variable Name	Description	2-PG as outcome		HbA1c as outcome	
		Data Summary Mean [a] (SD)[b]	All data Coefficient (SE) [c]	Data Summary Mean [a] (SD)[b]	All data Coefficient (SE) [c]
Length	Duration of the nutrition education intervention (months)	17.42 (12.09)	0.08 (0.11)	12.28 (7.74)	-0.00 (0.00)
Sample size	Sample size of the study	247.17 (136.12)	-0.00 (0.01)	176.72 (169.66)	0.00 (0.00)
Percentage of women	Percentage of women	60.92 (24.78)	0.07 (0.05)	52.39 (26.67)	-0.00 (0.00)
Setting	=1, if studies are conducted in primary care setting	0.79 (0.41)	5.29 (3.33)	0.61 (0.50)	0.02 (0.32)
Delivery Agent	=1, if intervention is delivered by a dietitian	0.58 (0.50)	2.75 (3.24)	0.50 (0.51)	-0.14 (0.18)
Study type	=1, if studies are RCT	0.67 (0.48)	-8.86 (4.52)	0.94 (0.24)	0.72 (0.39)
Location	=1, if studies are conducted in United States	0.04 (0.20)	2.66 (10.57)	0.50 (0.51)	0.08 (0.31)
Delivery channel	=1, if intervention employs in-person delivery	0.88 (0.34)	-5.57 (4.23)	0.89 (0.32)	-0.16 (0.33)
Mean age	Average age of sample	54.45 (5.42)	-0.17 (0.35)	52.92 (6.52)	-0.00 (0.01)
Group-based	=1, if intervention is delivered in groups	0.67 (0.48)	4.47 (4.15)	0.78 (0.43)	0.18 (0.13)
Baseline BMI	Average BMI at baseline	29.77 (3.09)	0.80 (0.65)	29.92 (3.41)	0.01 (0.02)
Constant	-		-24.29		-1.07

		(26.12)		(0.79)
Adjusted R-squared	93.49%		100.00%	

[a] Mean=Mean value
[b] SD=Standard deviation of included variables.
[c] SE= Standard errors
*Statistical significance at 10% level.
**Statistical significance at 5% level.
***Statistical significance at 1% level.

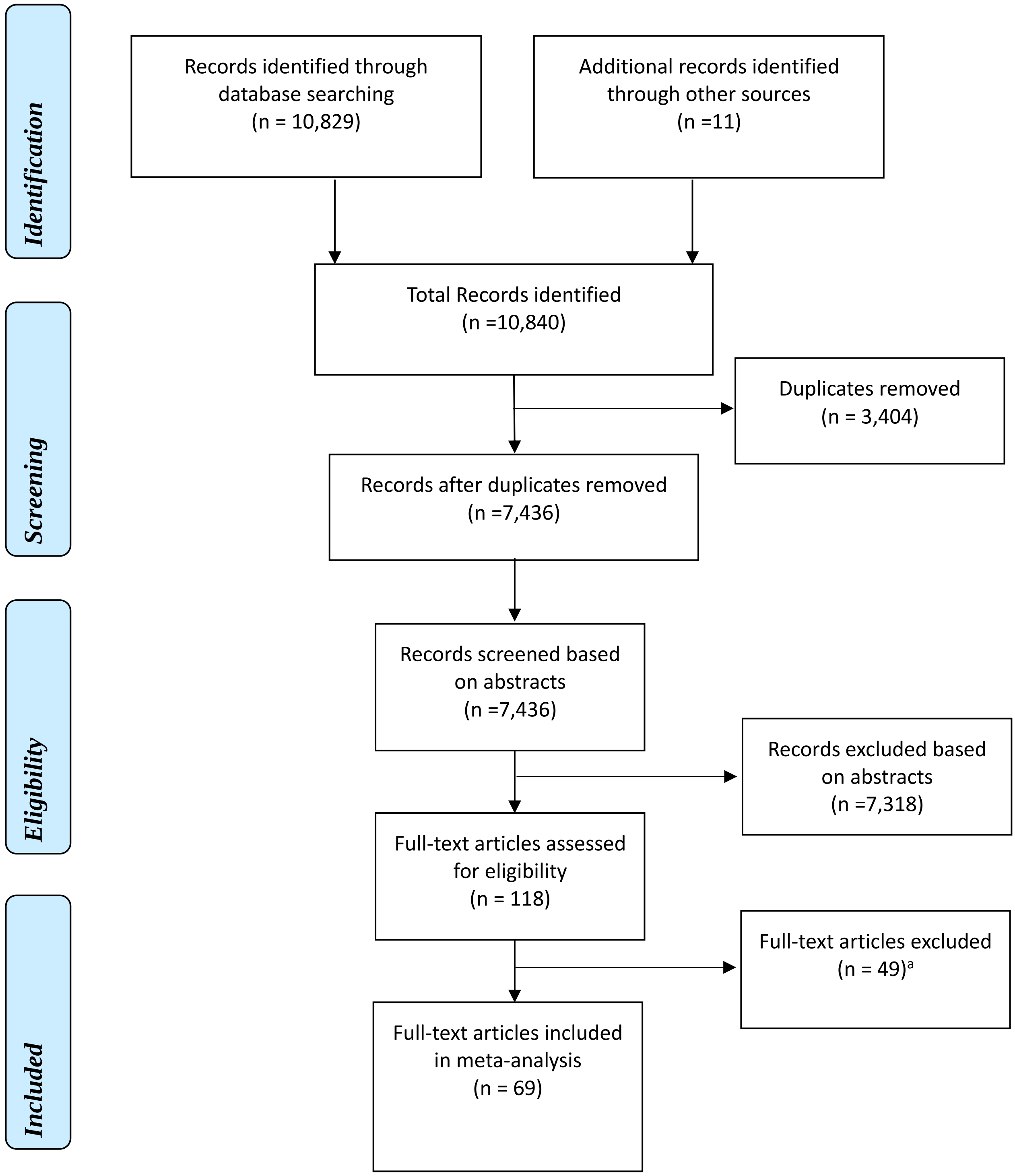

Figure 1.1. Meta-analysis Flow Diagram: The effectiveness of lifestyle intervention including nutrition education for diabetes prevention

[a] Studies did not meet the inclusion criteria: 19 studies included participants with diabetes; 1 study lasted less than 4 weeks; 5 studies did not include nutrition education;

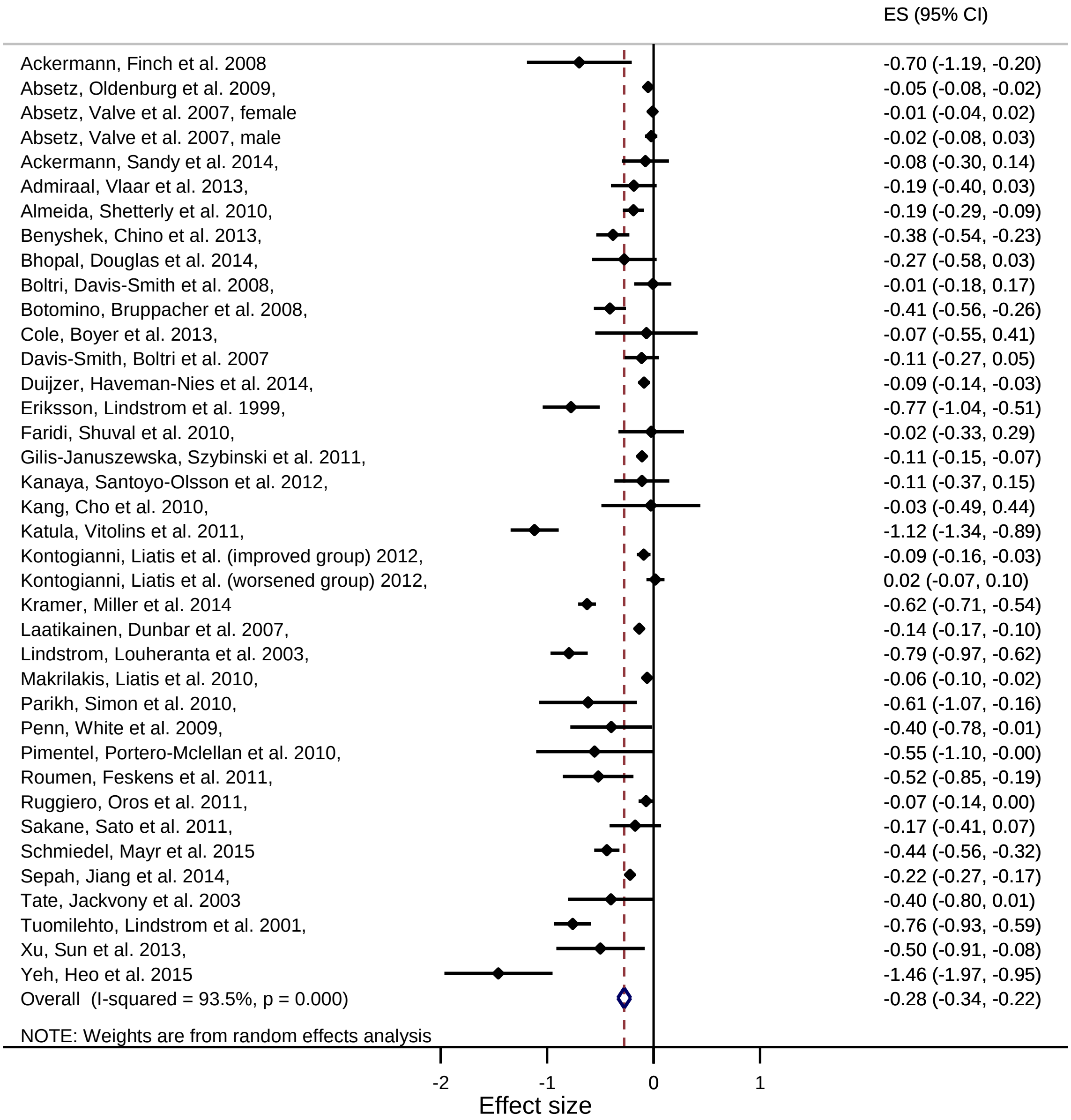

Figure 1.2. Forest plot for the overall summary effect size (ES) for weight change at 12 months. Each study is identified by author and year. Horizontal lines represent the ES for each study. The whiskers extending to each side represent the study effect’s 95% CI. The diamond indicates the overall mean difference.

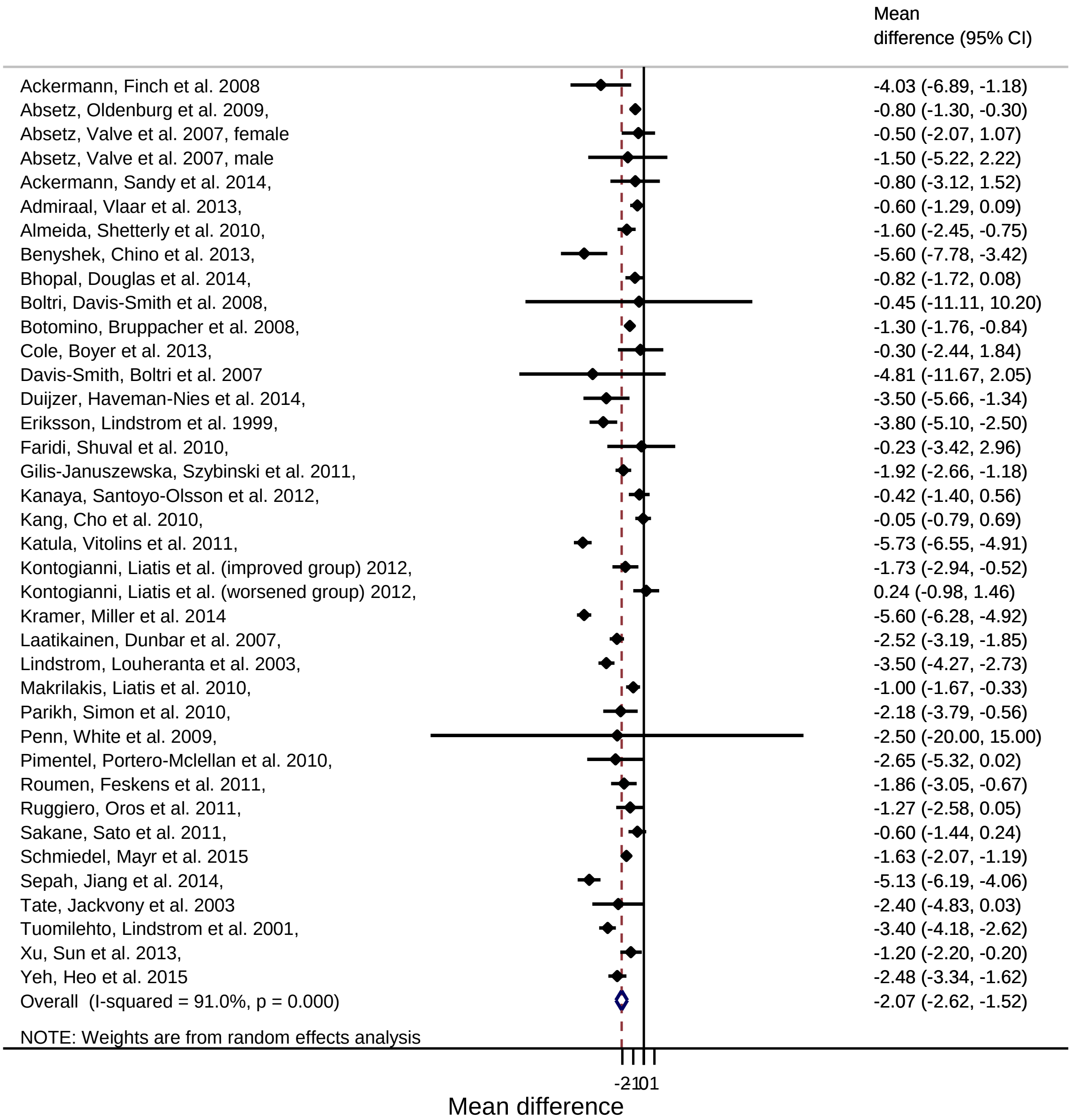

Figure 1.3. Forest plot for the overall summary mean difference relative to control group for weight change (in kilograms) at 12months. Each study is identified by author and year. Horizontal lines represent the mean difference for each study. The whiskers extending to each side represent the study mean difference’s 95% CI. The diamond indicates the overall mean difference.

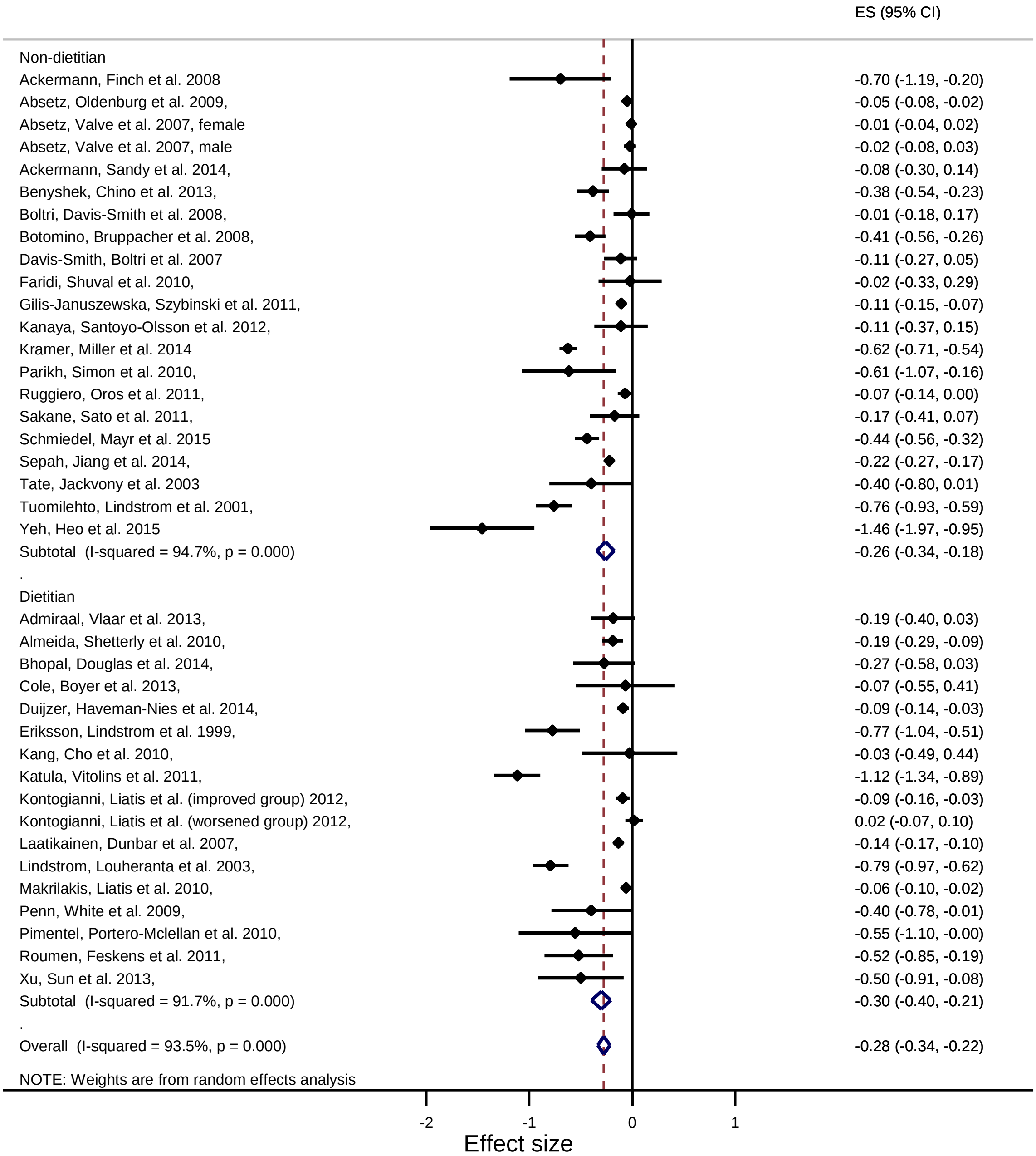

Figure 1.4. Forest plot for the study effect sizes (ESs) and the overall summary ES for weight change at 12 months by delivery agent (non-registered dietitian nutritionist vs registered dietitian nutritionist). Each study is identified by author and year. Horizontal lines represent the ES for each study. The whiskers extending to each side represent the study effect's 95% CI. The diamond indicates the overall ES

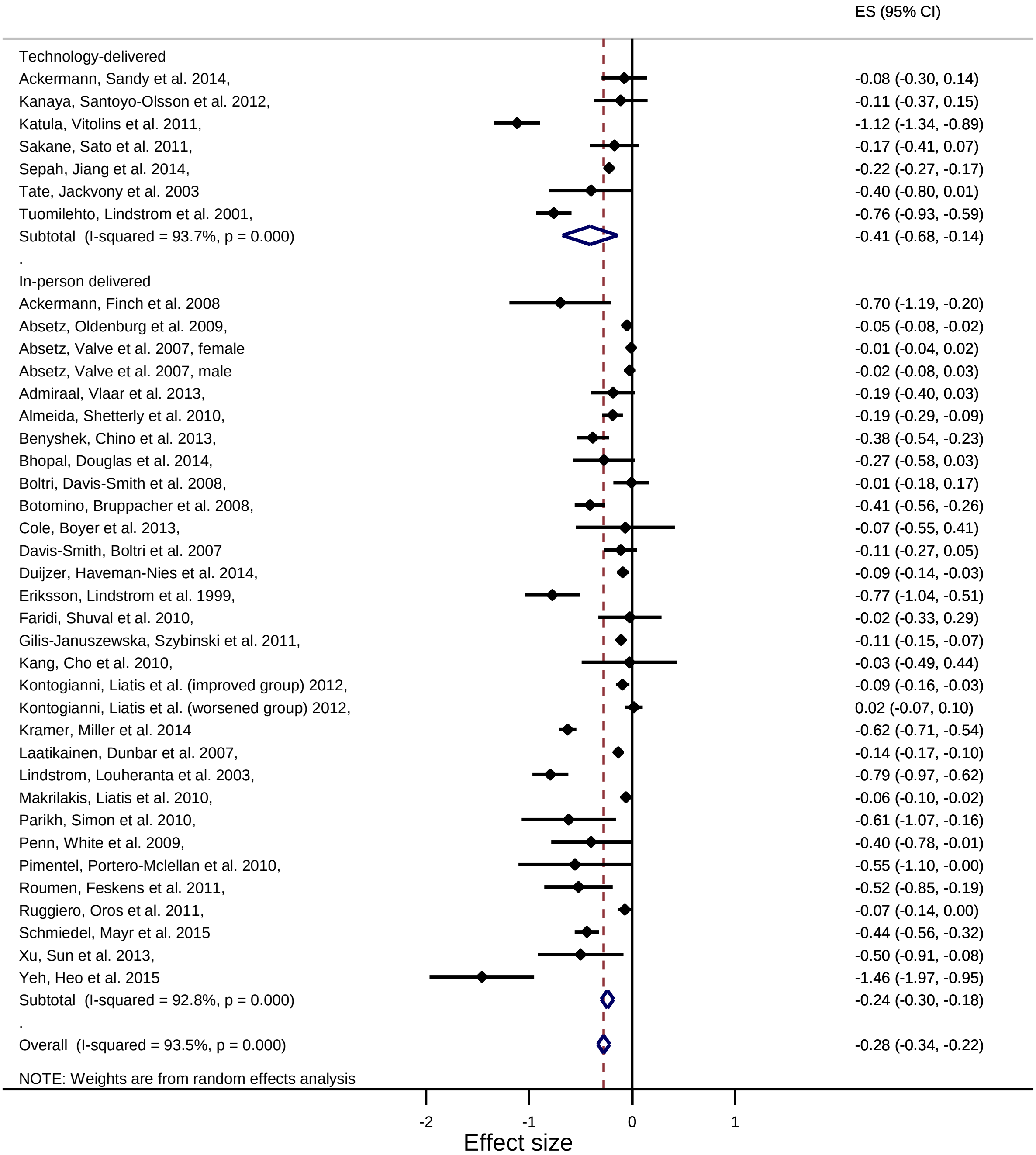

Figure 1.5. Forest plot for the study effect sizes (ESs) and the overall summary ES for weight change at 12 months by delivery channel (technology-delivered vs in-person delivered). Each study is identified by author and year. Horizontal lines represent the ES for each study. The whiskers extending to each side represent the study effect’s 95% CI. The diamond indicates the overall ES.

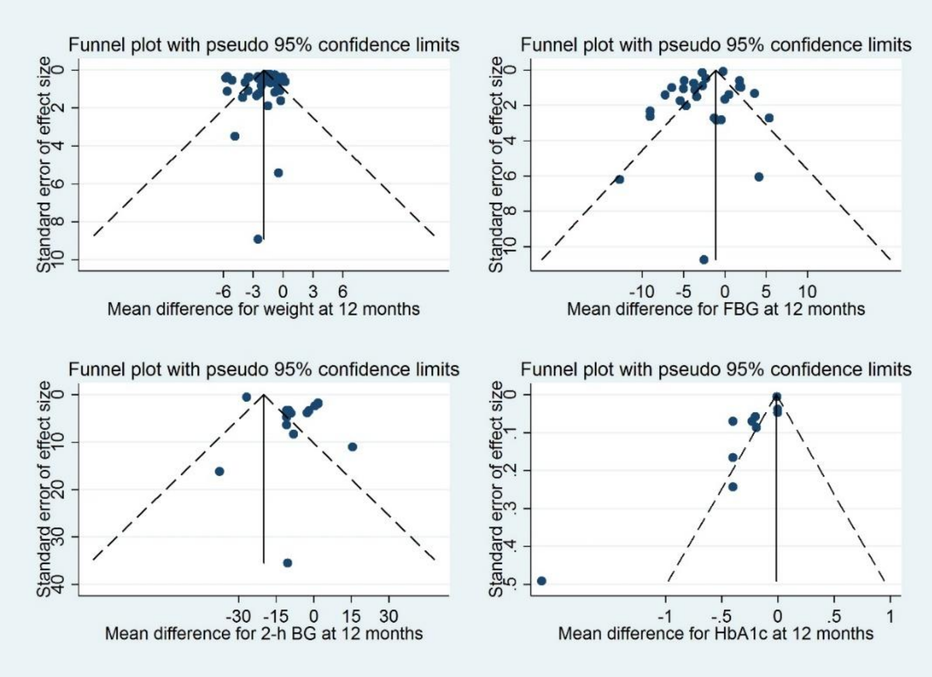

Figure 1.6. Funnel plots for risk of publication bias: Mean difference for weight, fasting blood glucose (FBG), 2-hour blood glucose (2-h BG), and hemoglobin A1c (HbA1c) at 12 months against the standard error. Scatter dots represent individual studies, dashed diagonal lines indicates pseudo 95% CI.

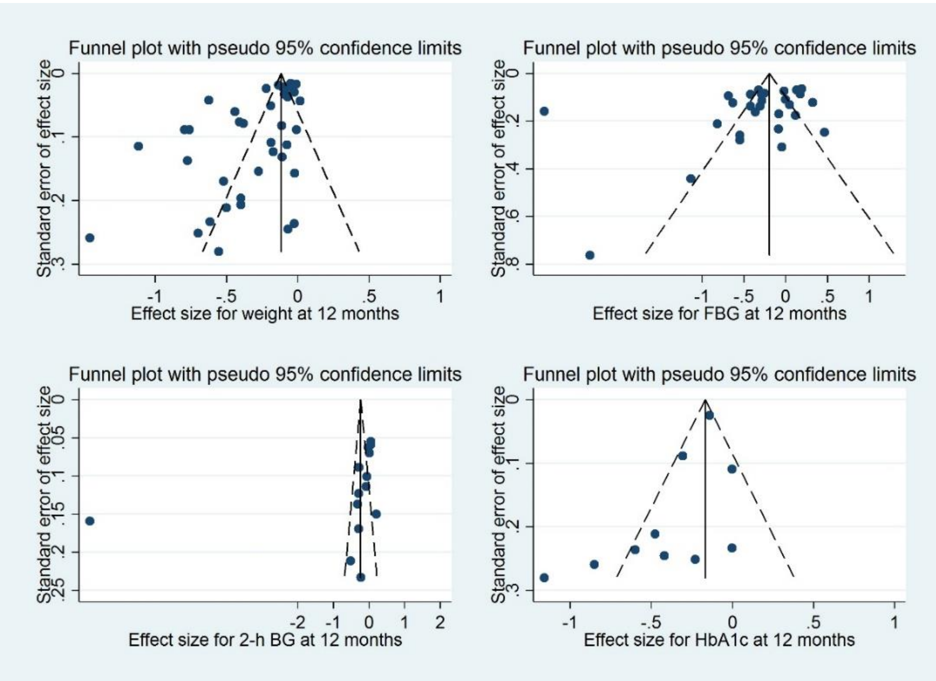

Figure 1.7. Funnel plots for risk of publication bias: Effect size in weight, fasting blood glucose (FBG), 2-hour blood glucose (2-h BG), and hemoglobin A1c (HbA1c) at 12 months against the standard error. Scatter dots represent individual studies, dashed diagonal lines indicates pseudo 95% CI.

Chapter 1.

Supplementary Table 1.1. The effectiveness and cost of lifestyle interventions including nutrition education for diabetes prevention: Example of the database search strategy using CAB Direct

Search ID number	Search terms	Results
1	(nutrition education) AND (diabetes prevention)	630
2	(dietary education) AND (diabetes prevention)	136
3	(Lifestyle intervention) AND (diabetes prevention)	689
4	(Behavioral intervention) AND (diabetes prevention)	109
5	(Lifestyle intervention) AND (diabetes prevention) AND (prediabetes)	54
6	(Glucose tolerance) OR (Glucose homeostasis) OR (Fasting glucose) AND (nutrition) AND (diabetes prevention)	554
7	(cost-effectiveness) AND (diabetes prevention) OR (prediabetes) AND (nutrition)	5
8	(cost) AND (Lifestyle intervention) AND (nutrition education) AND (diabetes prevention) OR (prediabetes)	44
9	(dietary education) AND (prediabetes)	7
10	(registered dietitian) OR (registered dietician) AND (diabetes)	11
Total number of articles		2239

Chapter 1.

Supplementary Table 1.2. The effectiveness and cost of lifestyle interventions including nutrition education for diabetes prevention: Example of the database search strategy using PubMed

Search ID number	Search terms	Search details	Results
1	(nutrition education) AND (diabetes prevention)	(("nutritional status"[MeSH Terms] OR ("nutritional"[All Fields] AND "status"[All Fields]) OR "nutritional status"[All Fields] OR "nutrition"[All Fields] OR "nutritional sciences"[MeSH Terms] OR ("nutritional"[All Fields] AND "sciences"[All Fields]) OR "nutritional sciences"[All Fields]) AND ("education"[Subheading] OR "education"[All Fields] OR "educational status"[MeSH Terms] OR ("educational"[All Fields] AND "status"[All Fields]) OR "educational status"[All Fields] OR "education"[All Fields] OR "education"[MeSH Terms])) AND (("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND ("prevention and control"[Subheading] OR ("prevention"[All Fields] AND "control"[All Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields]))	889
2	(dietary education) AND (diabetes prevention)	(("diet"[MeSH Terms] OR "diet"[All Fields] OR "dietary"[All Fields]) AND ("education"[Subheading] OR "education"[All Fields] OR "educational status"[MeSH Terms] OR ("educational"[All Fields] AND "status"[All Fields]) OR "educational status"[All Fields] OR "education"[All Fields] OR "education"[MeSH Terms])) AND (("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND ("prevention and control"[Subheading] OR ("prevention"[All Fields] AND "control"[All Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields]))	1452
3	(Lifestyle intervention) AND (diabetes prevention)	(("life style"[MeSH Terms] OR ("life"[All Fields] AND "style"[All Fields]) OR "life style"[All Fields] OR "lifestyle"[All Fields]) AND ("Intervention (Amstelveen)"[Journal] OR "intervention"[All Fields] OR "Interv Sch Clin"[Journal] OR "intervention"[All Fields])) AND (("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND ("prevention and control"[Subheading] OR ("prevention"[All Fields] AND "control"[All	1690

		Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields]))	
4	(Behavioral intervention) AND (diabetes prevention)	("behavior therapy"[MeSH Terms] OR ("behavior"[All Fields] AND "therapy"[All Fields]) OR "behavior therapy"[All Fields] OR ("behavioral"[All Fields] AND "intervention"[All Fields]) OR "behavioral intervention"[All Fields]) AND (("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND ("prevention and control"[Subheading] OR ("prevention"[All Fields] AND "control"[All Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields]))	1556
5	(Lifestyle intervention) AND (diabetes prevention) AND (prediabetes)	(("life style"[MeSH Terms] OR ("life"[All Fields] AND "style"[All Fields]) OR "life style"[All Fields] OR "lifestyle"[All Fields]) AND ("Intervention (Amstelveen)"[Journal] OR "intervention"[All Fields] OR "Interv Sch Clin"[Journal] OR "intervention"[All Fields])) AND (("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND ("prevention and control"[Subheading] OR ("prevention"[All Fields] AND "control"[All Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields])) AND ("prediabetic state"[MeSH Terms] OR ("prediabetic"[All Fields] AND "state"[All Fields]) OR "prediabetic state"[All Fields] OR "prediabetes"[All Fields])	173
6	(Glucose tolerance) OR (Glucose homeostasis) OR (Fasting glucose) AND (nutrition) AND (diabetes prevention)	(("glucose"[MeSH Terms] OR "glucose"[All Fields]) AND ("immune tolerance"[MeSH Terms] OR ("immune"[All Fields] AND "tolerance"[All Fields]) OR "immune tolerance"[All Fields] OR "tolerance"[All Fields] OR "drug tolerance"[MeSH Terms] OR ("drug"[All Fields] AND "tolerance"[All Fields]) OR "drug tolerance"[All Fields])) OR (("glucose"[MeSH Terms] OR "glucose"[All Fields]) AND ("homoeostasis"[All Fields] OR "homeostasis"[MeSH Terms] OR "homeostasis"[All Fields])) OR (("fasting"[MeSH Terms] OR "fasting"[All Fields]) AND ("glucose"[MeSH Terms] OR "glucose"[All Fields])) AND ("nutritional status"[MeSH Terms] OR ("nutritional"[All Fields] AND "status"[All Fields]) OR "nutritional status"[All Fields] OR "nutrition"[All Fields] OR "nutritional sciences"[MeSH Terms] OR ("nutritional"[All Fields] AND "sciences"[All Fields]) OR "nutritional sciences"[All Fields]) AND (("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND	690

		("prevention and control"[Subheading] OR ("prevention"[All Fields] AND "control"[All Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields]))	
7	(cost-effectiveness) AND (diabetes prevention) OR (prediabetes) AND (nutrition)	((("cost-benefit analysis"[MeSH Terms] OR ("cost-benefit"[All Fields] AND "analysis"[All Fields]) OR "cost-benefit analysis"[All Fields] OR ("cost"[All Fields] AND "effectiveness"[All Fields]) OR "cost effectiveness"[All Fields]) AND (("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND ("prevention and control"[Subheading] OR ("prevention"[All Fields] AND "control"[All Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields]))) OR ("prediabetic state"[MeSH Terms] OR ("prediabetic"[All Fields] AND "state"[All Fields]) OR "prediabetic state"[All Fields] OR "prediabetes"[All Fields])) AND ("nutritional status"[MeSH Terms] OR ("nutritional"[All Fields] AND "status"[All Fields]) OR "nutritional status"[All Fields] OR "nutrition"[All Fields] OR "nutritional sciences"[MeSH Terms] OR ("nutritional"[All Fields] AND "sciences"[All Fields]) OR "nutritional sciences"[All Fields])	444
8	(cost) AND (Lifestyle intervention) AND (nutrition education) AND (diabetes prevention)	((("economics"[Subheading] OR "economics"[All Fields] OR "cost"[All Fields] OR "costs and cost analysis"[MeSH Terms] OR ("costs"[All Fields] AND "cost"[All Fields] AND "analysis"[All Fields]) OR "costs and cost analysis"[All Fields]) AND (("life style"[MeSH Terms] OR ("life"[All Fields] AND "style"[All Fields]) OR "life style"[All Fields] OR "lifestyle"[All Fields]) AND ("Intervention (Amstelveen)"[Journal] OR "intervention"[All Fields] OR "Interv Sch Clin"[Journal] OR "intervention"[All Fields]))) AND (("nutritional status"[MeSH Terms] OR ("nutritional"[All Fields] AND "status"[All Fields]) OR "nutritional status"[All Fields] OR "nutrition"[All Fields] OR "nutritional sciences"[MeSH Terms] OR ("nutritional"[All Fields] AND "sciences"[All Fields]) OR "nutritional sciences"[All Fields]) AND ("education"[Subheading] OR "education"[All Fields] OR "educational status"[MeSH Terms] OR ("educational"[All Fields] AND "status"[All Fields]) OR "educational status"[All Fields] OR "education"[All Fields] OR "education"[MeSH Terms]))) AND (("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields]) AND ("prevention and control"[Subheading] OR ("prevention"[All Fields] AND "control"[All Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields]))	10

9	(dietary education) AND (prediabetes)	(("diet"[MeSH Terms] OR "diet"[All Fields] OR "dietary"[All Fields]) AND ("education"[Subheading] OR "education"[All Fields] OR "educational status"[MeSH Terms] OR ("educational"[All Fields] AND "status"[All Fields]) OR "educational status"[All Fields] OR "education"[All Fields] OR "education"[MeSH Terms])) AND ("prediabetic state"[MeSH Terms] OR ("prediabetic"[All Fields] AND "state"[All Fields]) OR "prediabetic state"[All Fields] OR "prediabetes"[All Fields])	76
10	(registered dietitian) OR (registered dietician) AND (diabetes)	((registered[All Fields] AND ("nutritionists"[MeSH Terms] OR "nutritionists"[All Fields] OR "dietitian"[All Fields])) OR (registered[All Fields] AND ("nutritionists"[MeSH Terms] OR "nutritionists"[All Fields] OR "dietician"[All Fields]))) AND ("diabetes mellitus"[MeSH Terms] OR ("diabetes"[All Fields] AND "mellitus"[All Fields]) OR "diabetes mellitus"[All Fields] OR "diabetes"[All Fields] OR "diabetes insipidus"[MeSH Terms] OR ("diabetes"[All Fields] AND "insipidus"[All Fields]) OR "diabetes insipidus"[All Fields])	88
Total number of articles			7068

Supplementary Table 1.3. The effectiveness and cost of lifestyle interventions including nutrition education for diabetes prevention: Characteristics of included studies (by publication date)

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
US studies with RCT[e] design								
Tate et al., 2003	92 (46+46)[f] Mean age (years): 48.5±9.4 Overweight/obese	12 months /0	Web site	IG[g]: Basic internet program plus behavioral e-counseling. CG[h]: Basic internet weight loss program.	12 Mo[i] IG: -4.4±6.2 [j] CG: -2.0±5.7[j] P=0.04	3 Mo IG: -4.6±7.9[j] CG: -0.3±8.4[j] P=0.01		
Ackermann, Finch et al., 2008	92(46+46) Mean age (years) CG: 60.1±10.5 IG: 56.5±9.7 BMI[k] ≥ 24/ ADA-score[l] ≥ 10	4 months/ 12 months	Wellness instructor	IG: 16 classroom-style meetings for goal setting, self-monitoring and problem-solving. CG: brief counseling, materials, and limited access to the YMCA.	4-6 Mo CG: -2.0 % (-3.3, -0.6) [m] IG: -6.0 % (-7.3, -4.7) [m] P<0.001 12-14 Mo CG:-1.8 % (-3.9, 0.3)[m] IG: -6.0% (-8.3, -3.8)[m] P=0.008			4-6 Mo CG: -0.1 (-0.2, 0.01)[j] IG: -0.1 (-0.2, 0.01)[j] P=0.96 12-14 Mo CG: 0 (-0.1, 0.2)[j] IG: -0.1 (-0.2,0.1)[j] P=0.28
Estabrooks and Smith-Ray, 2008	77(39+38) Mean age (years): 59 Prediabetic[o]	3 months /0	IVR[n] telephone messages	IG: a series of IVR telephone calls over the 12-week study period. CG: standard care 90-	BL[p] IG: 88.2±18.4[q] CG: 87.3±18.5[q] 3 Mo			

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten -ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
				min diabetes prevention class.	IG: 86±18.7[q] CG:85.8±18.2[q]			
Almeida, Shetterly et al., 2010	1520 (760+760) Mean age (years): 63±10 Overweight/ Prediabetic/IGT[r]	12 months /0	Dietitian	IG: a presentation by a dietitian to a class of 10-20 participants and a 90-miniute session. CG: a dummy date for participation in a small-group session.	12 Mo IG: -1.4 (-1.6, -1.1)[j, q] p<0.001 CG : -0.6 (-0.9, -0.4)[j, q] p<0.001			
Parikh, Simon et al., 2010	99 Mean age (years): 48 Overweight	6 months/ 6 months	Lay leaders	IG: culturally sensitive curriculum with simple, actionable messages to make lifestyle changes. CG: Delayed intervention	12 Mo IG: -3.3±3.3[j, q] CG:-1.1±3.7[j, q] P=0.01	12 Mo IG: 10±13[j] CG:11±11[j] p=0.83		12 Mo IG: -0.3±0.2[j] CG:-0.3±0.2[j] p=0.13
Vadheim, McPherson et al., 2010	27 (14+13) Mean age (years): CG: 53 IG: 50 Overweight/	4 months/ 6 months	RD[s]	IG: same core curriculum sessions via telehealth video conferencing. CG: a 16 weekly core curriculum sessions	4 Mo IG: -6.7±3.7[j] CG:-6.5±3.1[j] P=0.85			

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
	Prediabetic			and the 6 monthly after-core sessions.				
Katula, Vitolins et al., 2011	301 (150+151) Mean age (years): 57.9±9.5 Overweight/ Prediabetic	6 months/ 6 months	Commun-ity health workers (CHW[t])	IG: a weekly CHW-led group sessions during the first 6 months and two scheduled contacts with CHW each month from 7 to 12 months. CG: usual care of two individual sessions with a nutritionist during the first 3 months.	12 Mo -5.73±0.42[u] P<0.001	12 Mo -3.76±0.76[u] P<0.001		
Kanaya, Santoyo-Olsson et al., 2012	230 (113+117) Mean age (years) CG: 55 ±17 IG: 58 ±16 A capillary blood glucose value is between 106 and 160 mg/dl	6 months/ 6 months	Trained health depart-ment counselors	IG: a telephone-based counseling of education and skills training to modify diet and physical activity in Spanish and English. CG: wait-list control group.	6 Mo CG:-0.2±0.26[j, q] IG: -1.0± 0.3[j, q] P=0.03 12 Mo CG:-0.2±0.4[j, q] IG: -0.6± 0.32[j, q] P=0.4	6 Mo CG: 0.42±1.04[j] IG: -0.70±0.87[j] P=0.41 12 Mo CG: -1.39±0.96[j] IG: -0.88±1.02[j]		

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten -ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
						P=0.72		
Cole, Boyer et al., 2013	65(34+31) Mean age (years): 58.3±9.6 Prediabetic	3 months/ 12 months	RD	IG: three 90-minute nutrition shared medical appointments (SMA) sessions. CG: a 45- to 60-minute individualized counseling session with a registered dietitian.	3 Mo IG:-3.0±3.0[j] CG-1.6±3.3[j] P<0.05 12 Mo IG:-1.5± 4.4[j] CG-1.2±4.4[j]			3 Mo IG: 0.1±0.4[j] CG0.4±1.1 [j] P<0.05 12 Mo IG: 0.1±0.4[j] CG: 0.5±1.3[j] P<0.05
Islam, Zanowiak et al., 2013	48(25+23) Mean age (years): 59.7 Family history of diabetes/ADA score	6 months/ 0	CHW	IG: interventions with follow-up phone calls from the CHW to discuss the challenges and strategies for improving diet and physical activity. CG: intervention sessions were held every 3 weeks in a convenient community setting.	6 Mo IG: -0.5±1.7[j, q] CG: 0.3±1.5[j ,q] P=0.14	6 Mo IG:4.0±30.8[j] CG:0.4±27.4[j] P=0.74		

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
Katula, Vitolins et al., 2013	301 (150+151) Mean age (years): 57.9±9.5 Overweight/ Prediabetic	6 months/ 18 months	CHW	IG: three personalized consultations, two scheduled contact with the CHW each month, one group session and one telephone contact. CG: usual care of two individual sessions involving healthy eating and physical activity education.	24 Mo -4.9±0.71[u] P<0.001	24 Mo -4.35±1.14[u] P<0.001		
Ma, Yank et al., 2013	160 (79+81) Mean age (years): 53±11 Prediabetic/ Metabolic syndrome	3 months/ 12 months	RD	IG: face-to-face weekly classes via a home-based DVD to self-directed group. CG: the same classes in face-to-face manner for coach-led group over 12 weeks.	3 Mo IG: -4.5±0.8[j] CG: -5.4±0.7[j] P=0.09 6 Mo IG: -4.3±0.8[j] CG: -6.6±0.8[j] p<0.001 15 Mo IG: -4.5±0.9[j] CG: -6.3±0.9[j] P=0.04			
Xiao, Yank et al., 2013	160 (79+81) Mean age	3 months/	RD	IG: face-to-face weekly classes via a	24 Mo IG: -4.5±0.9[j]			

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
	(years): 53±11 Prediabetic/ Metabolic syndrome	21 months		home-based DVD to self-directed group. CG: the same classes in face-to-face manner for coach-led group over 12 weeks.	CG: 5.4±0.7[j]			
Ackermann, Sandy et al., 2014	306 (153+153) Mean age (years): 46.7±11.3 A parent or a sibling has diabetes/personal history of gestational diabetes	5 months/ 7 months	Lifestyle coach	IG: VOD programming in combination with an interactive web portal (VOD Plus). CG: DPP by Video On-Demand (VOD) alone.	5 Mo IG: 2.9% (0.7-4.2)[m] CG: 3.7% (1.9-5.0)[m] P=0.23			
Islam, Zanowiak et al., 2014	126(76+50) Mean age (years): IG: 46.3±11.6 CG: 47.8±9.5 Family history of diabetes/ADA score	6 months/ 0	CHW supervisor	IG: a multi-component CHW-led intervention, which is consisted of six 2-hour interactive group sessions. CG: standard acre including seeking preventive and acute care from their usual	BL IG: 72.7±12.6 CG: 79.3±10.5 3 Mo IG: 71.4±12.1 CG: 76.7±10.3 6 Mo IG: 70.4±11.5 CG: 78.8±8.8	BL IG: 114.5±36.8 CG: 111.3±22.0 3 Mo IG: 96.7±17.6 CG: 102.2±19.3 6 Mo		

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG**[b] **(mg/dl)**	**2-h BG**[c] **(mg/dl)**	**HbA1c**[d] **(%)**
				health care sources as needed.		IG: 88.9±16.5 CG: 113.0±12.0		
Fukuoka, Gay et al., 2015	61(30+31) Mean age (years): 55.2±9 Overweight/ obese/Prediab-etic/Diabetes risk score ≥5	5 months /0	Research staff members	IG: Six in-person sessions delivered by two trained non-medical research staff members with the aid of mDPP mobile app. CG: A brochure about pre-diabetes and standard medical care	3 Mo IG: -5.2±4.4[j] CG:0.4±1.8[j] P<0.001 5 Mo IG:-6.2±5.9[j] CG: 0.3±2.7[j] P<0.001			
Yeh, Heo et al., 2015	58 (30+28) Mean age (years) 58.8 Prediabetic/ Overweight	6 months/ 6 months	Trained lifestyle coaches	IG: 12 bi-weekly core sessions and two 6-monthly follow-up sessions	6 Mo IG:-2.42±1.86[j,m] CG:-0.07±1.46[j,m] 10 Mo IG: -2.28±1.86[j,m] CG: 0.2±1.46[j,m]	6 Mo IG:-0.18±0.38[j,m] CG:-0.12±0.34[j,m] 10 Mo IG: -0.29±0.38[j,m] CG:-0.09±0.34[j,m]		6 Mo IG: -0.19±0.24[j,m] CG:-0.05±0.29[j,m] 10 Mo IG:0.001±0.24[j,m] CG:0.23±0.29[j,m]

US studies with QED[v] **design**

Reference[a]	Sample size, mean age, and diabetes risk criteria	Active & mainten-ance phases	Delivery Agent	Intervention description	Weight (kg)	FBG[b] (mg/dl)	2-h BG[c] (mg/dl)	HbA1c[d] (%)
Davis-Smith, Boltri et al., 2007	10 Mean age was not reported Prediabetic	2 months/ 12 months	Volunteer healthcare profess-ionals	Six sessions over 7 weeks by volunteer healthcare professionals. Handouts for each session were distributed at the beginning of the session. Each session included a review of the activity logs.	BL 104.8±25.3[q] 6 Mo 101.8±27.2[q] 12 Mo 100±15.7[q] $P<0.05$	BL 109±8.3 6 Mo 99±9.8 12 Mo 100±5.8		
Boltri, Davis-Smith et al., 2008	8 Mean age (years): female 52.1 Male 52.4 Prediabetic	4 months/ 12 months	Group leader	An individualized lifestyle program including a 16-session church DPP over 4 months.	BL 93.3±15.4[q] 6 Mo 90.7[q] 12 Mo 92.8[q] $P<0.05$	BL 104±2.8 6 Mo 100 12 Mo 97.7 $P<0.05$		
Amundson, Butcher et al., 2009	293 Mean age (years): 53.6±9.7 Overweight/pre-diabetic/IGT/IFG/history of gestational	4 months/ 0	Dietitian	A group-based program through 16 weekly sessions followed with a monthly group sessions over a 6-month period led by the lifestyle coaches.	BL Male: 110.6±21.1 Female: 96.4±18.6 4 Mo Male: 102±20.4 $P<0.001$			

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
	diabetes				Female: 90.2±17.7 P<0.001			
Faridi, Shuval et al., 2010	161(83+78) Age range (years): 18-79 Overweight/ A history of gestational diabetes	12 months / 0	Certified diabetes educator	IG: A 10-week training session series led by a certified diabetes educator (2 hour per series) with 21 intervention CHAs[w] were held. CG: a delayed intervention.	12 Mo IG: 0.14±11.8[j, q] CG:0.37±8.8[j, q] P=0.8974			
Kramer, Kriska et al., 2010	48 (22+26) Mean age (years): 59.7 Overweight/ Prediabetic	3 months/ 0	Health care professionals	IG: materials of the GLB-DVD intervention with instructions to view one session/week. CG: a total of 12 health care professional contacts with related materials.	3 Mo IG:-5.4±5.2[j, q] CG: -6.3±6.5[j, q] P<0.001	3 Mo IG:-4.71±6.66[j] CG:1.15±10.52[j] P=0.98		3 Mo IG:-0.16±0.23[j] CG:-0.31±0.25[j] P<0.0001
Kramer, McWilliams et al., 2011	81 Mean age (years): 52.9 Overweight/	3 months/ 0	Health educators	A 12-session group lifestyle intervention by the trained diabetes educators in	3 Mo -5.1±4.8[j, q] P<0.001	3 Mo -2.9±11.3[j] P<0.001		

Reference[a]	Sample size, mean age, and diabetes risk criteria	Active & mainten-ance phases	Delivery Agent	Intervention description	Weight (kg)	FBG[b] (mg/dl)	2-h BG[c] (mg/dl)	HbA1c[d] (%)
	Prediabetic			groups with GLB related materials.				
Rosal, Lemon et al., 2011	27 Mean age (years): 27.8±5.1 Overweight/ Obese	4 months/ 0	Dietitian	8 group 2.5-hour sessions led by a WIC nutritionist and co-led by a peer and followed by two telephone contracts.	4 Mo -2.1±3.7[j, q] P=0.04			
Ruggiero, Oros et al., 2011	69 Mean age (years): 37.86±8.52 Prediabetic/ Overweight	6 months/ 6 months	A commun-ity resident or CHW	Culturally specific information on diabetes risk delivered in a small group format with supplemental educational materials in Spanish.	6 Mo -2.2±4.4[j, q] P=0.016 12 Mo -1.3±5.1[j, q] P=0.0649			
Benyshek, Chino et al., 2013	12 Mean age (years): 39 Overweight/ Range of HbA1c is 35 mmol/mol to 64 mmol/mol from a whole	4 months/ 8 months	Native lifestyle coaches	A 16-week intensive interventions included weight-loss curriculum, meal planning, fat gram and calorie counting, portion size and food content education.	4 Mo -5.79%[m] P=0.010	4 Mo -0.39%[m] P=0.502		

Reference[a]	Sample size, mean age, and diabetes risk criteria	Active & mainten-ance phases	Delivery Agent	Intervention description	Weight (kg)	FBG[b] (mg/dl)	2-h BG[c] (mg/dl)	HbA1c[d] (%)
	blood capillary blood sample.							
Cha, Kim et al., 2014	15 Mean age (years): 24.4±2.2 Prediabetic/ IFG	4 months/ 0	RD	A 12-week weekly intervention with each participants' reported weekly dietary and exercise habits via handheld device and/or Web site log-in and individualized phone counsel.	3 Mo -0.13[j] p=0.031	3 Mo 0.39[j] P=0.112		3 Mo -0.76[j] p=0.007
Kaholokula, Wilson et al., 2014	239 Mean age (years): 50.8±14.3 Overweight	3 months/ 0	CHA	Translated lessons from the original DPP-LI lessons on economical healthy eating and communicating effectively with the doctor.	3 Mo -1.7±3.5[j] P<0.01			

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG**[b] **(mg/dl)**	**2-h BG**[c] **(mg/dl)**	**HbA1c**[d] **(%)**
Kramer, Miller et al., 2014	68 Mean age (years): 52.9 Overweight/ obese/Prediab-etic/Metabolic syndrome	3 months/ 9 months	Trained diabetes educators	12 weekly 1-hour sessions conducted by the trained diabetes educator with the completion of home assignments.	4 Mo -5.9±10.3[j] P<0.001 12 Mo -5.6±2.5[j] P<0.001	4 Mo -3.6±12.5[j] P=0.04 12 Mo -4.7±14.7 [j] P=0.009		
Sepah, Jiang et al., 2014	220 Mean age (years): 43.6±12.4 Prediabetic/Overweight	4 months/ 8 months	Profess-ional health coach	The DPP lifestyle intervention in an online small-group format with participants ' communication via a private online social network.	12 Mo Core participants: -4.9±0.5[j, q] P<0.001 Post-core participants: -5.1±0.5[j, q] P<0.001			12 Mo Core participants: -0.37±0.07 p<0.0001 Post-core participants: 0.40±0.07 p<0.0001
Tang, Nwankwo et al., 2014	11 Mean age (years): 60±12 Overweight/ ADA score≥10	2 months/ 3 months	Peer lifestyle coaches	6 group-based face-to-face sessions delivered by peer over 8 weeks and 6 biweekly telephone support calls over a period of 12 weeks.	2 Mo -1.6±2.7[j, q] 5 Mo -1.2±2.7[j, q]			

Reference[a]	Sample size, mean age, and diabetes risk criteria	Active & mainten-ance phases	Delivery Agent	Intervention description	Weight (kg)	FBG[b] (mg/dl)	2-h BG[c] (mg/dl)	HbA1c[d] (%)
Brokaw, Carpenedo et al., 2015	3804 Mean age (years) 52.5±11.9 Overweight/ Prediabetic/IGT /IFG	4 months/ 6 months	RD	10 diabetes self-management education (DSME) programs, two DSME programs in collaboration with their local YMCA	4 Mo -6.2±5.2[j]	4 Mo Age<65 -2.5±7.2[j] P<0.001 Age≥65 -4.8±7.7[j] P<0.001		
Non-US studies with RCT design								
Eriksson, Lindström et al., 1999	212 (112+100) Mean age IG: 54 ±7 CG: 52 ±7 Overweight/IGT	12months/ 0	Dietitian	IG: frequent face-to-face dietary advice tailored to each subject individually and also in group sessions by a nutritionist. CG: dietary advice by verbal and written information at annual follow-up visits.	12 Mo IG: -4.7±5.5[j] CG: -0.9±4.1[j] P<0.001	12 Mo IG: 0±14.4[j, x] CG: 5.4±10.8[j, x] P<0.01	12 Mo IG: -16.2±28.8[j, x] CG: -5.4±39.6[j, x] P<0.05	

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten -ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG**[b] **(mg/dl)**	**2-h BG**[c] **(mg/dl)**	**HbA1c**[d] **(%)**
Wein, Beischer et al., 1999	193 (97+96) Mean age (years) IG: 39.5 CG:37.8 IGT	51 months /0	Dietitian	IG: Participants were given the same dietary advice, in addition, telephone was arranged 3-monthly. CG: The control group were given dietary questionnaires and the standard diet advice sheet.		BL CG:100.9 (99, 104.4)[x] IG: 99 (97.2, 102.6)[x] 51 Mo CG: 109.8 (104.4, 113.4)[x] IG: 102.6 (100.8, 106.2)[x] P=0.13	BL CG: 176.4 (174.6, 180)[x] IG: 178.2 (174.6, 180)[x] 51 Mo CG: 178.2 (171, 187.2)[x] IG: 176.4 (167.4, 185.4)[x] P=0.71	
Tuomilehto, Lindström et al., 2001	506 (256+250) Mean age (years) 55 IGT	12 months/ 38 months	Staff members	IG: tailored advices on diet and physical activity about how to achieve the goals of the intervention. CG: general oral and written information about diet and exercise at base line and at subsequent annual visits	12 Mo CG:-0.8±3.7[j] IG: -4.2±5.1[j] P<0.001	12 Mo CG: 1±12[j] IG: -4±12[j] P<0.001		

Reference[a]	Sample size, mean age, and diabetes risk criteria	Active & mainten-ance phases	Delivery Agent	Intervention description	Weight (kg)	FBG[b] (mg/dl)	2-h BG[c] (mg/dl)	HbA1c[d] (%)
Lindstrom, Louheranta et al., 2003	434 (231+203) Mean age (years) CG: 55 ±7 IG: 55 ±7 Overweight/IGT	12 months /36 months	Dietitian	IG: face-to –face consultation sessions with the study nutritionist with guide to increase level of physical activity. CG: general information about lifestyle and diabetes risk.	12 Mo CG: -1±3.7[j] IG: -4.5±5[j] P<0.0001	12 Mo CG:0±0.7[j] IG: -0.2±0.7[j] P<0.0001	12 Mo CG: -0.3±2.2[j] IG: -0.9±1.9[j] P=0.0001	12 Mo CG: 0.1±0.6[j] IG: -0.1±0.7[j] P=0.0003
Watanabe, Yamaoka et al., 2003	358 (102+256) Mean age (years): 55 1-h PG ≥10 mmol/l	12 months /0	Research staff	IG: information of reducing weight to the desirable level based on “Food Exchange Lists, Dietary Guidance for persons with Diabetes” CG: Subjects were told to avoid gaining weight by dieting and exercise.		12 Mo CG:2.2%±0.9[m] IG: -0.5%±0.9[m] P=0.153	12 Mo CG: 11.2%±3[m] IG: -8.2%±1.9[m] P<0.001	

Reference[a]	Sample size, mean age, and diabetes risk criteria	Active & mainten -ance phases	Delivery Agent	Intervention description	Weight (kg)	FBG[b] (mg/dl)	2-h BG[c] (mg/dl)	HbA1c[d] (%)
Kosaka, Noda et al., 2005	358 (102+256) Initial BMI no mean age A fasting plasma glucose value <140 mg/dl and 2-h plasma glucose value after a 100g glucose load of 160-239 mg/dl.	12 months /48 months	Research staff	IG: reduction of weight to the desirable level based on "Food Exchange Lists, Dietary Guidance for persons with Diabetes". CG: no gain in weight by dieting and exercise.		48 Mo CG: -0.39[j] IG: -2.18[j]		
Lindstrom, Ilanne-Parikka et al., 2006	522 (265+257) Mean age (years) 55 Overweight/IGT	12 months /38 months	Dietitian	IG: detailed and individualized personal counselling sessions with the study nutritionist. CG: general verbal and written health behavior information at baseline	BL CG: 86.7 IG: 85.5 P=0.3267 12 Mo CG: 84.8 IG: 82.2 P<0.001			

Reference[a]	Sample size, mean age, and diabetes risk criteria	Active & mainten-ance phases	Delivery Agent	Intervention description	Weight (kg)	FBG[b] (mg/dl)	2-h BG[c] (mg/dl)	HbA1c[d] (%)
Oldroyd, Unwin et al., 2006	54 (30+24) Mean age (years) CG: 57.5 IG: 58.2 IGT	6 months/ 18 months	Dietitian	IG: written nutrition education material and a graded physical activity plan. CG: no dietary or physical activity advice for the duration of the study.	6 Mo CG: 0.54±2.2[j] IG: -1.1±2.9[j] P=0.010	6 Mo CG: 3.24±19.8[j, x] IG: 0.9±10.8[j, x] P=0.560	6 Mo CG: -9±30.6[j, x] IG: -9.9±34.2[j, x] P=0.910	
Barclay, Procter et al., 2008	28 (17+11) Mean age (years) CG: 62.3 IG: 67.5 Overweight/ Prediabetic	6 months / 0	Nutrition scientist	IG: diet messages based on the Harvard diet pyramid. CG: standard healthy-eating and dietary advice based on the UK Food Standard Agency's guidelines for a healthy diet.	6 Mo CG: -0.3±1.36[j] IG: -2.73±3.15[j] P=0.03	6 Mo CG: 4.5±12.1[j] IG: -0.36±8.28[j] P=0.049		
Penn, White et al., 2009	102 (51+51) Mean age (years) CG: 57.4 IG: 56.8 Overweight/IGT	3 months/ 60 months	Dietitian and physio-therapist	IG: advice from a dietitian and physiotherapist with some group sessions and a regular quarterly newsletter. CG: 'usual care' by their primary care physician.	12 Mo CG: 0.01[j] IG: -2.3[j] P=0.007			
Kang, Cho	125	3	Experien-	1-year IG: 5 times of	12 Mo			12 Mo

Reference[a]	Sample size, mean age, and diabetes risk criteria	Active & mainten -ance phases	Delivery Agent	Intervention description	Weight (kg)	FBG[b] (mg/dl)	2-h BG[c] (mg/dl)	HbA1c[d] (%)
et al., 2010	(25+25+75) Mean age (years) CG: 47.47 ±5.79 1-year IG: 45.61 ±6.06 2-year IG: 45.84 ±5.17 FPG ≥5.6 mmol	months/ 24 months	ced staff and dietitian	20-30 min of face-to-face counseling based on the participant's health profiles. 2-year IG: same as the 1-year IG, but lasts for 2 years CG: general information on health at baseline	CG: -0.27±2.13[j] IG: -0.32±1.36 [j] 24 Mo CG: -0.27±2.13[j] -0.86±1.92 [j]			CG: 0.27±0.65[j] IG: -0.13±0.71[j] 24 Mo CG: 0.27±0.65[j] IG: -0.15±0.69[j]
Pimentel, Portero-Mclellan et al., 2010	51 (21+30) Mean age (years) CG: 59.8±9.2 IG: 51.7±14.5 Overweight/IGT	12 months / 0	Dietitian	IG: individual and group counselling with a team of nutritionists and written instructions. CG: no nutritional education	BL CG: 76±15 IG: 70.65±17 12 Mo CG: 76.2±16.2 p=0.43 IG: 68.2±17.6 p<0.00001	BL CG: 91.7±18.3 IG: 105±21.6 12 Mo CG: 90.2±28.9 p=0.72 IG: 90.8±14.2 p=0.03		BL CG: 6.5±1.8 IG: 6.7±1.8 12 Mo CG: 7±2 p=0.23 IG: 5.1±1.2 p=0.006
Moore, Hardie et al., 2011	274 (183+91) Mean age (years): 62.5 Family history of diabetes/IGT	6 months/ 0	General practitio-ner	IG: one pre-course individual session and six sessions over 6 months CG: a wait group for the HLC with	BL CG: 82.02±16.27 IG: 80.7±16.01 6 Mo CG:81.2	BL CG: 106.4±10.44 IG: 105.7±10.44 6 Mo	BL CG: 145.4±32.04 IG: 152.5±25.02 6 Mo	

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG**[b] **(mg/dl)**	**2-h BG**[c] **(mg/dl)**	**HbA1c**[d] **(%)**
				standard care.	±17.39 IG: 78.11 ±14.98	CG: 106.02±15.48 IG: 101.88±14.76	CG: 143.64±48.2 IG: 140.22±41.6	
Nilsen, Bakke et al., 2011	182 (93+89) Mean age (years) 46 FINDRISC-score[y] ≥ 9	6 months/ 18 months	Study physician	IG: a group-based program, one day each week for six weeks and a new gathering after 12 weeks. CG: usual care from general practitioner.	BL CG: 111.7±22 IG: 110.5±22 18 Mo CG: 108.7±23 p<0.001 IG: 108±20 P<0.001	BL CG: 99±14.4 IG: 100.8±14.4 18 Mo CG: 100.8±12.6 p=0.69 IG: 104.4±21.6 p=0.08		BL CG: 5.6±0.4 IG: 5.6 ±0.5 18 Mo CG: 5.6±0.4 p=0.11 IG: 5.6±0.5 p=0.29
Roumen, Feskens et al., 2011	147 (74+73) Mean age (years) CG: 58.8 ±8.4 IG: 55 ±6.5 IGT	12 months / 60 months	Research-er and/or dietitian	IG: dietary recommendations based on the Dutch guidelines for a healthy diet. CG: standard care.	BL CG: 84.08±12.06 IG: 86.83±13.24 12 Mo CG: 83.47±11.38 IG: 84.36±13.18	BL CG: 106.6±12.6 IG: 108.2±15.12 12 Mo CG: 106.9±11.52 IG: 107.3±15.8	BL CG: 158.4±37.62 IG: 159.3±36.18 12 Mo CG: 158.22±40.5 IG: 148.3±36.7	

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten -ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
Sakane, Sato et al., 2011	296 (150+146) Mean age (years) CG: 51± 6 IG: 51 ±7 IGT	6 months/ 36 months	Study nurse	IG: Four group sessions using slides, video tapes and a booklet with each session lasting two or three hours. CG: only one group session on prevention of diabetes at the baseline.	BL CG: 63.9±11.7 IG: 64.9±12.9 12 Mo CG: 63.1±11.7 IG: 63.5±12.9 P=0.023	BL CG: 109.8±9 IG: 106.2±9 12 Mo CG: 106.2±10.8 IG: 104.4±10.8 P=0.698	BL CG: 162±16.2 IG: 165.6±16.2 12 Mo CG: 149.4±36 IG: 144±37.8 P=0.083	
Salas-Salvadó, Bulló et al., 2011	418 (139+145+134) Age range: 55-80 Overweight/ Family history of premature cardiovascular disease	12 months / 48 months	Dietitian	IG1: MedDiets with extra virgin olive oil IG2: MedDiets with mixed nuts with personalized dietary advice by dietitian. CG: Low-fat control diet on cardiovascular and other chronic disease.	60 Mo IG1: -0.2±4.6[j] IG2: -0.6±4.2[j] CG: -0.6±4.3[j]			
Vermunt, Milder et al., 2012	925 (479+446) Age range (years) 40-70 FINDRISC-	6 months/ 0	General practition-er and dietitian	IG: 11 consultations of 20 min over 2.5 years alternatively with the nurse practitioner and the general practitioner.	6 Mo CG:-0.5±3.0[j] IG: -0.8±3.3[j] 18 Mo CG: -0.3±4.5[j] IG: -0.6±5.1[j]	6 Mo CG: -1.8±7.2[j] IG: -1.44±7.4[j] 18 Mo CG: -	6 Mo CG: -2.52±26.8[j] IG: -0.72±24.7[j] 18 Mo	

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
	score≥13			CG: oral and written information about T2D and healthy lifestyle.		1.44±8.28[j] IG: -0.09±7.38[j]	CG: 3.06±28.08[j] IG: 2.16±26.8[j]	
Admiraal, Vlaar et al., 2013	355 (177+158) Mean age (years) 44.9 ±10.1 IGT/IFG	6 months/ 6 months	Trained dietitians	IG: six to eight sessions in the first 6 months with two booster sessions in the next 6 months. CG: Two group sessions led by student dietitians.	12 Mo CG: 0.4±3.1[j] IG: -0.2±3.3[j] P=0.08	12 Mo CG: -9±14.4[j] IG: -9±16.2[j] P=0.66		12 Mo CG: 0±0.4[j] IG: 0±0.3[j] P=0.99
Sangeetha, Fatimah et al., 2013	62 (29+33) Mean age (years) CG: 31.5 ±4.5 IG: 30.9 ±4.3 History of gestational diabetes	6 months / 0	Research dietitian	IG: glycemic index (GI)-education, how to substitute high GI foods with low GI options. CG: conventional healthy dietary recommendation.	BL IG: 65.3±11.5 CG: 64.6±12.5 3 Mo IG: 64.6±11.5 CG: 64.7±12.6 6 Mo IG: 64±11.7 CG:64.5±13			

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten -ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
Telle-Hjellset, Raberg Kjollesdal et al., 2013	198 (101+97) Mean age (years) CG: 42 IG: 41 Metabolic syndrome	7 months/ 0	Research personnel	IG: six 2-hour educational sessions on the benefits of light physical activity CG: feedback on blood sugar levels with lifestyle advice in one single group session.			7 Mo CG: -3.96 (-9.9, 1.98) [j] IG: -9.54 (-15.12, -3.78) [j] P=0.186	7 Mo CG: 0.05 (-0.04, 0.15)[j] IG: 0.04 (0, 0.09)[j] P=0.878
Xu, Sun et al., 2013	88 (46+42) Mean age (years) IG: 60.35±9.8 CG: 56.55±8.6 BMI≥ 18.5 kg/m^2/fasting plasma glucose of 5.6-6.9 mmol/l	3 months/ 9 months	Study dietitian	IG: a daily meal replacement and intensive lifestyle intervention. CG: an educational lecture on balanced diet, regular exercise and how to control blood glucose.	12 Mo CG: -0.55±0.4[j] IG: -1.75±0.35[j] P=0.02	12 Mo CG: 6.84±1.62[j] IG: -2.16± 1.8[j] P=0.001	12 Mo CG: 15.3±15.48[j] IG: -22.32± 6.3[j] P=0.02	12 Mo CG: 0.07±0.08[j] IG: -0.12±0.04[j] P=0.02
Bhopal, Douglas et al., 2014	171(85+86) Mean age (years) CG: 52.2 ±10.3 IG: 52.8	3 months/ 36 months	Dietitian	IG: consultation with a dietitian throughout the study. Families had 15 visits from a dietitian over 3 years. CG:standardized	36 Mo -1.64 [u] (-2.83, -0.44) P=0.01	36 Mo -2.34[u] (-7.02, 2.34) P=0.3361	36 Mo -10.08 [u] (-23.76, 3.42) P=0.1428	

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten -ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG**[b] **(mg/dl)**	**2-h BG**[c] **(mg/dl)**	**HbA1c**[d] **(%)**
	±10.2 IGT/IFG			written and verbal advice.				
Parker, Byham-Gray et al., 2014	81 (43+38) Mean age (years) IG: 51.1 ±12.36 CG: 49.61 ±15.6 Overweight/IFG	3 months/ 3 months	RD	IG: medical nutrition therapy based on the American Diabetes Association Standards Medical Care by a registered dietitian nutritionist. CG: usual care		3 Mo IG: -1.66±17.16[j] CG: -1.97±17.67[j] P=0.94		
Dawes, Ashe et al., 2015	56(33+23) No mean age A1C is between 5.7% to 6.4%/ Fasting blood glucose is between 6.1 to 6.9 mmol/L/2-hour 75 g oral glucose is	6 months /0	Lifestyle change facilitators	IG: Facilitators made telephone calls twice per months for 6 months to aid the participants in forming attaining goals according to intervention manual. CG: Usual care was offered.	6 Mo IG:-3.4±3.1[j] CG: -0.3±1.8[j]			6 Mo IG: -0.07±0.21[j] CG: 0.03±0.24[j]

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG**[b] **(mg/dl)**	**2-h BG**[c] **(mg/dl)**	**HbA1c**[d] **(%)**
	between 7.8 to 11.0 mmol/l							
Schmiedel, Mayr et al., 2015	1092(530+562) Mean age (years): 57.5 ±11.3 FINDRISC-score ≥ 7	12 months / 0	Pharma-cists	IG: three individual counseling sessions and five group-based lectures lasted 75–90 min (program GLICEMIA). CG: Only assessment and information about health status was provided.	12 Mo IG:-1.52±3.84[j] CG: 0.11±3.58[j]			
Non-US studies with QED design								
Absetz, Valve et al., 2007	352 Mean age (years) Female: 58 ±4.3 Male : 59 ±3.7 The diabetes risk score ≥	12 months / 0	Public health nurses	Information on self-monitoring of behavior, goal setting and planning with group discussions facilitated by nurses or a physiotherapist.	BL Female: 86±13.2 Male: 100±18.1 12 Mo Female: 85.5±13.3 Male:	BL Female: 100.8±14.4 Male: 106.2±12.6 12 Mo Female: 102.6±12.6 Male:	BL Female: 117±30.6 Male: 124.2±32.4 12 Mo Female: 118.8±34.2 Male:	

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
	12				98.5±18.1	109.8±14.4	122.4±41.4	
Kilkkinen, Heistaro et al., 2007	248 Mean age (years) 57.4 The diabetes risk score ≥ 12	12 months / 0	Trained study nurses and dietitian	Six group counseling sessions of dietary and physical activity guidance facilitated by trained study nurses, a dietitian and a physiotherapist.	3 Mo -2.254[j] P=0.001	0.005[j,x] P<0.386		
Laatikainen, Dunbar et al., 2007	311 Mean age (years) 56.7 ±8.7 Diabetes Risk Score ≥12	8 months/ 4 months	Study nurses and dietitians	Six structured 90-minute group sessions over 8 months using the Health Action Process Approach.	3 Mo -2.38[j] (-2.79, -1.98) 12 Mo -2.52[j] (-3.19, -1.85)	3 Mo 0[j] (-1.26, 1.44) 12 Mo -2.52[j] (-3.6, -1.26)	12 Mo -10.44[j] (-14.2, -6.48)	
Botomino, Bruppacher et al., 2008	1370 Mean age (years) 59.9± 11 Overweight	3 months/ 12 months	Pharma-cists	IG: intensive individualized advices on weight reduction, nutrition habits and physical activity. CG: Standard interventions.	BL CG: 77.9±10.4 IG: 83.6±11.5 12 Mo CG: 76.8±10.6 p<0.001 IG: 81.2±11.5 p<0.001			

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten-ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
Absetz, Oldenburg et al., 2009	352 Mean age (years) Female: 58 ±4.3 Male : 59 ±3.7 Diabetes Risk Score ≥12	8 months/ 36 months	Public health nurses	Information on self-monitoring of behavior, goal setting and planning with group discussions facilitated by nurses or a physiotherapist.	36 Mo -0.5±2.1[j] P=0.002	36 Mo 0±14.4[j] P<0.001	36 Mo 1.8±34.2[j]	
Makrilakis, Liatis et al., 2010	191 Mean age (years) 56.3 ±10.8 FINDRISC-score ≥15	12 months / 0	RD	Six sessions held by a RD at the area of the participants' residence or work.	12 Mo 1±4.7[j] P=0.022			
Gilis-Januszewska, Szybinski et al., 2011	175 Middle-aged FINDRISC-score≥14	4 months/ 8 months	Trained nurses	10 group sessions on lifestyle changes, diet and physical activity education. Six telephone motivation sessions and two motivation letters were followed.	12 Mo 1.92±5.01 [j] P<0.05	12 Mo -1.98±12.96[j]	12 Mo -5.58±42.3[j]	

Reference[a]	**Sample size, mean age, and diabetes risk criteria**	**Active & mainten -ance phases**	**Delivery Agent**	**Intervention description**	**Weight (kg)**	**FBG[b] (mg/dl)**	**2-h BG[c] (mg/dl)**	**HbA1c[d] (%)**
Kontogianni, Liatis et al., 2012	112 (71+41) Mean age (years) 56.3±10.8 FINDRISC-score ≥9	12 months /0	RD	6 group-based sessions offered by a RD at the area of the participants' residence or work.	12 Mo Improved group (IG): -1.73±5.2 [j] p=0.007 Worsened group(WG): 0.24±4.0 [j] p=0.704	12 Mo IG: -3.41±12.7[j] p=0.027 WG: 4.13±38.8[j] p=0.505	12 Mo IG: -2.65±32.2[j] p=0.49 WG: 15.53±70.8[j] p=0.173	
Duijzer, Haveman-Nies et al., 2014	31 Mean age (years) 54.1 ±8.5 IFG	10 months /0	Dietitian	Tailored dietary advices during individual consultations and one group session.	10 Mo -3.5±5.4 [j] P=0.005	10 Mo 5.4±14.4[j] P=0.062		
Dunbar, Jayawardena et al., 2014	3114 Mean age (years) 61.3 ± 0.1 AUSDRISK-score [z] ≥ 12	8 months / 0	Trained facilitator	A group-course six-session intensive for 8-15 people followed by sixth intervention session at 8 months after the first session.	BL 86.5±0.3 8 Mo 84.2±0.3 P<0.001			
Weir, Johnson et al., 2014	45 Mean age (years) 58.6 ±8.2 Prediabetic	6 months/ 0	Dietitian	A 3-hour dietitian-led pre-diabetes education session on how to prevent or delay type 2 diabetes.	BMI (kg/m^2)[ǂ] BL: 31.6±6.7 3 Mo: 31.6±7.2 6 Mo: 31.0±6.9 P=0.798			

[a] Each study is identified by author and year.

[b] FBG=Fasting blood glucose

[c] 2-h BG=2-hour blood glucose
[d] HbA1c=Hemoglobin A1c
[e] RCT=Randomized control trial
[f] sample size of intervention group+ sample size of control group
[g] IG=Intervention group
[h] CG=Control group
[i] Mo=month
[j] Change in outcome over time.
[k] BMI=body mass index
[l] ADA score=American Diabetes Association (ADA) risk assessment score
[m] Percent change is reported in the study
[n] IVR=Interactive voice response
[o] Prediabetes is defined as fasting blood glucose between 100 to125 mg/dl
[p] BL= baseline
[q] Pound is converted to kilogram
[r] IGT=Impaired glucose tolerance
[s] RD=Registered dietitian
[t] CHW=Community health worker
[u] Between-group difference
[v] QED=Quasi-experimental design
[w] CHA=Community health advocates
[x] mmol/l is converted to mg/dl.
[y] FINDRISC=Finnish Diabetes Risk score
[z] AUSDRISK=The Australian diabetes risk tool
[ǂ] Only BMI is reported.

Supplementary Table 1.4. The effectiveness of lifestyle intervention including nutrition education for diabetes prevention: Mean difference (intervention group compared with control group) in outcomes by subgroups (delivery agent and delivery channel)

Outcome	**3 months**		**6 months**		**12 months**		**13-60 months**	
Delivery Agent								
	Dietitian	Non-dietitian	Dietitian	Non-dietitian	Dietitian	Non-dietitian	Dietitian	Non-dietitian
Weight	-3.46*** (-4.88, -2.03)[a]	-2.85*** (-4.13, -1.56)	-2.91** (-5.44, -0.38)	-2.14*** (-2.67, -1.61)	-1.90*** (-2.73, -1.06)	-2.23*** (-2.99, -1.46)	-1.47** (-2.36, -0.58)	-0.68**[b] (-1.20, -0.17)
FBG[c]	-2.12 (-4.78, 0.55)	-3.72*** (-4.85, -2.58)	-2.32[b,d] (-7.00, 2.36)	-4.59*** (-7.65, -1.54)	-2.84*** (-3.10, -2.58)	-1.57 (-3.20, 0.07)	-2.17** (-3.12, -1.23)	0.43[d] (-1.07, 1.94)
2-h BG[e]	-	-	-	-	-9.73 (-21.52, 2.06)	-2.98 (-7.42, 1.47)	-3.70***[b,d] (-7.14, -0.26)	0.73[d] (-3.07, 4.52)
HbA1c[f]	-	-0.13[d] (-0.67, 0.41)	-	0.00[b] (-0.01, 0.01)	-0.27*** (-0.47, -0.07)	-0.15 (-0.30, 0.01)	-0.23***[d] (-0.33, -0.12)	-
Delivery Channel								
	IP[g]	TECH[h]	IP	TECH	IP	TECH	IP	TECH
Weight	-3.30*** (-4.60, -1.99)	-2.83*** (-4.66, -1.00)	-2.41*** (-3.43, -1.39)	-2.83*** (-4.57, -1.09)	-1.89*** (-2.43, -1.35)	-2.69*** (-4.49, -0.90)	-1.17** (-1.95, -0.39)	-0.74[d] (-1.53, 0.05)
FBG	-3.11*** (-4.97, -1.24)	-2.28 (-7.68, 3.11)	-4.22*** (-6.89, -1.55)	-	-1.91 (-2.95, -0.87)	-3.89*** (-6.46, -1.32)	-2.01** (-3.54, -0.48)	-
2-h BG	-	-	-0.27 (-3.54, 3.00)	-	-6.83 (-17.18, 3.52)	-9.59[d] (-14.6, -4.62)	-2.77[b,d] (-7.14, 1.61)	-
HbA1c	-	-0.13[d] (-0.67, 0.41)	0.00 (-0.01, 0.01)	-	-0.14***[b,d] (-0.23, -0.04)	-	-0.17[d] (-0.37, 0.02)	-

[a] The 95% confidence intervals are in the parenthesis.
[b] Indicates that fixed-effect model was used to calculate the summary mean difference in outcomes.
[c] FBG=Fasting blood glucose
[d] The number of studies is less than 4.
[e] 2-h BG=2-hour blood glucose
[f] HbA1c=Hemoglobin A1c
[g] IP=In-person intervention
[h] TECH=Technology-delivered intervention with/without in-person contact.
*Statistical significance at 10% level

**Statistical significance at 5% level.
***Statistical significance at 1% level.
- Insufficient data for analysis

Supplementary Table 1.5. The effectiveness of lifestyle intervention including nutrition education for diabetes prevention: Effect sizes according to study design (randomized controlled trial [RCT] vs quasi-experimental design [QED]) and study location (in the United States [US] vs not in the United States [non-US]) over time, in the active intervention and overall (active+maintenance study phases)

Outcome	**3 months**		**6 months**		**12 months**		**13-60 months**	
Active Intervention Phase								
Study Design								
	RCT[a]	QED[b]	RCT	QED	RCT	QED	RCT	QED
Weight	-0.37*** (-0.64, -0.09)[c]	-0.2*** (-0.26, -0.14)	-1.02*** (-1.95, -0.08)	-0.07***[d] (-0.08, -0.07)	-0.45*** (-0.65, -0.26)	-0.04** (-0.08, -0.01)	-	-
FBG[e]	-0.33*** (-0.55, -0.11)	-0.22*** (-0.41, -0.03)	-0.86 (-2.37, 0.65)	-	-0.87 (-1.82, 0.08)	0.05 (-0.17, 0.28)	-	-
2-h BG[f]	-	-	-0.03 (-0.14, 0.09)	-	-2.17 (-5.45, 1.11)	0.02 (-0.05, 0.1)	-	-
HbA1c[g]	-0.11[h] (-0.84, 1.07)	-	-0.16 (-0.37, 0.04)	-	-0.69[d, h] (-1.52, 0.14)	-	-	-
Study Location								
	US	NON-US	US	NON-US	US	NON-US	US	NON-US
Weight	-0.24*** (-0.29, -0.18)	-0.19*** (-0.32, -0.07)	-1.21*** (-2.56, 0.13)	-0.39*** (-0.6, -0.17)	-0.19*** (-0.28, -0.09)	-0.07*** (-0.09, -0.05)	-	-
FBG	-0.35*** (-0.51, -0.2)	0.03 (-0.05, 0.11)	-1.28 (-3.93, 1.36)	-0.2 (-0.51, 0.11)	-	-0.35 (-0.78, 0.08)	-	-
2-h BG	-	-	-	-0.03 (-0.14, 0.09)	-	-0.95 (-2.06, 0.16)	-	-
HbA1c	-0.61**[d] (-0.77, -0.46)	-	-0.22[d,h] (-0.55, 0.11)	-0.13[d,h] (-0.39, 0.13)	-	-0.69[d,h] (-1.52, 0.14)	-	-
Overall Intervention Phase								
Study Design								
	RCT	QED	RCT	QED	RCT	QED	RCT	QED
Weight	-0.37***[d] (-0.64, -0.09)	-0.2*** (-0.25, -0.14)	-0.93*** (-1.61, -0.24)	-0.07*** (-0.08, -0.07)	-0.45*** (-0.58, -	-0.13*** (-0.19, -	-0.18*** (-0.36, -0.01)	-

Outcome	**3 months**		**6 months**		**12 months**		**13-60 months**	
					0.32)	0.07)		
FBG	-0.33***[d] (-0.55, -0.11)	-0.25** (-0.44, -0.06)	-0.86 (-2.37, 0.65)	-1.21***[h] (-1.96, -0.47)	-0.53*** (-0.89, -0.17)	-0.11 (-0.29, 0.06)	-0.15***[d] (-0.23, -0.07)	-
2-h BG	-	-	-0.03 [h] (-0.14, 0.09)	-	-1.25 (-2.82, 0.32)	0.02 (-0.03, 0.08)	-0.13*** (-0.22, -0.04)	-
HbA1c	-0.11 (-0.84, 1.07)	-	-0.16 [h] (-0.37, 0.04)	-	-0.4*** (-0.62, -0.18)	-	-0.29 (-0.59, 0.01)	-
Study Location								
	US	NON-US	US	NON-US	US	NON-US	US	NON-US
Weight	-0.24*** (-0.29, -0.18)	-0.18*** (-0.28, -0.09)	-0.85*** (-1.3, -0.4)	-0.21*** (-0.3, -0.13)	-0.34*** (-0.48, -0.21)	-0.23*** (-0.29, -0.17)	-0.49*** (-0.74, -0.24)	-0.05*** (-0.17, 0.07)
FBG	-0.37*** (-0.52, -0.23)	0.03h [h] (-0.05, 0.11)	-1.29 (-3.47, 0.88)	-0.2 (-0.51, 0.11)	-0.37*** (-0.57, -0.17)	-0.28*** (-0.54, -0.03)	-	-0.09**[h] (-0.16, -0.02)
2-h BG	-0.20 [h] (-0.96, 0.55)	-	-	-0.03 [d,h] (-0.14, 0.09)	-0.22 [d,h] (-0.68, 0.23)	-0.68*** (-1.32, -0.04)	-	-0.06 [h] (-0.14, 0.01)
HbA1c	-0.61** (-0.77, -0.46)	-	-0.22 [h] (-0.55, 0.11)	-0.13 [h] (-0.39, 0.13)	-0.15*** (-0.20, -0.10)	-0.44** (-0.74, -0.13)	-	-0.28 [h] (-0.43, 0.13)

[a] RCT=Randomized control trial
[b] QED=Quasi-experimental design
[c] The 95% confidence intervals are in the parenthesis.
[d] Indicates that fixed-effect model was used to calculate the summary mean difference in outcomes.
[e] FBG=fasting blood glucose
[f] 2-h BG=2-hour blood glucose
[g] HbA1c=hemoglobin A1c

[h] The number of studies is less than 4.
[*]Statistical significance at 10% level
[**]Statistical significance at 5% level.
[***]Statistical significance at 1% level.
- Insufficient data for meta-analysis

Chapter 1.

Supplementary Table 1.6. The effectiveness of lifestyle intervention including nutrition education for diabetes prevention: Mean difference (intervention group compared with control group) in outcomes by subgroups (design and locations

Outcome	**3 months**		**6 months**		**12 months**		**13-60 months**	
Design								
	RCT[a]	QED[b]	RCT	QED	RCT	QED	RCT	QED
Weight	-1.74***	-3.98***	-2.66***	-2.38***	-1.89***	-2.38***	-1.21***	-
	(-3.06, -0.41)[c]	(-5.21, -2.75)	(-4.02, -1.31)	(-2.54, -2.22)	(-2.52, -1.26)	(-3.46, -1.30)	(-1.97, -0.46)	
FBG[d]	-4.39***[e,f]	-2.72***	-3.32***	-4.41**[e]	-3.22***	-1.36	-2.04**	-
	(-6.93, -1.85)	(-4.60, -0.84)	(-6.11, -0.54)	(-6.28, -2.53)	(-4.55, -1.88)	(-3.23, 0.52)	(-3.78, -0.30)	
2-h BG[g]	-	-	-0.27[e]	-	-14.05***[e]	1.02[e, f]	-3.88***[e]	-
			(-3.54, 3.00)		(-22.74, -5.37)	(-1.00, 3.04)	(-7.13, -0.64)	
HbA1c[h]	-0.03**[e]	-	0.00	-	-0.14	-	-0.17[e]	-
	(-0.46, -0.40)		(-0.01, 0.01)		(-0.23, -0.04)		(-0.37, 0.02)	
Location								
	US	Non-US	US	Non-US	US	Non-US	US	Non-US
Weight	-3.55***	-1.84***	-3.06***	-1.82***	-2.79***	-1.58***	-3.41***	-0.55***
	(-4.72, -2.38)	(-2.47, -1.22)	(-4.60, -1.53)	(-2.57, -1.06)	(-3.98, -1.60)	(-2.04, -1.12)	(-4.34, -2.48)	(-1.07, -0.03)
FBG	-3.65***	0.05[e,f]	-4.50***	-2.48[e,f]	-3.16***	-1.76***	-	-1.01**[f]
	(-4.83, -2.48)	(-0.06, 0.17)	(-7.64, -1.36)	(-6.24 1.29)	(-5.00, -1.31)	(-3.30, -0.22)		(-1.87, -0.15)
2-h BG	-	-	-	-0.27[e,f]	-8.00 [e, f]	-19.96**	-	-1.70[f]
				(-3.54, 3.00	(-24.40, 8.40)	(-20.88, -19.05)		(-4.25, 0.85)
HbA1c	-0.18[e]	-	-0.52[e]	-0.05[e,f]	-0.17***	-0.26***	-	-0.17[e]
	(-0.61, 0.25)		(-0.19, 0.08)	(-0.13, 0.03)	(-0.32, -0.01)	(-0.47, -0.04)		(-0.37, 0.02)

[a] RCT=Randomized control trial

[b] QED=Quasi-experimental design

[c] The 95% confidence intervals are in the parenthesis.

[d] FBG=Fasting plasma glucose

[e] The number of studies is less than 4.

[f] Indicates that fixed-effect model was used to calculate the summary mean difference in outcomes.

[g] 2-h BG=2-hour blood glucose

[h] HbA1c=Hemoglobin A1c

*Statistical significance at 10% level
**Statistical significance at 5% level.
***Statistical significance at 1% level.
- Insufficient data for analysis

Supplementary Table 1.7. The effectiveness of lifestyle intervention including nutrition education for diabetes prevention: Study quality rating results [a]

Reference	**Relevance Questions[b]**	**Validity Questions[c]**										**Quality**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Tate, Jackvony et al. 2003,	Yes	Yes	Yes	Yes	Yes	Unc[d]	Yes	Yes	Yes	Yes	Yes	+[e]
Davis-Smith, Boltri et al. 2007,	Yes	Yes	unc	No	Yes	No	Yes	unc	unc	Yes	Yes	0[f]
Ackermann, Finch et al. 2008,	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	Yes	+
Boltri, Davis-Smith et al. 2008,	Yes	Yes	unc	No	No	Yes	Yes	Yes	Yes	Yes	Yes	0
Estabrooks and Smith-Ray 2008,	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Amundson, Butcher et al. 2009	Yes	Yes	Yes	N/A[g]	unc	unc	Yes	Yes	Yes	Yes	unc	0
Almeida, Shetterly et al. 2010,	Yes	Yes	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	Yes	+
Faridi, Shuval et al. 2010,	Yes	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	Yes	Yes	+
Kramer, Kriska et al. 2010,	Yes	Yes	Yes	No	Yes	unc	Yes	Yes	unc	Yes	Yes	+
Parikh, Simon et al. 2010,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+
Vadheim, McPherson et al. 2010,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	+
Katula, Vitolins et al. 2011,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+
Kramer, McWilliams et al. 2011,	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+
Rosal, Lemon et al. 2011,	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+
Ruggiero, Oros et al. 2011,	Yes	Yes	Yes	unc	unc	Yes	Yes	Yes	unc	Yes	Yes	+
Kanaya, Santoyo-Olsson et al. 2012,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+
Benyshek, Chino et al. 2013,	Yes	unc	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	0
Cole, Boyer et al. 2013,	Yes	Yes	unc	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Islam, Zanowiak et al. 2013,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	+
Katula, Vitolins et al. 2013,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+
Ma, Yank et al. 2013,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+
Xiao, Yank et al. 2013,	Yes	Yes	Yes	unc	Yes	Yes	Yes	unc	Yes	Yes	Yes	+
Ackermann, Sandy et al. 2014,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+

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Reference	Relevance Questions[b]	Validity Questions[c] 1	2	3	4	5	6	7	8	9	10	Quality
Cha, Kim et al. 2014,	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	0
Islam, Zanowiak et al. 2014,	Yes	Yes	Yes	unc	unc	unc	Yes	Yes	unc	Yes	Yes	0
Kaholokula, Wilson et al. 2014,	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	+
Sepah, Jiang et al. 2014,	Yes	Yes	No	No	unc	unc	Yes	unc	Yes	Yes	unc	0
Tang, Nwankwo et al. 2014	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+
Brokaw, Carpenedo et al. 2015	Yes	Yes	Yes	N/A	Yes	Yes	Yes	unc	Yes	Yes	Yes	+
Fukuoka, Gay et al. 2015	Yes	Yes	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	+
Yeh, Heo et al. 2015	Yes	Yes	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	+
Eriksson and Lindgärde 1991	Yes	Yes	No	Yes	Yes	unc	Yes	unc	unc	unc	unc	0
Eriksson, Lindström et al. 1999	Yes	Yes	Yes	Yes	Yes	unc	Yes	unc	Yes	unc	unc	+
Wein, Beischer et al. 1999	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	unc	Yes	unc	0
Tuomilehto, Lindström et al. 2001	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	Yes	Yes	unc	+
Lindstrom, Louheranta et al. 2003	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	unc	Yes	unc	+
Watanabe, Yamaoka et al. 2003	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	unc	+
Kosaka, Noda et al. 2005	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	unc	+
Lindström, Ilanne-Parikka et al. 2006	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	Yes	Yes	Yes	+
Oldroyd, Unwin et al. 2006	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	Yes	Yes	unc	+
Absetz, Valve et al. 2007	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	unc	+
Kilkkinen, Heistaro et al. 2007	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	unc	Yes	unc	+
Laatikainen, Dunbar et al. 2007	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	unc	unc	Yes	+
Barclay, Procter et al. 2008	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	unc	Yes	Yes	+
Botomino, Bruppacher et al. 2008	Yes	Yes	Yes	Yes	unc	unc	Yes	Yes	Yes	Yes	unc	+
Absetz, Oldenburg et al. 2009	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	unc	Yes	+
Penn, White et al. 2009	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	unc	unc	+
Kang, Cho et al. 2010	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	+

Reference	Relevance Questions[b]	Validity Questions[c] 1	2	3	4	5	6	7	8	9	10	Quality
Makrilakis, Liatis et al. 2010	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Pimentel, Portero-Mclellan et al. 2010	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Gilis-Januszewska, Szybinski et al. 2011	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	unc	unc	unc	0
Moore, Hardie et al. 2011	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	Yes	unc	+
Nilsen, Bakke et al. 2011	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Roumen, Feskens et al. 2011	Yes	Yes	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	+
Sakane, Sato et al. 2011	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Salas-Salvadó, Bulló et al. 2011	Yes	Yes	Yes	Yes	unc	No	Yes	Yes	Yes	Yes	Yes	+
Kontogianni, Liatis et al. 2012	Yes	Yes	Yes	unc	unc	unc	Yes	Yes	Yes	Yes	Yes	+
Vermunt, Milder et al. 2012	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	unc	unc	+
Admiraal, Vlaar et al. 2013	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Sangeetha, Fatimah et al. 2013	Yes	Yes	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	+
Telle-Hjellset, Raberg Kjollesdal et al. 2013	Yes	Yes	Yes	Yes	Yes	unc	Yes	Yes	unc	Yes	Yes	+
Xu, Sun et al. 2013	Yes	Yes	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	+
Bhopal, Douglas et al. 2014	Yes	Yes	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	+
Duijzer, Haveman-Nies et al. 2014	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Dunbar, Jayawardena et al. 2014	Yes	Yes	Yes	unc	Yes	unc	Yes	unc	Yes	unc	Yes	0
Parker, Byham-Gray et al. 2014	Yes	Yes	Yes	Yes	Yes	unc	Yes	unc	unc	unc	Yes	0
Weir, Johnson et al. 2014	Yes	Yes	Yes	unc	Yes	unc	Yes	unc	Yes	Yes	Yes	+
Dawes, Ashe et al. 2015	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	Yes	Yes	+
Schmiedel, Mayr et al. 2015	Yes	Yes	Yes	Yes	Yes	unc	Yes	unc	Yes	Yes	Yes	+

[a] Kappa statistic (a measure of interrater reliability score) is 0.67, indicating substantial amount of agreement between the two raters. Results from one rater are reported in this table.

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[b]Four relevance questions (eg, “Is the intervention or procedure feasible?”) are included in the Quality Criteria Checklist. Available at: https://www.uwgb.edu/laceyk/NutSci486/EA%20Quality%20Criteria%20Checklists.doc.
[c]Ten validity questions (eg, “Was the research question clearly stated?” and “Were study groups comparable?”) are included in the Quality Criteria Checklist. Available at: https://www.uwgb.edu/laceyk/NutSci486/EA%20Quality%20Criteria%20Checklists.doc.
[d] Unc=unclear.
[e] +=Positive: Indicates that the report has clearly addressed issues of inclusion/exclusion, bias, generalizability, and data collection and analysis.
0 =Neutral: Indicates that the report is neither exceptionally strong nor exceptionally weak.
[g] NA=not available

CHAPTER 2.

Household Relative-Deprivation Effects on Child Health in China

2.1. Introduction

China has reached the fastest rate of growth in economy since the implementation of reform and become the world's second largest economy [1]. Despite the past three decades of sustained economic growth, it lags behind other countries on many health indicators. For instance, its total health spending is only 5.6% of GDP , which is less than 10.3% in Japan and 17.1% in the U.S. [2]. Its health system ranks 144 among a total of 190 countries according to World Health Organization Ranking [3]. Its mortality rate is 11 per 1000 live births which is still much higher than 2 in Japan and 6 in the U.S. [4]. About 6.9 million children under the age of five died in the world. Almost 60% of under-five deaths of children in the world (total number of children under the age of five died in the world was 6.9 million in 2011) occur in China alone [5]. Meantime, childhood obesity, psychological and behavioral problems have been becoming increasingly prominent as well as major threats to child health like preterm birth and low birth weight, childhood obesity and injuries in China [5]. Improvement in health fails to accompany the massive growth in material living standards for the Chinese population.

Potential explanations for the unfavorable development in health in a fast-growing economy include the income inequality hypothesis and relative deprivation hypothesis[6-10]. China is a representative case for study because it has experienced rising income inequality and widening socioeconomic differences[11-13]. Through the transition after the big leap in economy, the distribution of wealth in China is a highly skewed one for more inequality [14]. The Gini index of income inequality skyrockets from 0.28 in 1990s to 0.47 in 2014, with highest estimate of 0.49 in 2008 [15,16]. They are above the warning level of 0.4 set by the United Nations, indicating that the gap between the rich and the poor is serious and urgent need for income distribution reform to narrow the wealth gap [16]. Income inequality has been evidenced to be linked to poorer health status by previous studies[7,10,17-20]. For example, Wilkinson finds a strong and large correlation between the income inequality and life expectancies. He argues that inequality itself has hazardous effect on health [21]. Li et.al. finds that high inequality in a community poses hazards to health using survey data from China [6]. One mechanism underlying the relation between income inequality and health is the negative psychosocial effects of relative deprivation

[21]. The hypothesis states that an individual is adversely affected when he/she feels economically deprived as compared to peers in his/her reference group, suggesting that a person's health is a function of his own income as well as the incomes of others [22]. A number of empirical studies have found relative deprivation to be an important predictor of health outcomes in developed countries[23-25]. In addition, emerging studies have attempted to identify the relation between relative deprivation and health outcomes in developing economies [26], and several studies have focused on the effects in China [6,27-30]. While several studies have investigated the association between relative deprivation and child health[31-34], we are not aware of any research studying this relationship in China. Understanding whether and how relative deprivation affects children's health may provide valuable information for designing proper policies and treatments.

The purpose of this study is to investigate the association between relative deprivation and health outcome among children in China using data collected from China Health and Nutrition Survey. We hypothesize that being relatively deprived has an adverse effect on children's health in China. The structure of this study is organized as following: Section 2 presents a literature review of relative deprivation and health. Section 3 summarizes the relative deprivation measurement issues used in current literature and describes our methods of measures. Section 4 describes the mechanisms to select reference groups. Section 5 describes a two-stage integrated model and Section 6 describes the data. Estimation results are displayed in Section 7 and discussions are included in section 8.

2.2. A review of relative deprivation and health

Absolute income hypothesis posits that higher income leads to better health outcomes. Some early evidence have shown that higher incomes protect health. Kitigawa et al., for example, found that white males with higher incomes were less likely to die than those with lower incomes [35]. Rogot et al. found that people aged 25 or older with family income below $50000 were more likely to have lower life expectancy than those with family income above $50000 [36]. However, absolute income hypothesis could not explain why American mortality rate was higher than many poorer countries despite the United States was much richer in absolute income level [8]. Wilkinson found that absolute income levels were no longer vital to mortality in the United States because the correlation coefficient for the association between mortality and median income level dropped to -0.06 when distribution of income within each state was controlled for [21]. Hence, Wilkinson pointed out that income distribution played an important role in health inequality[8,37,38]. Kaplan reported that income inequality was significantly associated with mortalities, rate of low birth weight and sedentary activities [39]. Several mechanisms have been proposed to explain the link between income inequality and health, including disinvestment in human capital, erosion of social capital and social comparison [40]. Social comparison indicates that health is affected by direct psychosocial effects of comparison, which is known as relative deprivation hypothesis.

The relative income and relative deprivation hypothesis are two different names for the same hypothesis. This idea was first perceived by economists centuries ago. Adam Smith (1776) pointed out that people who failed to consume in accordance to a reference group's normative consumption level might feel shameful and socially disgraceful. Stouffer et al. found that feelings of relatively deprived were formed when soldiers comparing themselves with those having different opportunities for promotion [41]. The relative deprivation hypothesis is rooted in the fact that people compare themselves with other individuals [42] or their circumstances in relation to a set of objective circumstances [43].

There are a number of considerable evidences for the impact of relative deprivation on health outcomes for adults in developed countries and empirical results are mixed among studies using different surveys. Self-reported/self-assessed health is a common measure for individual health status and is often reported to be negatively related to relative deprivation. Most of these studies use cross-sectional data on different samples, such as a Dutch cohort of 15-74 years old people [44], a sample of 25-46 years adults from the Swedish Survey of Living [24], a sample of individuals aged 25-64 [45] and persons aged 18 or more living in the U.S. [23]. Jones et al. used a panel data including 11 waves of data from the British Household Panel Survey and provided evidence in favor of a negative association between relative deprivation and self-assessed health [46]. Eibner and Evans found that high relative deprivation was associated with poor self-reported health as well as higher probability of death and high blood pressure or disabilities using data from

National Health Interview Survey. They also found relative deprivation was linked to a host of poor health habits, such as smoking, not wearing safety belts, high body mass index and little exercising [22]. While other studies reported positive or no effect of relative deprivation on health outcomes. For example, Deaton et al found a protective effect of income inequality on mortality by investigating Current Population Survey from 1975 to 1995 [47]. Mellor et al. find little support for the relative deprivation effect on health using Current Population Survey (CPS) [48].

Several studies began to extend the research of relative deprivation to developing countries. Cojocaru investigated that if relative deprivation determined well-being using data from the United Nations Development Program in six countries and reported that relative deprivation had a strong negative effect on subjective satisfaction [26]. Chen et al. found that relative income was related to obesity and hypertension among rural adults aged 20 and older in the China Health and Nutrition Surveys [27]. Ling used the same survey but found that an increase in relative deprivation level reduced the probability of being overweight for older adults in China. The results also indicated that those less relatively deprived were not necessarily healthier than those more relatively deprived [30].

Very limited research have studied the relationship between relative deprivation and health outcomes among children. Drukker et al. found that socioeconomic deprivation was associated with children's general health and satisfaction [49]. Lhila investigated that if a mother's relative deprivation was related to infant health and reported that pregnant women with lower socioeconomic status gave birth to slightly lighter babies [32]. Charlton et al. proved that adolescents who lived in more deprived neighborhoods tend to be inactive [50]. Elgar et al. used data on 11-15-year adolescents to find that having better off schoolmates can contribute to poorer health behaviors [31]. Also, neighborhood poverty and socio-economic deprivation was reported to have negative effects on children's mental health [51].However, the health outcomes of relative deprivation among children has not been thoroughly studied in China. The effect of relative deprivation on children's health is important for policy makers because the number of Chinese children is expected to grow after the end of one child policy and level of income equality is growing high. China's National Statistics Bureau reported that 16 million new children were born annually from 2003 to 2013. This number rises to 17.86 million in 2016 when the two-child policy is expanded.[52]

Several critics have been raised about the conflicting results among existing literature. Concerns include lack of individual-level data, omission of important variables and selection bias. Aggregate data may suffer spurious correlation problems. When aggregate-level study reveal a positive relationship between income inequality and mortality, the individual-level study may not show a relationship between the two [53]. Omission of important variables is mainly due to lack of data on socioeconomic or health related information. Education, for instance, is not included in several inequality studies [19,39]. Selection bias occurs because of unobserved factors such as characteristics of the same region [22] and true reference group for an individual. This study contributes to the literature by focusing on relative deprivation and health outcomes in the following aspects. First, this paper focuses the attention on child health outcomes in China. To our knowledge, this study is the first one to explore the effect of relative deprivation on child health in China. Second, we take up the challenge of examining the mechanism of relative deprivation effects on both parents' and children's health outcomes. We have modified an integrated two-stage collective household production model that is designed to depict parent-child interaction developed by You and Davis (2010). We incorporate relative deprivation into children and parents' health production functions. Through the structure model we are able to identify the direct and indirect effect of household level income deprivation has on children's health outcome. We use individual-level information from CHNS, which is rich in household and individual characteristics and health-related information. The findings of this paper can inform a better evaluation on policies related to reducing income inequality since it will inform the spillover effect to children's health which is important not only for short-term social health care cost burden relieve but also important for longer-term public health and social welfare improvement.

2.3. Relative deprivation measurement and reference group

In evaluating the link between relative deprivation and health, special attention is given to the measurement of relative deprivation. The empirical investigations have used a variety of definitions and measures of relative deprivation. Most of the literature use the level of relative income as a measurements of relative deprivation. However, other measurements like affluence scores and self-reported feelings of relative deprivation are utilized in the literature as well.

2.3.1 Yitzhaki index

The most commonly used measurement for relative deprivation is the Yitzhaki Index. In 1979, Yitzhaki developed a mathematical operationalization of relative deprivation based on Runciman's definition. Runciman (1966, page11) defined relative deprivation as "A person is relatively deprived of X by the following four qualifications (1) he does not have X, (2) he sees some other person or persons, which may include himself at some previous or expected time, as having X, (3) he wants X, and (4) he sees it as feasible that he should have X".

Yitzhaki proposed income as the object of relative deprivation because income can be viewed as a measure of the individual's ability to consume commodities [54]. The degree of relative deprivation is measured by the following relative deprivation function of person i with income I_i :

$$D(I_i) = \int_{I_i}^{I^*} [1 - F(z)]dz \tag{2.1}$$

where I^* is the highest income in the reference group. $F(z)$ is the cumulative income distribution. Yitzhaki Index measures the degree of relative deprivation by summing up income distance, and at the societal level it equals to the Gini coefficient multiplied by the mean income which is the absolute Gini index [54]. The absolute Gini index [55] indicates that with same average income level the more unequal a society is the higher the degree of relative deprivation. It also implies that greater mean income leads to higher level of relative deprivation with Gini coefficient being equal.

Most of the studies that used Yitzhaki index as a measurement of relative deprivation are based upon different types of incomes: individual-level income [22,23], household income [23,45,56]. A few studies use the Family Affluence Score (FAS) as a basis to calculate the Yitzhaki Index. FAS is initially a four-item index of material assets or common indicators of wealth such as car ownership and number of computers [57]. It is updated to six-item by adding two more items: bathrooms and dishwasher [58]. Elgar et al. define relative deprivation of an individual with affluence score of x_i as [59]:

$$RD_i = \frac{1}{N}\sum_j (x_j - x_i), \quad \forall (x_j > x_i) \tag{2.2}$$

where N is the number of individuals in a reference group. The Yitzhaki Index is not sensitive to different income scale and leads to a problem in some cases [22]. In use of Yitzhaki Index, for example, doubling in income for everyone in a reference group leads to relative deprivation double. This would be problematic when examining relative deprivation over time or across different groups [22,32].

2.3.2 Deaton Index

Deaton Index overcomes the problem of income scale in using the Yitzhaki Index [60] and extends it by dividing by the mean income of the reference group as follows [61]:

$$DRD_i = \frac{1}{\mu N}\sum_j (I_j - I_i) \qquad \text{for all } I_j > I_i \tag{2.3}$$

Where μ is the average income of reference group and N is the number of individuals in a reference group. Deaton Index assumes that the proportion of total income earned by people with higher income in the reference group matters in the determination of degree of relative deprivation.

Different from Yitzhaki Index, change in income below an individual's income will affect his or her level of relative deprivation when using Deaton Index. Several studies have used Deaton Index directly or in a different way [22,30,32,56]. Eibner and Evans use the Deaton index differently for they use the individual i's own income instead of the mean income of the reference group and they argue this index is sensitive to changes in the income distribution for individuals with less income [22].

2.3.3 Income distribution and rank-based measures

Measures related to income distributions in studies include income quartiles [23,30,56], coefficient of income variations [27] and Gini coefficient[30]. Dichotomous relative deprivation variable is rare but used in one study. Yngwe et al. defines a person to be relatively deprived as having an income below 70% of the mean level in the reference group [24]. Turley uses percentile rank (Ri) as a measure of relative economic standing. Percentile rank is defined as the ratio of families in the neighborhood with lower incomes than the individual to the total number of families in the neighborhood, indicating that people at higher ranking have higher values of Ri [34]. Another measurement of relative deprivation is based upon rank, where socioeconomic positions matters, such as standard of living [44].

One feature shared by the above indexes is that the relative deprivation is constructed by the researchers instead of self-reported measurement. These measures are problematic because they may not be perceived to be relevant by the individual. For example, if an individual doesn't realize that the neighbors are better off, he may not feel relatively deprived. Wilkinson has argued that subjective perceptions of relative ranking may be more important than income in the determination of health [9,62]. Also, subjective index is found to be more strongly related to self-rated health status relative to objective index [63]. Subjective socioeconomic status (SES) rank is one of these type of indexes. Respondents were given a question as follows: "Think of a ladder of with 10 rungs as representing where people stand in the society. At the top of the ladder are the people who are the best off, who have the most money, most education, and best jobs. At the bottom are the people who are the worst off, those who have the least money, least education, and worst jobs or no job. Please place an X on the rung that best represents where you stand on the ladder." Adler et.al. argue that this one-item indicator is related to physiological and psychological functioning by increasing stress or the vulnerability to stress [63].

Another type of subjective index is self-reported level of relative deprivation compared to certain reference groups. In a study using data from United Nations Development Program, respondents are asked to evaluate if their standard of living is better, same or worse compared to that of the majority of people in their settlement, district of residence or country of residence, they are also asked if their parent and grandparents have a higher/same/lower position in society when they are the same age as the respondent [26]. Manyo and Park use a similar index by asking the respondents to compare themselves with three non-geographical reference groups (relatives, classmates and coworkers) and four geographical reference groups (neighbors, people living in county or city, province and nation) [64].

Though subjective measurements are useful, information on subjective evaluation of relative deprivation is often unavailable in many surveys. In our study, self-reported measure is not available in CHNS. So we will use Yitzhaki Index and Deaton Index based on household income. First, information of income is rich in CHNS and can be used to evaluate the ability of household members to consume. Second, most of the literature have employed those two indicators, making comparisons between their results and ours reasonable. Further, we select income rank as a third measurement of relative deprivation because Elgar et al. have concluded that socioeconomic status impacted adolescents' health through the psychosocial impact of relative deprivation and social rank [59].

2.4. Reference Group

2.4.1 Reference group used in the literature

When measuring the level of relative deprivation, it is a challenge to determine the ways in which the concept of reference group should be used. Because the true reference group is unknown and there is no best definition of reference group in the literature to date. Instead, the researchers have to select a reference group according to previous studies and data constraints.

Reference groups based on geographic proximity are common in the literature. For instance, national-level reference group is defined that the whole country constitutes a reference group and individuals compare with every other individual in the society [9,46]. State/area-level reference group is defined as the state/area of residence as a reference group[23,32,61]. Neighbor-level reference group consists of neighbors of an individual. For example, Turley defines a child's reference group as his/her neighbors and argues that neighborhoods probably provide many of a child's reference group members because children typically attend neighborhood-based schools [34].

Reference groups defined by individual characteristics are also in use in the research. Ling defines reference group as those in the peer groups [30]. Multiple reference groups based upon a combination of different characteristics are not rare in the literature. Eibner et al. use reference groups that are defined in four different ways based on combination of state, age-group, race and education [22]. Yngwe et al. define 40 reference groups combining indicators of social class, age and living regions [24]. Kondo et al. construct reference groups using a combination of occupation, age and geographic area [45]. Cojocaru uses both the local reference groups (e.g. town, district, country) and reference groups based on likeness (e.g. parents and grandparents) [26].

2.4.2 Summary of the literature using different reference groups

Reference groups based upon geographic proximity and combination of different characteristics are popular in research for adults. However, the effects of different reference groups are various. Cojocaru compares the effects of different reference groups and finds that local reference groups are easier to be observed than other levels of geographic proximity. It is found that the proportion of respondents who are unable to compare their standard of living with their grandparents is high, indicating that making a comparison with grandparents is more difficult than with parents. And the effects are greater for grandparents than that for parents [26]. Manyo and Park find that former classmates and relatives are salient reference groups for urban residents and geographic reference groups for rural residents [64]. Eibner and Evans notice that the effects of relative deprivation varies as the definition of reference group changes. For example, the results show that relative deprivation increases the probability of wearing seatbelt when defining state as a reference group. However, the effects become negative and statistically significant when using reference group defined with state/age, state/age/race and state/age/race/education [22].

Information of social relationships like classmates or relatives cannot be identified in the CHNS. However, location information like community/village and other characteristics are provided in CHNS. We will model multiple reference groups and check all their effects on health outcomes. We construct reference groups based on the following combinations of geographic proximity and demographic characteristics. Reference groups are defined as: 1) province, 2) community/village, 3) age and community/village, 4) age, community/village and gender.

2.5. Model

2.5.1 Theoretical model

In this section, we propose a collective household production model to investigate the effect of relative deprivation on child health according to the model developed by You and Davis [65]. This model is based on the following facts: (1) health production depends on not only generic factors but also a set of health-related inputs such as food and exercise for both parents and child; (2) the child's choice sets of goods and time are constrained by the parents' choices on household resource allocation. The first component is elaborated through a collective household model and the second component is captured by imposing a two-stage Stackelberg game structure where the parents are leaders and child is the follower.

2.5.1.1 Child's Optimization Problem

The child's health outcome (H_c) is based on the amount of food consumption (x_f^c) and time for exercise (t_{ex}^c). This health production process is conditional on four exogenous factors: (1) child's food consumption is limited by the quantity of food provided by the parents (X_f^i); (2) The quality of food plays an important role in the production of child health and is measured by parents' time for food preparation and process (T_f^i); (3) the production efficiency is affected by child biological and genetic factors like age and gender (k); (4) home environmental factors E_h may impact child's health. The home/family environment has been proved to be a critical factor in the development of childhood obesity [66,67]. Evidence shows that childhood family adversity exerts negative long-term physical health outcomes [68]. The child health production function is therefore as:

$$H_c = H_c(x_f^c, t_{ex}^c; X_f^i, T_f^i, k, E_h) \tag{2.4}$$

The child's conditional utility function depends on the child's health outcomes (H_c), the amount of food consumed (x_f^c) and time for exercise (t_{ex}^c) as well as consumption of other time (t_o^c) and goods (x_o^c). Child's utility depends on the home environment (E_h) and level of relative deprivation (RD). Psychological experiments have been conducted and provide evidence that children make social comparisons. For example, two young children are content when being served the same amount of orange juice for several days. However, they notice the difference if one of them is served only three quarters of a glass and the other is served a full glass [69]. Through comparisons with other schoolmates, relative deprivation is associated with poorer health behaviors such as less physical activity, fewer breakfast and less healthy food choices among adolescents [31]. So the child utility function is written as:

$$u_c = u_c(H_c, x_f^c, x_o^c, t_{ex}^c, t_o^c; E_h, RD^c) \tag{2.5}$$

Maximizing the child's utility function in equation (2.5) subject to child's health production function (2.4) and a time constraint of $t_{ex}^c + t_o^c = T$ yields the child's best response functions ($x_f^{c*}, x_o^{c*}, t_{ex}^{c*}, t_o^{c*}$) with arguments (X_f^p, X_f^m, T_f^p, T_f^m, k, E_h, RD^c). The child's health production and utility functions are then respectively:

$$H_c^* = H_c(X_f^i, T_f^i, k, E_h, RD^c) \qquad i = P, M \tag{2.6}$$

$$u_c^* = u_c(X_f^i, T_f^i, k, E_h, RD^c) \qquad i = P, M \tag{2.7}$$

2.5.1.2 Parents' Optimization Problem

Parental health is based on their food consumption (X_f^i) and time for exercise (T_{ex}^i). The efficiency of parents' health production is affected by the biological factors such as age and gender (K). Home /family environment (E_h) may have impact on parents' health as well. For example, chronically stressful family environment may produce chronic anxiety, leading to enhanced health risks [70]. High-density living is associated with increased likelihood of infections and higher death rates [71]. Work environment (E_w^i) may affect parents' health. For instance, high job strain is related to mental ill health [72]. Toxins at work lead directly to contraction of certain kinds of cancers for the poor and African-Americans [70]. Accordingly, the health production functions for parents are formed as:

$$H_i = f(X_f^i, T_{ex}^i; K^i, E_h, E_w^i) \qquad i = P, M \tag{2.8}$$

Utility for each parent is determined by consumption of food (X_f^i) and other goods (X_o^i). Time allocation matters in the determination of their utility level like time for food purchase and process (T_f^i), time for exercise (T_{ex}^i), time for work (T_w^i) and other time consumption (T_o^i). In addition, parental utility is determined by his own health status (H_i), his spouse's health status (H_j) and his child's health status (H_c^*) and child's utility (u^*). So utility for each parent is characterized as:

$$V_i = V_i(X_f^i, X_o^i, T_f^i, T_{ex}^i, T_w^i, T_o^i, H_c^*, u_c^*, H_i, H_j; E_h, E_w^i, RD^i) \qquad i = P, M \qquad (2.9)$$

The allocation process of resources within household is assumed to be Pareto-efficient. The household allocates the resources by maximizing a weighted sum of each parent's utility. Hence, the household function of utility can be written as

$$V = \lambda(p, w, I, K, E_h, E_w) \cdot V_P(\cdot) + [1 - \lambda(p, w, I, K, E_h, E_w)] \cdot V_M(\cdot) \qquad (2.10)$$

The Pareto weight, $\lambda \in [0,1]$, depends on factors affecting each member's bargaining position like individual wages and non-labor income.

The household faces the following budget constraint
Error! Reference source not found. and time constraint
Error! Reference source not found.:

$$\sum_i (P_o X_o^i + P_f X_f^i) = \sum_i (W^i + T_w^i + I^i) \qquad (2.11)$$

$$T_f^i + T_{ex}^i + T_w^i + T_o^i = T \qquad (2.12)$$

P_f and P_o represent price of food and other goods. W^i and I^i denote individual wage rates and unearned income.

We assume parents maximize household utility function (2.10) subject to equations (2.8), (2.11) and (2.12). Hence, the maximization results the parents' optimal input functions as:

$$X_j^{i*} = X_j(P_o, P_f, W^i, I^i, E_h, E_w^i, RD^c, RD^i, K^i, k) \qquad (2.13)$$

$$T_k^{i*} = T_k(P_o, P_f, W^i, I^i, E_h, E_w^i, RD^c, RD^i, K^i, k) \tag{2.14}$$

Parents' health productions are as follows:

$$H^{i*} = H_i(P_o, P_f, W^i, I^i, E_h, E_w^i, RD^c, RD^i, K^i, k) \tag{2.15}$$

The final reduced-form health production for child is derived by substituting equations (2.14) to (2.15) into equation (2.6):

$$H_c^{**} = H_c(P_o, P_f, W^i, I^i, E_h, E_w^i, RD^c, RD^i, K^i, k) \tag{2.16}$$

Ideally, analysis of total effect of relative deprivation requires estimation of child's health production and its input functions because parents' relative deprivation has effect on child health through inputs function. Unfortunately, reliable food expenditure is not available in our dataset. Besides estimating the final reduced-form health production for child, an analysis of a system of equations (2.6), (2.14) and (2.15) is also conducted to estimate the effect of relative deprivation on both child health and parent health. Knowledge of the health production technology for both parents and children is useful for predicting and assessing the effects of health-related policies. Also, such information is useful for helping parents to better achieve child health goals.

2.5.2 Empirical Analysis

This study will center on evaluating the effect of relative deprivation on child health through estimating both the reduced form health production function**Error! Reference source not found.** and the system of equations (2.6), (2.14) and (2.15).

First, the reduced-form production of child's health is estimable with appropriate data. We can estimate the direct effect of relative deprivation of child's health outcome through equation (2.16). Since this type of reduced-form function is commonly used in other studies, our results are comparable with results in other literature.

The final reduced form for child's health is estimated in the following linear form:

$$H_{cit} = X_{it}^{'}\beta + u_i + \varepsilon_{it} \tag{2.17}$$

Where H_{cit} is the health of child i at time t, X_{it} represents a set of explanatory variables which may affect child health, including both child and parent's relative deprivation. The u_i denotes the individual unobserved time-invariant error term component, assumed to be drawn from a distribution with a mean of zero and constant variance. The error term ε_{it} is assumed to be uncorrelated with X_{it} and u_i .

Second, we also estimate the system of equations (2.6), (2.14)and (2.15) because parameter estimates in food-input (2.13) and parents' health production functions (2.15) may provide additional information of interest. The indirect pathways of relative deprivation, through which the child's health outcomes are affected, can be solved in the system. For example, relative deprivation may affect time allocation of parents through equation (2.14) and lead to a change in child's health outcomes through equation (2.6). So parents can alleviate the effect of relative deprivation on child's health through resources allocation such as the amount of food and their time for preparing and processing food. This indirect impact of relative deprivation on child's health outcomes depends on the relative importance of X_f^i and T_f^i in the child's health production function. To make it clearer, an estimation system of equations (2.6), (2.14) and (2.15) can be written in matrix notation as:

$$\begin{aligned} T^F = \alpha_0 &+ \sum_{j=F,M} \alpha_1^j I^j + \sum_{j=F,M} \alpha_2^j w^j + \sum_{j=F,M} \alpha_3^j E_w^j \\ &+ \sum_{j=F,M} \alpha_4^j K^j + \sum_{j=F,M} \alpha_5^j RD^j + \alpha_6 P_f + \alpha_7 P_o + \alpha_8 E_h \\ &+ \alpha_9 k + \varepsilon_1 \end{aligned} \tag{2.18}$$

$$\begin{aligned} T^M = \beta_0 &+ \sum_{j=F,M} \beta_1^j I^j + \sum_{j=F,M} \beta_2^j w^j + \sum_{j=F,M} \beta_3^j E_w^j \\ &+ \sum_{j=F,M} \beta_4^j K^j + \sum_{j=F,M} \beta_5^j RD^j + \beta_6 P_f + \beta_7 P_o + \beta_8 E_h \\ &+ \beta_9 k + \varepsilon_2 \end{aligned} \tag{2.19}$$

$$H_c = \mu_0 + \sum_{j=F,M} \mu_1^j X_f^j + \sum_{j=F,M} \mu_2^j T_f^j + \mu_3 E_h + \mu_4 RD^c + \mu_5 k + \varepsilon_3 \tag{2.20}$$

Where $T^F = (T_f^F, T_{ex}^F)$ and $T^M = (T_f^M, T_{ex}^M)$. The derived reduced form can be obtained by substituting equations (2.18) and (2.19) into equation (2.20).

$$\begin{aligned}\tilde{H}_c = \tilde{\theta}_0 + \sum_{j=F,M} \tilde{\theta}_1^j I^j + \sum_{j=F,M} \tilde{\theta}_2^j w^j + \sum_{j=F,M} \tilde{\theta}_3^j E_w^j \\ + \sum_{j=F,M} \tilde{\theta}_4^j K^j + \sum_{j=F,M} \tilde{\theta}_5^i RD^j + \tilde{\theta}_6 P_f + \tilde{\theta}_7 P_o + \tilde{\theta}_8 E_h \\ + \tilde{\theta}_9 k + \tilde{\theta}_{10} RD^c + \varepsilon_3\end{aligned} \tag{2.21}$$

where

$$\tilde{\theta}_k = \tilde{\alpha}_k^j \tilde{\mu}_k^j + \tilde{\beta}_k^j \tilde{\mu}_k^j \tag{2.22}$$

$$\tilde{\theta}_m = \tilde{\alpha}_m \tilde{\mu}_k^j + \tilde{\beta}_m \tilde{\mu}_k^j \tag{2.23}$$

$$\tilde{\theta}_8 = \tilde{\alpha}_8 \tilde{\mu}_k^j + \tilde{\beta}_8 \tilde{\mu}_k^j + \mu_3 \tag{2.24}$$

$$\tilde{\theta}_9 = \tilde{\alpha}_9 \tilde{\mu}_k^j + \tilde{\beta}_9 \tilde{\mu}_k^j + \mu_5 \tag{2.25}$$

$$\tilde{\theta}_{10} = \tilde{\mu}_4 \tag{2.26}$$

From parameter estimates in equation (2.21), we can see that there are several pathways through which relative deprivation has effect on child health. Based upon our model, relative deprivation of both child and parents will affect child's health outcomes. Relative deprivation of parent affect the child's health outcomes through time and food consumption and these impacts depend on α_5^j, β_5^j and μ_2^j.

One advantage of our framework is that our models underlie the importance of the family domain in understanding the effect of relative deprivation on child health outcomes, articulating the complicated pathways of direct effect of relative deprivation as well as the indirect effect through parents. Also, the collective model of estimating a system of input demands in equations (2.14) - (2.15) and child's health production function in equation (2.6) is advantageous over the unitary framework. The collective model may help researchers and policy makers identify different targets of interests, such as child' health outcomes or parents' time for food preparing and processing.

2.6. Data

The models are estimated using data from the China Health and Nutrition Survey (CHNS) because it contains detailed information on health outcomes, demographic, socioeconomic and geographical variables. The CHNS is an ongoing longitudinal project started in 1989 and followed up through 2011 as the newly released dataset, covering 9 waves of data in total. It was conducted by an international team of researchers from the Carolina Population Center at the University of North Carolina at Chapel Hill, the Institution of Nutrition and Food Hygiene, and the Chinese Academy of Prevention Medicine. A random clustering sample process is conducted to draw the sample in nine provinces in China, i.e., Heilongjiang, Liaoning, Shandong, Henan, Hubei, Jiangsu, Hunan, Guizhou, Guangxi with Beijing and Chongqing being added to this survey recently. Heilongjiang is not included in waves of 1989, 1991 and 1993 and Liaoning is not included in wave of 1997. The response rates at household level (from 79.3% in 1997 to 94.9% in 1991) is high on average [73]. Hence, CHNS is representative of the diverse population in China. As our interest lies on the effects of relative deprivation on children's health, we restrict our sample of households with children aged under 18 years old. Also, we deleted sample from 1989 because parent's identifier is not reported.

We include children aged between 12-18 years old for analyzing self-reported health status and children aged under 18 years old for analysis for BMI model. Subsample of the first group of children consists of an unbalanced panel of 1608, 1455, 1382, 870, 925, 609 individuals in 1991, 1993, 1997, 2000, 2004, and 2006 respectively. Subsample of the second group of children includes an unbalanced panel of 4598, 4088, 3607, 3490, 2180, 1791, 1680 and 2178 in 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011.

2.6.1 Dependent variables

We use two dependent variables to measure health outcomes, a dichotomized measure of self-reported health status (SRHS) and BMI.

2.6.1.1 Self-reported health status

SRHS is used to measure general health status and can be viewed as perception of an individual's health relative to other people in the reference group [46]. Self-reported health status is proved to be consistent with objective health status measured by a range of prevalent diseases, such as hypertension, diabetes mellitus, and so on[74]. It has been proved to be highly correlated with communicable disease [75] and mortality [76]. Further, it has been shown to predict survival inequalities [77]. Paralled studies show that SRHS is a valid measurement of general health for different populations[78-81]. For example, evidence shows that subjective health assessment is a valid index for health status [82] and can be used to predict coronary heart disease [83].

SRHS is obtained from the children and adult questionnaires form CHNS. A question is asked to respondents aged 12 and older about their health status compared to others: "Right now, how would you describe your health compared to that of other people your age?" Respondents indicate on a four-step Likert scale measure (ranging from "poor" to "excellent”).This question is recorded in insurance file in year of 1991, 1993 and 1997 and then in physical exam file in year of 1997 and after. Hence, the source of SRHS comes from two different files. We use the observations from insurance file in 1997 because it includes similar amount of observations and less missing value (14236 observations with 22 missing values in insurance file vs.14323 observations with 2863 missing values in physical exam file). Following previous study, SRHS is dichotomized by one if the individual i reporting good and better health and zero otherwise [46]. Six waves (1991, 1993, 1997, 2000, 2004 and 2006) of data from CHNS are utilized for analyzing the determinants of child’s SRHS. Our sample is restricted to children aged between 12 to 18 years old who have information of family income, age and race. A total of 746 observations are included in analysis for children’ self-reported health status.

2.6.1.2 Body mass index

SRHS is self-reported and may be subject to potential response bias [64,84]. To control for such problems, actual physical health measurement (BMI) is suggested by previous studies [64]. BMI is a good measure for levels of body fat and can be used to indicate ill health during childhood and later in life. With increase in body mass index (BMI), more impaired health-related quality of life (a measurement of overall impact of a condition on physical and mental health and wellbeing) is reported by individuals [85,86]. Overweight/obese children and adolescents are associated with problems in physical and mental health[87-90]. Health risks related to obesity include mortalities due to heat disease, stroke, diabetes, and other causes [22]. We therefore include BMI as a second measurement of an individual’s health.

Both weight and height are reported in the section of physical measurement. They are measured by a physician, nurse, health worker or other health professional and recorded in each wave of data. BMI for adults is calculated as body weight in kilograms divided by squared body height in meters for adults as in the following ratios:

$$BMI = \frac{Weight\ \ in\ kgs}{(Height\ in\ meters)^2} \tag{2.27}$$

BMI for children and adolescents is different from BMI in adults because BMI in growing children varies with age and sex. BMI z-scores (BMI standard deviation scores) are proper measurement for assessing weight status in children by adjusting for child age and sex [91]. We calculate the children's BMI z-score by using the 2006 WHO child growth standards for children aged 0 -5 and 2007 WHO child growth reference for children aged 5-18 [92].

2.6.2 The independent variables

2.6.2.1 Income variables

The primary income variables used in the empirical models is annual per capita household income inflated to 2011 Chinese yuan. Household income is not adjusted by the household size. Individual income is problematic because individuals who are not earners often report an income of zero, leading to overestimated level of relative deprivation. Per capita household income takes into account the above problems by dividing the total household income by the number of people in the household aged over 14 and plus ½ times the number of children with a age below 14.

In CHNS, household income variable is derived by summing of all sources of income and revenue minus expenditures. Specifically, the household income is comprised of wage income, net income from sources like farming, raising livestock and poultry, fishing and business. In addition, it includes state subsidies, food subsidies and transfers from friends and extended family members. HHINC_CPI is a constructed variable of annual total household income inflated to the year of 2011. PCINC is obtained using HHINC_CPI divided by the number of people in the household age 14 and plus ½ times the number of children under age 14. Following previous studies[46,93,94], log of per capita household income is used to allow for a non-linear relationship of the inputs and health outcomes.

2.6.2.2 The relative deprivation measures

Relative deprivation is measured by the following indexes: (1) YRD_{ij}, measure of relative deprivation as proposed by Yitzhaki (1979); (2) DRD_{ij}, measure of relative deprivation proposed by Deaton (2001); (3) $Rank_{ij}$, percentile rank as proposed by Turley (2002). Where i represents the reference groups defined by different characteristics (1=province, 2=community/village, 3=age and community/village, 4=age, community/village and gender) and j represents household member (p=father, m=mother and c=child). We use per capita household income for imputing level of relative deprivation.

2.6.2.3 Other independent variables

Time for food preparation and process T_f^i is sum of two parts: average minutes spent buying food per week and average minutes spent preparing food per week. Time for exercise T_{ex}^i (parents) and t_{ex}^c (children) is sum of time for exercise and time spent on traveling to and from work or school on foot or by bicycle. Exercise activities include martial arts, gymnastics, dancing, acrobatics, track and field, soccer, basket, tennis, badminton, volleyball and other activities. An individual's time for transportation to and from work or school on foot or by bike was considered as another component of exercise time. Time for these activities was recorded for both adults and children.

The family environmental factors include measurements of family stability and density of living. Studies have found that family stability has positive effects on a child's health outcomes [95]. Family stability is usually defined in terms of family structure, such as single parenthood. So, we use indicators for a single-father or single-mother household. Household size is measured by the number of total members in the household (Hhsize). Parent's work environment is measured by a dummy variable with value of one indicating that if a person engages light physical activities during work time and a value of 0 indicating that a person engages moderate or heavy physical work. Office work, for example, is considered as light physical work, driving as moderate and farming as heavy physical work.

In the adult survey, an individual is inquired with the following question "On the average, what was your monthly wage/salary last year, excluding subsidies and bonuses".

Average monthly wage was collected for both parents as well as subsidies. Subsidies include grocery subsidy, health allowance, bath and haircut allowance, book and newspaper allowance, housing and other subsidies in Chinese yuan.

Use of food price is restricted in the CHNS, so we use CPI related to food at province level as a proxy for the food price and overall CPI as a proxy for the price of other commodities. Each year's overall index of CPI (CPI) and food index of CPI (CPI_food) are obtained from Statistical Yearbook of China State Statistical Bureau ranging 1990 to 2011 [96].

We also control for individual's age, gender, race and education. A dummy variable "$Insurance_j$" is used to indicate if an individual has medical insurance (j represent household member, p=father, m=mother and c=child). Table 2.1 presents the descriptions of variables in our analysis.

2.7. Results

2.7.1 Self-reported health status

Table 2.2 shows the summary statistics of variables of interest in our analyses, including the mean and standard deviation. On average, 75% of included fathers and 70% of mothers reported good health. Among the children aged 12 to 18 years old, about 85% of them reported good health when comparing with others at the same age. The average age of children was 14.84. Mean ages for father and mother are 43 and 41 years respectively. The vast majority of the children (90%) included in our sample are in school. More than a half (56%) of these children are from urban areas.

Three types of measurements for relative deprivation are utilized in our study. We use household per capita to calculate the level of relative deprivation because household income could reflect the ability of the household to consume commodities. The level of relative deprivation is assumed to be identical within household when considering province and community as reference groups. Specifically, father, mother and children have the same reference group comparing other people in the same community or province as their reference group, leading to the same relative deprivation for them. The mean of relative deprivation depends on the type of measurements and the definition of reference groups. For example, the mean Yitzhaki's index is 1991.71 Yuan and 2207.63

Yuan for household members when using province and community as reference group respectively, indicating that Yizhaki's index at province level is larger than that at community level. However, Deaton's index and percentile rank are higher when province is regarded as reference group (e.g., 0.29 vs. 0.26 for Deaton's index and 0.63 vs. 0.44 for percentile rank). Fathers and mothers have a similar relative deprivation as using community, age and community, age and gender as reference groups respectively. For child's relative deprivation, with narrowing down the reference group to people in a smaller area, the level of relative deprivation is decreasing except for the case of Yitzhaki' relative deprivation. Yitzhaki's index has the highest level of relative deprivation for children when using community as a reference group. The average household size is approximately 3 (3.41). On average, the per capita household income is roughly 8273 Yuan/year. Most of the fathers and mothers have medical insurance (73% and 60% respectively) and only 38% of the children are insured.

All analyses were performed by using STATA 13 [97]. The models were estimated based on a range of techniques. Firstly, we tested probit and logit models as the outcome of interest is a binary variable. Given the nested structure of the data, we investigated the association by using a two level multilevel model with children (i) clustered within communities (j) and within province (k). We employed Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) to compare across different models. AIC measured the overall fit of the model by adjusting the number of parameters (K) in the model (AIC=-2log-likelihood +2K). [98,99]. BIC corrected by the number of observations (n) in the model (BIC=-2log-likelihood +2Klnn) [100]. Nested models were compared by the likelihood ration (LR) tests. Table 2.3 shows the results of comparison across different models: probit (Model 1), logit (Model 2), random effects at the community level (Model 3) and random effects at both the community and the province levels (Model 4). Intraclass correlation coefficient (ICC) is the between-groups effects divided by the sum of within- and between effects, which is to examine the existence of clustering effect. Mixed effect model is not proper in this study if ICC is non-significant. These different models with relative deprivation were inspected according to different reference groups.

The intraclass correlation coefficients are extremely low both in Model 3 and Model 4 for four reference groups, indicating there are little similarities within communities and provinces. Likelihood-ratio tests comparing the mixed model (Model 3 and Model 4) to ordinary logistic regression are not significant for the data. It manifests that mixed effects models are not suitable for this dataset. According to AIC and BIC values, Probit model fits the data better than the other models. Similar procedure were performed for Deaton's index and percentile rank. The comparison results of the different models are presented in Appendix Table 2.1 and Appendix Table 2.2 (Available upon request). Probit model fits the data for three relative measurements than other types of models. Hence, we report the results of Probit model of the child's self-reported health status for three measurements of relative deprivation. For ease of presentation, we only present the average marginal effects (AMEs) of relative deprivation and reflect each type in each panel—the Yitzhaki's index is scaled by dividing by 100.

Table 2.3 displays the average marginal effects of Probit model in estimation of child's self-reported health status using four reference groups. When the other factors holding constant, the higher the level of relative deprivation the lower possibility it is for children to report good health as using province and community as reference groups for all three measurements. Relative deprivation have no significant effects on child's self-reported health as using Yitzhaki's index in group 3 (community and age) and group 4 (community, age and gender) of all household members. Father's Deaton index and mother's percentile rank present statistically significant negative effects on the possibilities of reporting good health among children: the possibility of a child reporting good health increases as a father's Deaton's index decreases or mother's percentile rank rises (indicating the decrease in relative deprivation). Most of the statistically significant coefficients are consistent, reflecting that relative deprivation has a negative effect on children's self-reported health status irrespective of the type of relative deprivation measurements except for father's percentile rank using community and age as reference group. It has significant positive impact on child's self-reported health status, indicating that the probability that a child reporting good health decreases when fathers' percentile rank increases when using community and age as reference group.

The results for children in urban and rural areas are displayed in Table 2.4. When using community as a reference group, all three types of relative deprivation measurements show a significant, plausible impacts on children's self-reported health status. For reference group of province, only Deaton index and percentile rank have statistically significant effects on children's self-reported health status. While using community-age and community-age-gender reference groups, the impact of three measurements of relative deprivation are no longer statistically significant except for father's Deaton index in group 4 (Community, age and gender) and mother's percentile rank. The average marginal effects show that as father's Deaton index decreases using group 4 as reference group or mother's percentile rank increases using group 3 or group 4 as reference group, the probability of a child reporting good health increases. The results for children in rural area are dissimilar with that for children in urban area. Yitzhaki's index and Deaton's index have no statistically significant effects on children's self-reported health status. When using province as a reference group, percentile rank has statistically significant positive effect on children's self-reported health status. Also, mother's percentile rank has a significant impact on children's health status when using community-age and community-age-gender reference groups. While father's percentile rank has a negative impact on child's health outcome when models using community-age and community-age-gender reference groups, indicating that the probability of reporting good health is lower when father's relative deprivation measured by percentile rank increases. Those effects are out of our expectations.

Table 2.5 presents the average marginal effects in estimation of children's self-reported health status for boys and girls respectively. The left panel show the AMEs for boys and the right panel for girls. In the left panel, all three measurements show expected effects on children's health when using community as reference group. The average marginal effects of relative deprivation imply that an increase in relative deprivation leads to a fall in the probability that a child reporting good health when using community as reference group. Both Yitzhaki's index and Deaton index show that relative deprivation has a statistically significant, negative effect on self-reported health status when using group 3 and group 4 as reference group. In cases of province as a reference group, father's percentile rank shows a positive effect on children's health status, indicating that the boys are more likely to report good health when father's percentile rank increases. When using community-age and community-age-gender as reference groups, mother's percentile ranks have statistically significant positive effects for both boys and girls. The positive AMEs of percentile rank suggest that the increase in percentile rank leads to higher probability of reporting good health status by boys. The right panel shows that the AMEs of Yitzhaki's index and Deaton index have no statistically significant effects on girls' health status except that father's Yitzhaki's index using community-age-gender reference group has a positive effect. The positive AMEs of father's relative deprivation indicates that the probability that a girl reports good health is higher when father is more relatively deprived, which is opposite to our expectation. Percentile ranks in cases of province and community as reference groups manifest positive marginal effects, suggest that the probability for a girl in good health is higher when percentile rank increases. Similar effects are observed for mothers' percentile ranks when using community-age and community-age-gender reference groups. While father's percentile rank using community-age group present negative effect on a girl's health status, indicating that a girl is more likely in good health if the father's percentile rank drops.

2.7.2 BMI

Summary statistics of BMI are reported in Table 2.6, including sample means and standard deviation for analysis for BMI (1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011). It reveals that measurements of relative deprivation become smaller when more specific reference groups are used as definition. For instance, Yitzhaki's index decreases from 2867 Yuan to 1206 Yuan when changing the reference group from province to community-age-gender. The mean BMI is 23.46 and 22.87 for fathers and mothers respectively. The mean age of father is 40 while the mean age of mother is 38. Children have a mean BMI z-score of -0.17 for those having an average of 12 years old. Most of them (92%) are in school and about 53% of them are from urban area. Nearly half (51%) of them are insured, which is much lower than the insurance rate for their parents (e.g., 79% of fathers and 69% of mothers have insurance).

The models for BMI estimation employed a range of specifications. Given the nested structure of the data, we used random effects linear regression models with children (i) clustered within communities (j) and within province (k). Models for comparison include random intercepts at community level (Model 1); random intercepts at community and province level (Model 2); random coefficient of food price at province level (Model 3) and random coefficients of food price and overall price at province level (Model 4). AIC and BIC are used to compare non-nested models. The likelihood ratio is adopted to compare nested models. Comparison results of Yitzhaki's index and that for Deaton and percentile rank are listed in Appendix (Appendix Table 2.3 for Deaton index and Appendix Table 2.4 for percentile rank, available upon request). We select models with random intercepts at community and province levels according to AIC. The results were presented for three measurements in Table 2.7.

Full sample for BMI estimation indicates that Yitzhaki's index has a statistically significant impact on children's BMI z-score when using province as a reference group. The AME shows that the children's BMI z-score increases as the household Yitzhaki's index rises. Mother's Yitzhaki's indexes reflect statistically significant positive effect on children's BMI z-score as well when using reference groups defined by community-age group. Deaton index has no significant effects on children's BMI z-score when using different reference groups. Household percentile rank has a statistically a significant negative impact on children's BMI z-score when using community as reference group. Mother's percentile rank is negatively associated with children's BMI z-score. The negative AMEs of percentile rank suggest that the children's BMI z-score rises when the percentile rank decreases (high percentile rank indicates higher level of relative deprivation).

Comparisons between children in urban and rural areas are listed in Table 2.8. The AMEs in case of urban area are presented in the left panel and show that Yitzhaki's indexes have statistically significant positive impacts on children's BMI z-score when using province as a reference group. Mother's Yitzhaki's indexes have statistically significant positive effects on children's BMI z-score. The positive AMEs indicate that the children's BMI z-score increases as the Yitzhaki's indexes rise. Household Deaton index at community level and mother's Deaton index using reference group defined by community and age have significant positive effects on children's BMI z-score. Percentile rank at province and community level show negative effects on children's BMI z-score as well as the mother's percentile rank using reference group defined by community, age and gender. The negative AMEs of percentile rank suggest that children's BMI z-sore increase as the percentile rank falls, which is in accordance with our expectation. The right panel shows the AMEs of relative deprivation using different reference groups. The AMEs show that no statistically significant effects are observed for all three measurements of relative deprivation, indicating that relative deprivation has no effect on children's BMI z-score.

Comparison of AMEs of relative deprivation in analyses of boys and girls are presented in Table 2.9. Yitzhaki's indexes show statistically significant positive effects for both boys and girls when using province as a reference group, indicating that BMI z-score of both boys and girls increases as the Yitzhaki's indexes at province level rises. The AMEs of Yitzhaki's indexes for boys also show that relative deprivation using community as reference or mother's relative deprivation using community and age have positive effects on children's BMI z-score. Girls' Yitzhaki's indexes using refrence group defined by community and age indicates that girls' BMI z-score increases dramatically when they are relatively more deprived. Deaton index shows no statistically significant effects on both boys' and girls' BMI z-score. Father's percentile rank has a statistically significant positive effect when using community-age as a reference group, indicating that boys' BMI z-score rises as the fathers' percentile rank increases. Household's percentile rank using community as reference group has a negative effect on girls' BMI z-score. In addition, mothers' percentile rank has statistically significant negative effects on girls' BMI z-score except when using community-age-gender as reference group. Further, the girls' percentile rank has a larger negative effect on their BMI z-score when using community-age-gender as reference group.

2.8. Discussion

This study investigates the association between relative deprivation and child's health in China. We develop an integrated two-stage collective model to investigate this relationship within the household framework. Our purpose of this study is twofold: first, we intend to explore the association between relative deprivation and children's health outcomes; and then we intend to examine the underlying mechanism of relative deprivation on child health. Three measurements of relative deprivation are employed and four reference groups are formulated by combination of different characteristics.

With a few exceptions, the results are consistent across three different measurements for relative deprivation. We find that relative deprivation is negatively related to child's health in China: the probability of reporting good health status by a child is lower when relative deprivation is higher. In addition, higher relative deprivation is associated with higher children's BMI z-score.

By subgroup analysis, we find that children in urban areas seem to react more often than children in rural areas. For example, most of the AMEs of relative deprivation at province and community level are significantly related to children's self-reported health status. The rural-urban differences may be due to the different environments between rural and urban communities, especially in the context of schools [101]. Rural schools usually have lower per-pupil school expenditure, more poorly paid and less well-trained teachers compared to urban schools [102]. Factors like high density and large school size in urban areas may causes more peer pressure for urban children. Hesketh et al. argues that the competitive educational environments make children more stressful based on questionnaires from China [103]. More research are needed to make better understanding of the regional differences among children.

Comparison of results between boys and girls show that boys seem to react to relative deprivation measurements in more cases than that for girls, especially for the analysis of children's self-reported health status. Balsa et al. discover that adolescent males react differently from adolescent females to the relative deprivation. Their results show that relative deprivation only has a positive impact on risky behaviors for males, like alcohol consumption and drinking to intoxication [104]. Our results show similar observations that the relative deprivation by Yitzhaki's indexes or Deaton index is significantly associated with boys' self-reported health status when using different reference group except for reference group defined by province. But the results for BMI z-score are similar across boys and girls.

The results for children's self-reported health status (Table 2.3) and BMI z-score (Table 2.7) provide some supports for the relative salience of a reference group defined by community. According to AIC and BIC (results are available upon request), the results indicate that models using reference groups defined by community are best fit for the data except for Yitzhaki's index in the estimation of BMI z-score. Possible reasons for relative deprivation using community as a reference group being relatively salient is that local level of relative deprivation is easy to evaluate for both children and parents. Senik points out that local comparisons such as school mates are of significant importance [105]

Our findings are consistent with previous studies using different surveys. Elgar et al. find that adolescents' psychosomatic symptoms are affected negatively by the relative deprivation calculated by family affluence score [59]. Lhila and Simon suggest that mother's relative deprivation was negatively associated with infant health measured by their birth weight [32]. Balsa et al investigates the effects of relative deprivation on adolescents' risky behaviors and concludes that relative deprivation is positively associated by adverse health behaviors [104]. Elgar et al. draws a conclusion that relative deprivation is related to skipping breakfast and lower chances of dieting to reduce weight based on the data from Canadian Health Behavior in School-aged Children study [31]. All these evidences support the fact that the relative deprivation has adverse effects on children's health outcomes. Our study utilizes the self-reported health status and BMI z-score in the analysis and gives rise to the similar discoveries using a sample from CHNS.

There are some limitations in our analysis. Firstly, we have to construct the reference groups by combinations of province, community, age and gender as we cannot observe the real reference group. However, it is possible that people compare with other people in reference groups defined by other individuals or geographic characteristics, like through virtual communities on internet, which we are unable to test. Secondly, we calculate the relative deprivation by per capita household income for children. Previous studies use Family Affluence Score for imputing relative deprivation for children. We are unable to acquire similar affluence score from our dataset due to limited variables. Thirdly, there are possible biases caused by omitted variables. The variables, indicating an individual knows the Dietary Guidelines for Chinese population have a lot of missing observations, and have to be removed from our final models. Fourth, health outcomes include self-reported health status by children and the parents. These self-reported responses may cause inaccurate measurements.

2.9. Conclusion

This study examines the effects of relative deprivation on children's health outcomes such as the probability of reporting good health and children's BMI z-score. We utilize

Probit and a combination of multi-level mixed effects models to investigate these effects. The results show that children who are more relatively deprived have lower probability of reporting good health and higher BMI z-score.

This study has several contributions to the literature. Firstly, we have provided further evidence for the link between relative deprivation and children's health outcomes by using CHNS. For three different measurements of relative deprivation and four reference groups, there is a statistically significant negative association between relative deprivation and children's health outcomes. This information is important for policy makers in China, especially for those who are in charge of polices related to income inequality, such as income distribution policies. As we can expect that the number of children will continue to grow in the future due to the end of one child policy, decreasing the adverse effect of relative deprivation on children's health outcomes may have long-term benefits on individual well-being. Secondly, we conduct subgroups analysis by region and by gender. The comparison results show that children from urban area react more to relative deprivation relative to children in rural area and boys react more compared to girls. Hence, income inequality contributes to health inequalities among children, which may finally lead to inequalities in education level, employment and health when they those children become adults [106]. Health policies and surveillance for children's health need to be put forward and more efforts are required to investigate the underlying mechanism of the effects of relative deprivation on health outcomes. If life stress through comparison is the main reason for adverse health outcomes, schools in relatively deprived area may develop strategies of relieving stress for students. Policies or approaches that aims to promote children's health and equality in health are needed. In addition, future research is needed to find a better way to construct reference groups such as designing dataset that could construct reference groups directly.

2.10. References

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Table 2.1. Variable Description

Variable	Description	Unit
Dependent variable (LHS variable in the system of equations)		
$SelfHealthStatus_i$	An individual's self-reported health status: 1 is good or excellent; 0 otherwise	1/0
BMI[a]	An individual's body mass index	$Kg./(mt.)^2$
$FoodTime_k$	An individual's time for food purchase, preparation and cook	mins./day
Independent variables (RHS Variables in the system of equations)		
AllCPI[b]	Overall index of Consumer Price Index at province level	-
FoodCPI[b]	Food index of Consumer Price Index at province level	-
Wage	Father's average monthly wage if a father lives in the household or mother's average monthly in a single-household	Chinese Yuan
CapitaIncome	Per capita household income	Chinese Yuan
UEIncome	An individual's household subsidies	Chinese Yuan
$YReDepr_{ij}$	Yitzhaki's index of relative deprivation for an individual	Chinese Yuan
$DReDepr_{ij}$	Deaton's index of relative deprivation for an individual	-
$PercentileRank_{ij}$	An individual's percentile rank	-
$ExerTime_i$	An individual's exercise time	hours./week
Age_i	An individual's age	year
$Ethnicity_i$	An individual's ethnicity, 1 is Chinese Han; 0 otherwise	1/0
$Education_i$	An individual's level of education	rank
$LightActivityWork_k$	An individual's activity at work, 1 is light activity at work; 0 otherwise	1/0
$Insurance_i$	An individual's insurance, 1 is the individual has insurance; 0 otherwise	1/0
InSchool	A child is in school, 1 is this child is included in a school; 0 otherwise	1/0
Gender	A child's gender, 1 is boy; 0 is girl	1/0
$DietGuidanceScore_i$	An individual's score of diet knowledge survey	credits
DuoHeaded	A child's parent live in the household, 1 is both parents live in the household; 0 otherwise	1/0
HouseholdSize	Number of members in the household	number

Note: i represents role in the household, i=p, father; i=m, mother; i=c, child. k represents father or mother. j represents different reference group, j=1, people in province as a reference group; j=2, people within community/village as a reference group; j=3, people of the same age within community/village as a reference group; j=4, people of the same age and gender within community/village as a reference group.

[a]BMI z-score is reported for individuals aged under 18 years.

[b]1989 is used as the Base Year

Table 2.2. Descriptive Statistics of the sample in analysis for children's self-reported health status (adult and children)

Variable	**Mean**	**Standard Deviation**	**Min**	**Max**	**N**
Father's Self-reported Health Status	0.75	0.43	0.00	1.00	742
Mother's Self-reported Health Status	0.70	0.46	0.00	1.00	744
Child's Self-repoted Health Status	0.85	0.36	0.00	1.00	746
Yitzhaki's index_province	1,991.71	1,766.43	0.00	13,873.35	746
Yitzhaki's index_community	2,207.63	2,508.13	0.00	27,006.69	746
Father's Yitzhaki's index_ Father's Yitzhaki's index_ community, age	1,149.82	1,900.32	0.00	15,767.02	746
Mother's Yitzhaki's index_community, age	1,269.85	2,033.75	0.00	17,097.91	746
Child's Yitzhaki's index_ community, age	1,330.54	2,128.47	0.00	23,587.63	746
Father's Yitzhaki's index_ community, age, gender	1,043.18	1,939.92	0.00	16,385.50	746
Mother's Yitzhaki's index_ community, age, gender	1,075.14	1,913.62	0.00	19,140.65	746
Child's Yitzhaki's index_ community, age, gender	961.21	2,007.54	0.00	24,284.11	746
Deaton's index_province	0.29	0.17	0.00	0.82	746
Deaton's index_community	0.26	0.19	0.00	0.76	746
Father's Deaton's index_ Father's Yitzhaki's index_ community, age	0.14	0.17	0.00	0.77	746
Mother's Deaton's index_community, age	0.16	0.18	0.00	0.76	746
Child's Deaton's index_ community, age	0.16	0.18	0.00	0.80	746
Father's Deaton's index_ community, age, gender	0.13	0.17	0.00	0.77	746

Variable	**Mean**	**Standard Deviation**	**Min**	**Max**	**N**
Mother's Deaton's index_ community, age, gender	0.13	0.17	0.00	0.76	746
Child's Deaton's index_ community, age, gender	0.12	0.17	0.00	0.77	746
Percentile rank_province	0.63	0.22	0.10	0.99	746
Percentile rank _community	0.44	0.28	0.00	0.94	746
Father's Percentile rank _ Father's Yitzhaki's index_ community, age	0.32	0.28	0.00	0.93	746
Mother's Percentile rank _community, age	0.33	0.28	0.00	0.92	746
Child's Percentile rank _ community, age	0.37	0.29	0.00	0.93	746
Father's Percentile rank _ community, age, gender	0.29	0.28	0.00	0.88	746
Mother's Percentile rank _ community, age, gender	0.29	0.28	0.00	0.88	746
Child's Percentile rank _ community, age, gender	0.29	0.28	0.00	0.91	746
Per capita income	8,272.90	7,274.40	1,399.29	78,540.50	746
Household Size	3.41	0.75	3.00	10.00	746
Parent wage rate	507.83	504.61	59.00	4,000.00	746
Father's age	42.78	4.60	33.70	63.60	746
Mother's age	40.79	3.91	31.90	57.30	746
Child's age	14.84	1.66	12.00	17.90	746
Urban	0.56	0.50	0.00	1.00	746
Father's insurance	0.73	0.54	0.00	9.00	746

Variable	**Mean**	**Standard Deviation**	**Min**	**Max**	**N**
Mother’s insurance	0.60	0.66	0.00	9.00	746
Child’s insurance	0.38	0.85	0.00	9.00	746
In School	0.90	0.30	0.00	1.00	746

Table 2.3. Average marginal effects of Probit model estimating child's self-reported health using different relative deprivation measurement (Selected results)

Independent variable	**Province**	**Community**	**Community and age**	**Community, age and gender**
Yitzhaki's index				
Father's Yitzhaki's index	-0.23**	-0.11*	-0.16	-0.07
	(0.11)	(0.06)	(0.10)	(0.08)
Mother's Yitzhaki's index			0.08	0.07
			(0.09)	(0.09)
Child's Yitzhaki's index			3.78	-2.09
			(9.53)	(8.61)
Deaton's index				
Father's Deaton's index	-0.28**	-0.20**	-0.27**	-0.23**
	(0.12)	(0.09)	(0.12)	(0.10)
Mother's Deaton's index			-0.03	0.07
			(0.12)	(0.11)
Child's Deaton's index			0.09	-0.02
			(0.11)	(0.10)
Percentile rank				
Father's percentile rank	0.27***	0.18***	-0.12*	-0.07
	(0.09)	(0.05)	(0.07)	(0.06)
Mother's percentile rank			0.23***	0.18***
			(0.06)	(0.06)
Child's percentile rank			-0.01	-0.05
			(0.06)	(0.06)
N	744	744	744	744

Notes: Standard errors in parentheses; ***Significant at 1%, **Significant at 5%, *significant at 10%.

Table 2.4. Average marginal effects of Probit model estimating child's self-reported health using different relative deprivation measurement by region (urban area vs. rural area) (Selected results)

Relative deprivation index	**Province**	**Community**	**Community and age**	**Community, age and gender**	**Province**	**Community**	**Community and age**	**Community, age and gender**
			Urban				**Rural**	
Yitzhaki index								
Father's Yitzhaki index	-0.25 (0.15)	-0.16* (0.09)	-0.20 (0.14)	-0.06 (0.12)	-0.05 (0.14)	-0.07 (0.10)	-0.05 (0.13)	0.00 (0.12)
Mother's Yitzhaki index			0.10 (0.11)	0.12 (0.11)			0.04 (0.14)	0.05 (0.16)
Child's Yitzhaki index			10.94 (13.87)	1.93 (13.95)			-4.67 (11.36)	-13.40 (9.24)
Deaton index								
Father's Deaton index	-0.38** (0.18)	-0.21* (0.13)	-0.28 (0.18)	-0.25* (0.14)	-0.22 (0.17)	-0.16 (0.12)	-0.15 (0.16)	-0.10 (0.12)
Mother's Deaton index			-0.04 (0.16)	0.02 (0.13)			0.00 (0.17)	0.13 (0.15)
Child's Deaton index			0.15 (0.16)	0.09 (0.15)			-0.03 (0.14)	-0.21 (0.13)
Percentile rank								
Father's percentile rank	0.29** (0.12)	0.23*** (0.07)	-0.02 (0.10)	-0.04 (0.09)	0.28** (0.12)	0.09 (0.08)	-0.34*** (0.10)	-0.19** (0.08)
Mother's percentile rank			0.18* (0.09)	0.21** (0.09)			0.37*** (0.10)	0.20** (0.09)
Child's percentile rank			0.01 (0.09)	-0.06 (0.08)			-0.05 (0.08)	0.01 (0.07)
N	416	416	416	416	325	325	325	325

Notes: Standard errors in parentheses; ***Significant at 1%, **Significant at 5%, *significant at 10%.

Table 2.5. Average marginal effects of Probit model estimating child's self-reported health using different relative deprivation measurement by gender (boy vs. girl) (Selected results)

Relative deprivation index	Province	Community	Community and age	Community, age and gender	Province	Community	Community and age	Community, age and gender
	Boy				Girl			
Yitzhaki's index								
Father's Yitzhaki index	-0.23 (0.15)	-0.30*** (0.10)	-0.35*** (0.12)	-0.36*** (0.10)	-0.18 (0.14)	0.00 (0.08)	0.14 (0.15)	0.25* (0.13)
Mother's Yitzhaki index			0.00 (0.12)	0.02 (0.13)			0.15 (0.13)	-0.03 (0.13)
Child's Yitzhaki index			-1.71 (12.25)	-0.12 (10.50)			-14.94 (11.65)	-9.70 (12.73)
Deaton index								
Father's Deaton index	-0.28 (0.18)	-0.33*** (0.12)	-0.49*** (0.17)	-0.50*** (0.12)	-0.24 (0.17)	-0.09 (0.12)	0.10 (0.17)	0.06 (0.17)
Mother's Deaton index			-0.01 (0.16)	0.13 (0.15)			-0.08 (0.16)	-0.07 (0.16)
Child's Deaton index			0.12 (0.15)	-0.02 (0.12)			-0.10 (0.16)	-0.03 (0.14)
Percentile rank								
Father's percentile rank	0.29** (0.13)	0.21*** (0.08)	-0.09 (0.10)	-0.08 (0.10)	0.21* (0.12)	0.16** (0.07)	-0.16* (0.09)	-0.08 (0.07)
Mother's percentile rank			0.24** (0.10)	0.18* (0.09)			0.18** (0.08)	0.18** (0.08)
Child's percentile rank			-0.03 (0.09)	-0.02 (0.08)			0.06 (0.08)	-0.06 (0.07)
N	384	384	384	384	360	360	360	360

Notes: Standard errors in parentheses; ***Significant at 1%, **Significant at 5%, *significant at 10%

Table 2.6. Descriptive Statistics of the sample for analysis of BMI (adult and children)

Variable	**Mean**	**Standard Deviation**	**Min**	**Max**	**N**
Father's BMI	23.46	3.21	15.36	38.44	1679
Mother's BMI	22.87	3.07	14.69	36.21	1679
Child's BMI z-score	-0.17	1.27	-3.82	10.85	1679
Yitzhaki's index_province	2,867.99	3,233.77	0	21,093.62	1679
Yitzhaki's index_community	2,856.01	4,294.35	0	66,189.02	1679
Father's Yitzhaki's index_ Father's Yitzhaki's index_ community, age	1,754.36	3,959.88	0	88,252.02	1679
Mother's Yitzhaki's index_community, age	1,798.17	3,869.15	0	66,224.70	1679
Child's Yitzhaki's index_ community, age	1,756.24	3,709.47	0	47,763.64	1679
Father's Yitzhaki's index_ community, age, gender	1,479.39	3,494.89	0	66,189.02	1679
Mother's Yitzhaki's index_ community, age, gender	1,579.80	3,764.75	0	49,668.52	1679
Child's Yitzhaki's index_ community, age, gender	1,206.59	3,246.94	0	47,763.64	1679
Deaton's index_province	0.28	0.18	0	0.93	1679
Deaton's index_community	0.24	0.19	0	0.88	1679
Father's Deaton's index_ Father's Yitzhaki's index_ community, age	0.15	0.18	0	0.89	1679
Mother's Deaton's index_community, age	0.15	0.18	0	0.91	1679
Child's Deaton's index_ community, age	0.15	0.18	0	0.87	1679
Father's Deaton's index_ community, age, gender	0.13	0.17	0	0.91	1679
Mother's Deaton's index_ community, age, gender	0.13	0.18	0	0.91	1679
Child's Deaton's index_ community, age, gender	0.11	0.17	0	0.84	1679
Percentile rank_province	0.64	0.23	0.01	1	1679
Percentile rank _community	0.46	0.27	0	0.95	1679
Father's Percentile rank _ Father's Yitzhaki's index_ community, age	0.34	0.29	0	0.92	1679
Mother's Percentile rank _community, age	0.34	0.28	0	0.92	1679
Child's Percentile rank _ community, age	0.38	0.29	0	0.93	1679

Variable	**Mean**	**Standard Deviation**	**Min**	**Max**	**N**
Father’s Percentile rank _ community, age, gender	0.3	0.29	0	0.9	1679
Mother’s Percentile rank _ community, age, gender	0.3	0.28	0	0.89	1679
Child’s Percentile rank _ community, age, gender	0.29	0.28	0	0.89	1679
Per capita income	11,179.52	11,216.43	1,034.42	150,000.00	1679
Household Size	3.33	0.72	3	10	1679
Parent wage rate	783.59	891.41	59	4,000.00	1679
Father’s age	39.86	5.4	26	63.6	1679
Mother’s age	37.89	4.92	22.8	57.3	1679
Child’s age	11.96	3.29	5	17.9	1679
Urban	0.53	0.5	0	1	1679
Father’s insurance	0.79	0.58	0	9	1679
Mother’s insurance	0.69	0.62	0	9	1679
Child’s insurance	0.51	0.8	0	9	1679
In School	0.92	0.27	0	1	1679

Table 2.7. Average marginal effects of multilevel model estimating child's BMI z-score using different relative deprivation measurement (Selected results)

Independent variable	Province	Community	Community and age	Community, age and gender
Yitzhaki's index				
Father's Yitzhaki's index	0.54**	0.14	-0.10	0.04
	(0.21)	(0.13)	(0.17)	(0.16)
Mother's Yitzhaki's index			0.36**	0.12
			(0.16)	(0.14)
Child's Yitzhaki's index			6.03	7.35
			(13.89)	(14.18)
Deaton's index				
Father's Deaton's index	1.17	2.19	-1.94	0.89
	(2.44)	(1.98)	(2.78)	(2.73)
Mother's Deaton's index			3.96	-0.05
			(2.93)	(2.42)
Child's Deaton's index			56.89	80.86
			(170.08)	(202.24)
Percentile rank				
Father's percentile rank	-1.27	-3.29***	1.30	-0.66
	(1.48)	(1.02)	(1.27)	(1.34)
Mother's percentile rank			-2.21*	-1.46
			(1.28)	(1.25)
Child's percentile rank			-145.65	-56.01
			(119.41)	(95.46)
N	1,679	1,679	1,679	1,679

Notes: Standard errors in parentheses; ***Significant at 1%, **Significant at 5%, *significant at 10%.

Table 2.8. Average marginal effects of multilevel model estimating child's BMI z-score using different relative deprivation measurement by region (urban area vs. rural area) (Selected results)

Relative deprivation index	Province	Community	Community and age	Community, age and gender	Province	Community	Community and age	Community, age and gender
	Urban				Rural			
Yitzhaki index								
Father's Yitzhaki index	0.77*** (0.23)	0.12 (0.19)	-0.22 (0.25)	0.03 (0.22)	0.29 (0.22)	0.19* (0.10)	0.17 (0.30)	-0.02 (0.38)
Mother's Yitzhaki index			0.63** (0.26)	0.32 (0.23)			-0.02 (0.26)	0.05 (0.21)
Child's Yitzhaki index			20.60 (22.85)	14.98 (17.25)			-5.78 (18.50)	2.25 (28.81)
Deaton index								
Father's Deaton index	7.28 (4.50)	4.51* (2.70)	-1.94 (2.87)	0.38 (2.41)	-2.56 (2.80)	-0.18 (2.44)	0.31 (3.84)	0.23 (5.23)
Mother's Deaton index			8.39* (4.62)	4.66 (3.36)			-2.18 (3.39)	-2.77 (3.57)
Child's Deaton index			-3.19 (222.52)	-14.80 (251.06)			77.69 (316.18)	181.17 (216.32)
Percentile rank								
Father's percentile rank	-5.31** (2.59)	-4.24** (1.78)	1.05 (1.72)	0.22 (1.35)	1.29 (2.08)	-1.52 (0.92)	1.44 (1.82)	-2.03 (1.93)
Mother's percentile rank			-2.61 (1.78)	-2.16* (1.10)			-1.84 (1.55)	-0.39 (1.77)
Child's percentile rank			-128.97 (193.72)	-118.86 (121.04)			-162.49 (152.33)	6.07 (179.30)
N	888	888	888	888	791	791	791	791

Notes: Standard errors in parentheses; ***Significant at 1%, **Significant at 5%, *significant at 10%.

Table 2.9. Average marginal effects of multilevel model estimating child's BMI z-score using different relative deprivation measurement by gender (boy vs. girl) (Selected results)

Relative deprivation index	Province	Community	Community and age	Community, age and gender	Province	Community	Community and age	Community, age and gender
	Boy				Girl			
Yitzhaki's index								
Father's Yitzhaki index	0.52**	0.32**	-0.35	-0.09	0.31*	-0.08	-0.06	0.13
	(0.23)	(0.15)	(0.29)	(0.28)	(0.18)	(0.14)	(0.27)	(0.21)
Mother's Yitzhaki index			0.59***	0.14			0.11	0.02
			(0.20)	(0.21)			(0.35)	(0.31)
Child's Yitzhaki index			4.80	20.57			23.14*	3.88
			(17.76)	(28.46)			(13.18)	(19.97)
Deaton index								
Father's Deaton index	1.87	3.37	-4.77	0.50	0.08	0.65	-2.75	-0.29
	(3.63)	(2.78)	(3.72)	(3.18)	(1.56)	(2.57)	(4.20)	(3.14)
Mother's Deaton index			5.25	-2.95			4.27	2.94
			(3.41)	(3.83)			(4.59)	(2.96)
Child's Deaton index			89.44	278.23			254.66	89.39
			(275.69)	(372.36)			(202.76)	(238.72)
Percentile rank								
Father's percentile rank	-1.07	-2.44	4.77**	0.46	-1.24	-3.63***	-0.61	-0.06
	(2.60)	(1.93)	(2.20)	(1.78)	(0.95)	(1.23)	(1.05)	(1.10)
Mother's percentile rank			-2.17	-0.48			-2.67	-3.01*
			(2.33)	(1.22)			(1.89)	(1.77)
Child's percentile rank			-313.32	-57.84			-94.25	-138.61*
			(187.35)	(155.05)			(76.23)	(83.89)
N	873	873	873	873	806	806	806	806

Notes: Standard errors in parentheses; ***Significant at 1%, **Significant at 5%, *significant at 10%.

CHAPTER 3.

The Joy of Cooking? Analysis of Well-Being in Food Activities and Implications for Nutrition Policies

3.1. Introduction

Eating patterns have been shifting away from home-prepared food over the last several decades in the United States[1-3]. Meals consumed at home have been increasingly purchased from restaurants or delivered by restaurants [4,5]. The expenditure on food away from home (FAFH) has been increasing rapidly from 128.56 billion dollars in 1970 to 359.82 billion dollars in 2013 compared to a rise from 230.59 to 360.12 billion dollars of expenditure on food at home (FAH) (all in 1988 dollars) [6]. Meanwhile, average time for food preparation and cleanup is less than that 30 years ago [7]. Specifically, food preparation time alone has been decreasing from 112.8 min/day in 1965-1966 to 65.6 min/day in 2007-2008 [8]. The increase in consumption of FAFH and decrease in home food production are associated with rising risk for obesity as well as other chronic diseases [9,10], leading to high healthcare cost of these diseases in the United States. For instance, annual costs for obesity is estimated to range from $147 to about $210 billion [11]. FAFH contains relatively higher saturated fat, calories and sodium density compared to home foods [12,13] , and FAFH is usually associated with excess weight gain [14,15]. Meanwhile, home-prepared food is associated with much healthier dietary intakes [16]. Evidence shows that young adults who regularly prepare food tend to meet dietary recommendations and consume fast food less frequently [17]. In addition, home cooking can increase consumption of vegetables and fruits [18] and cooking frequently at home is related to healthier diets [19].

A healthy eating pattern is an effective strategy for improving personal health because the dietary modification is shown to prevent all-cause mortality by consuming more fruits and vegetables [20]. Many governmental institutions provide a number of programs to improve quality of diets by promoting home cooking. Traditional Food Stamp Program (TFSP) has been renamed as Supplemental Nutrition Assistance Program (SNAP) to highlight the newly emphasized nutrition goal in addition to the hunger-fighting goal before. SNAP offers economic benefits to eligible, low-income individuals and families. The average monthly SNAP benefits for eligible participants was $275 in 2013 [21]. However, the nutrition level recommended by those programs is still not met with the targeted population[22-24]. According to the National Cancer Institute method for assessing usual dietary intakes, 75% and 87% of the US population have intakes of fruits and vegetables below the sex-age group recommended level [25]. Studies show that SNAP participants choose more low-quality food relative to non-participants [26,27] and not enough time is being spent on home food production. Taillie and Poti suggest increasing home cooking as a strategy to improve nutrition intake for SNAP participants [10].There are many possible reasons and the most popular for economist is the value of time[23,28-30] and the opportunity cost of time[31-35]. However, there could be a more basic, fundamental and simple explanation: the activity is simply not enjoyable. The theory of compensating wage differentials says you do not have pay or compensate workers as much for engaging in an activity if they enjoy the activity versus if they don't enjoy.

To design targeted policies that can demonstrate better effectiveness, it is vital to understand what factors affect home food production. One issue that has received no attention in the food and nutrition literature is the role of process benefit in home food production. Studies on subjective well-being have been significantly increasing over the last two decades, but none have looked at the implications for food nutrition policy. In this study, we follow the literature and define "process benefits" as the direct effects on utility form engaging in an activity [36] and explore its role in the home food production. Attitude towards the engaging activities [37], level of satisfaction [38] and joy [39], defined as "process benefits" by the literature, are expected to influence the decisions on time allocation to an activity. The logic of standard SNAP benefit effect is based on the hypothesis that ignores process benefit. Process benefits (positive or negative ones) can either boost or counter a policy effect. For individuals with negative "process benefits" on FAH related activities, the effect of program benefits will be attenuated by the disutility of engaging in the activity. Thus, it is important to explain process benefits in food production.

The primary purpose of this study is to determine associations between certain demographic and process benefits in food production. Specifically, do process benefits differ by variables that determine SNAP eligibility? Home food production requires a series of activities before and after the meals. At a minimum, it requires meal planning, food preparation and transformation of a collection of food ingredients into a meal and clean-up [40]. The current study includes analyses of two major categories of food-related activities: "food and drink preparation, presentation and clean-up ("food production" for the rest of this paper)" and "food purchasing" (grocery shopping), covering the most activities for home food production. We analyze these two categories separately because we believe that the effects of the demographic and socio-economic factors are different on the process benefits related to food production and food purchasing activities. The findings will be informative to design better effective policies through targeting subgroups with different FAH process benefits. Section 2 introduces the conceptual framework by utilizing a household production framework and incorporating the concept of process benefit to analyze the optimal goods and time allocation. Section 3 summarizes briefly the current measurements of experienced utility and proposes the measurements we utilize in this study. Section 4 describes the dataset from ATUS Well-being module. Section 5 presents an econometric approaches for model estimation and Section 6 displays the estimation results. Discussions and conclusions are included in Section 7.

3.2. Conceptual framework

The conceptual model of this study is developed within a household production model. According to the household production framework [41,42], individual's utility depends on commodities that are produced using both goods and time. Each individual faces the same time constraint (i.e., 24 hours per day), leading time to be a valuable and scarce resource in the production of commodities. A household derives utility from the produced home food commodity, from the time spent on home food production, from the time for market work and from the leisure activities:

$$U = U\left(Z, \mathrm{t}_f, \mathrm{t}_w, \mathrm{t}_l; D_i, D_h\right) \quad (3.1)$$

where $Z\left(x_f, t_f; D_z\right)$ is the home food commodity production function, x_f and t_f are market good inputs and time inputs respectively. t_w and t_l represent time for work and leisure. The household utility also depends on the individual and household demographics: D_i and D_h. The efficiency of food production is affected by individual factor D_z, like cooking skills and knowledge. The difference between the standard household production model and our model lies in the fact that we include direct process benefits from the time spent in home food production: a second direct component, t_f, in the utility function in equation (1). Utility from time in the standard model comes purely from the consumption of the home-produced commodity (e.g. a meal), which is the same if process benefits are zero in our model. Household framework typically leads to a full constraint as equation (3.2)

$$wT + I = px_f + wt_f + wt_l \quad (3.2)$$

where I is the non-labor income, p is the composite price of market goods and w is wage rate. $wT + I$ is the full expenditure on food. Assuming that various concavity and differentiability conditions are satisfied (e.g., $U_z > 0$, $U_{zz} < 0$, $U_{t_f t_f} < 0$, $Z_{x_f} > 0$, $Z_{t_f} > 0$, $Z_{x_f x_f} < 0$, $Z_{t_f t_f} < 0$, $U_{zt_f} < 0$, $U_{zx_f} < 0$). The marginal utility and marginal product are assumed to be positive but decreasing. The first order condition with respect to t_f for an optimal allocation can be written as following:

$$U_z Z_{t_f} + U_{t_f} = \lambda \mathrm{w} \tag{3.3}$$

λ is the marginal utility of full income. The left term in equation (3.3) is marginal utility from time through two channels: the consumption of food commodities produced at home (e.g., meals) and process benefits from home food production (e.g., cooking and food presentation). The first component of utility is derived from the outcome attributed to time spent on food production. For example, an individual may spend time cooking a meal and obtain utility from consumption of the meal. The second benefit is from the actual process of time spent on the home food production and last during that process. Without considering process benefits, the marginal utility from time on food production is $U_z Z_{t_f}$.

$$\frac{\partial U_z Z_{t_f}}{\partial t_f} = \underset{(-)}{U_{zz}} \underset{(+)}{Z_{t_f}} + \underset{(-)}{U_{zt_f}} \underset{(+)}{Z_{t_f}} + \underset{(+)}{U_z} \underset{(-)}{Z_{t_f t_f}} < 0 \tag{3.4}$$

It can be seen that the marginal utility from time for food production is expected to decrease as the time for food production increases ceteris paribus, indicating a negative relationship between time for food production and marginal utility from it. The marginal utility curve of time for food production is pictured in Figure 3.1. The optimal allocation for time spent on food production is $t*$ when the first order condition is met. The optimal time allocation without process benefits is t^* and is considered as the policy target time in traditional model in which the process benefits are zero. However, individual may have positive or negative process benefits derived from the process of food production (e.g., cooking).

(1) If the process benefits are positive, then $U_{t_f} > 0$. The marginal utility from time for food production increases with positive process benefit, leading a shift of marginal utility curve to the right. At new equilibrium, the optimal time allocation increases to t^p, which is greater than the original policy target time t^*. The equilibrium in traditional household production is not achieved and becomes as $U_z Z_{t_f} < \lambda \mathrm{w}$ in case of positive process benefits.

To come back to the original equilibrium, a decrease in the amount of time for food production or a shift in the marginal utility of time for food production is needed. Firstly, the policy target time could be reached with a decrease in time for food production ceteris paribus indicating that the same amount of subsidy from SNAP may do more to those households who enjoy home cooking (positive process benefits) in terms of encouraging them to put in more expenditure on goods that are merely produced. Secondly, changes of other factors may shift the marginal utility curve of time for food production and lead to policy target time. Food expenditure is an important input in home food production and is expected to influence the marginal utility of time for food production. If market goods and time input are complements, then $Z_{t_f x_f} < 0$. Equation 3.5 indicates that the marginal utility of time for food production shifts to the left with an increase of market goods that are complements to time input.

$$\frac{\partial U_z Z_{t_f}}{\partial x_f} = \underset{(-)}{U_{zz}} \underset{(+)}{Z_{x_f}} + \underset{(+)}{U_z} \underset{(-)}{Z_{t_f x_f}} \tag{3.5}$$

The impact of a change in markets goods that is substitute of time input needs assumption of the magnitude. For example, if the market goods and time are substitutes, then we have $Z_{t_f x_f} > 0$. If we are willing to assume that $\underset{(-)}{U_{zz}} \underset{(+)}{Z_{x_f}} < \underset{(+)}{U_z} \underset{(+)}{Z_{t_f x_f}}$, the an increase in substitute goods increases the marginal utility of time for food production. A decrease in substitute goods leads the marginal utility curve shifts to the left to reach the policy target time. Therefore, to reach the policy target time, more complementary market goods or less substitute goods is needed, indicating that education message targeting those will be more effective at focusing providing households who have positive process benefits with information on local fresh produce procurement, produce storage, and new recipes, etc. In sum, a fall in time for food production and a rise in market food that require more time may lead to policy target time for a subgroup who have positive process benefits.

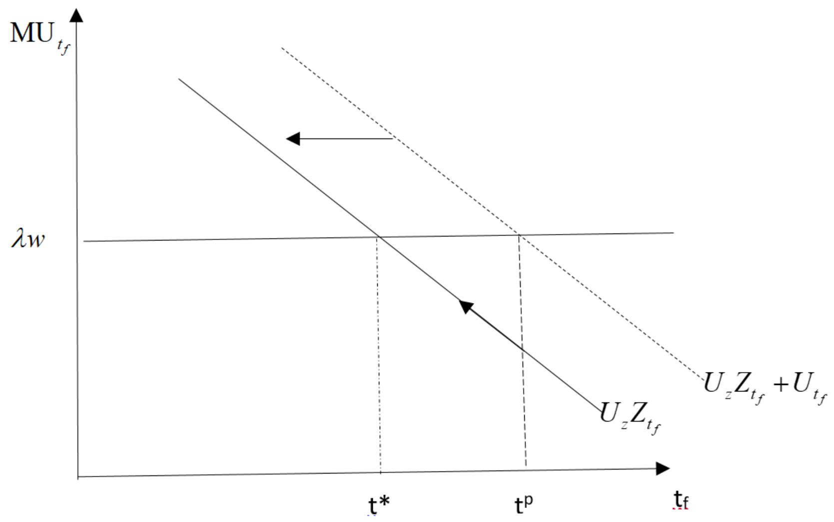

Figure 3.1. Marginal utility from time for food production with and without positive process benefits

(2) If process benefits are negative, then $U_{t_f} < 0$. The marginal utility from time for food production decreases with negative process benefits, leading a shift of marginal utility curve to the left, as pictured in Figure 3.2. At new equilibrium, the optimal time allocation decreases to t^N, implying that not enough time is spent on food production according to the policy target time. The equilibrium in traditional household production becomes an inequality as $U_z Z_{t_f} > \lambda \mathrm{w}$ in case of negative process benefits.

To regain the equilibrium in traditional model, an increase in time for food production or a shift of marginal utility of food time to the right is needed. First, an increase in time for food production ceteris paribus will reach the equilibrium and policy target time. Simply stated, if there is no joy in doing the activity (e.g., cooking) you will do less of it and this lack of joy reduces the impact of any policy designed to get you to engage in the activity (e.g., cooking) because negative process benefits mean more subsidies are needed to achieve the same effects as without process benefits. As discussed in the positive process benefits, a decrease in complementary market goods or an increase in substitute market goods will lead to the marginal utility curve shift to the right in order to reach the policy target time. This indicates that households with negative process benefits may spend SNAP subsidy on more processed food such as frozen pizza, chips etc. that are relatively low in nutrient quality. This may explain why SNAP currently is struggling at improving meeting the nutrient goal. Therefore, the education message will be more effective for those households by focusing on motivating home food production, understanding health benefits and role modeling etc.

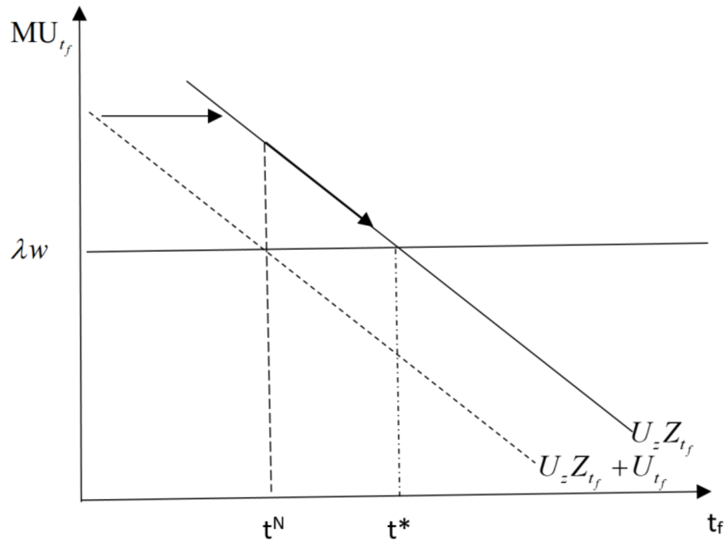

Figure 3.2. Marginal utility from time for food production with and without negative process benefits.

Empirical findings on individual and household heterogeneity effects

Traditionally, women usually perform the task of the food preparation [43,44]. The process benefits from food production may be greater for women than that for men because that women have favorable attitudes and advanced skills in home food production. Using the Dutch Time Competition Survey, Poortman et al. find that women have more favorable attitudes toward cooking [45]. In addition, women are observed to have higher cooking skills than men in all age groups [46]. Hence, a female respondent usually receive more process benefits from cooking and spends more time on food production and may compared to men.

Education level is related to food choices [47] and may have positive impacts on efficiency of food production [48], indicating that individuals with higher education may produce more efficiently than those with lower education. Respondents with higher education, especially nutrition education, may consider the home food production in a meaningful way [49]. It is likely that respondent with higher education have more process benefits. Therefore, individuals with higher level of education may receive more process benefits relative to respondents with lower education and spend less time on the production of the same amount of food.

Employment status may affect the time available for other activities, including food production. Thus, employment makes the time constraint more binding. For example, full-time employment may reduce the amount of time for producing home-prepared food. High time pressure is found to be related with poor situational well-being [50]. Hence, full-time employment is expected to decrease the process benefits and reduce the time devoted to time for food production as well.

Analogously, older people may have more time available for food production as they are retired or their children go to college. They may receive more process benefits from home food production as they have less time pressure. Also, an increase in process benefits may be due to the fact that they are more skilled at food production and get more satisfaction because of cooking competence [51].

Cooking can be considered as transformation of a natural object into a cultural one [52]. Ethnicity have impacts on cooking culture [53] and meal consumption [54]. For example, evidences show that Chinese people devote more time on home food production relative to individuals in other countries [55]. Matsumoto investigated ethnic differences in affect intensity using an American sample and the results showed that blacks perceived greater intensity relative to Caucasians and Asians [56]. It is possible that white or Asian respondent receive more process benefits compared to black respondents.

Home food production for larger household may be related to more process benefits. As the number of people in the household increases, it is more likely that the respondent could interact with family or get help from other family members [57]. Thus the food preparation goes from a alone to a social activity. Also studies show that eating alone is less enjoyable[58]. Hence, respondents in larger household may spend more time on food production together and obtain more process benefits. Whether young children live in the household and the number of young children may have negative effects on time for food production, because mothers of younger children may devote more time to take care of children. Therefore, time pressure for those increases and leads to intense stress related to activities for food production and lead the respondents gain less process benefits from home food production.

3.3. Measurements of experienced utility

The concept of utility was initially proposed by Jeremy Bentham (1748-1832) as "the value of a pleasure or pain considered by itself, will be greater or less, according to the four following circumstances: 1. Its intensity; 2. Its duration; 3. Its certainty or uncertainty; 4.Its propinquity or remoteness"[59]. This The Benthamite utility was regarded as a continuous hedonic flow of pleasure or pain and summarized as "tendency of an object or action to increase or decrease overall happiness" [60].It was similar to process benefits called by Juster et.al. and experienced utility called by Kahneman [61,62]. Juster and his colleagues defined process benefits as the "direct subjective consequences from engaging in some activities to the exclusion of others." [61]. The Benthamite utility was difficult to be applied in empirical research at that time mainly because of the impossibility to observe or measure hedonic experience [62]. Kahneman and his colleagues used Bentham's concept as experienced utility and referred to modern usage as decision utility. They initiated a comprehensive program and proposed a method of measuring experienced utility [60,63]. Furthermore, Kahneman distinguished remembered utility from instant utility though both of these were experienced utility. He defined remembered utility as the retrospective evaluations of past episodes and argued that remembered utilities could determine if a past situation should be continued or avoided [62]. It was suggested that an individual's choice was affected by the remembered utility [64]. Another type of experienced utility was instant utility, which was referred to the pleasure or distress of the moment and measured by immediate (real time) reports of current subjective experience [62].

Kahneman and his colleagues demonstrated two characteristics of remembered utility: the Peak-end evaluation and duration neglect. Several experiments show that the respondents did not take the feeling of every moment during whole duration into account but two moments instead: the moment of peak and the end of the duration. Hence, two determinants of the remembered utility were the peak and end instant utility (or disutility) [62]. In addition, they found that the duration of episodes had few or no effects on the remembered utility due to Peak-End evaluation, which they referred to as duration neglect.

Support for those two observations came from diverse experiments with various designs. In one experiment, participants watched sixteen short, plotless film clips and reported instant utility (or disutility) by an array of colored lights. Two versions of each film were available: a short version (about 45 seconds) and a long version (about 120 seconds). Both versions had similar contents or affective values. After watching the film clips, the participants reported their remembered utility by answering the question “Overall, how much pleasure (displeasure or discomfort) did you experience during the film.” The results lent some supports for the two observations of Peak-End evaluation and duration neglect [65]. In the other experiment, participants went through two trials: they immersed one hand in cold water (14 c) for a short period (about 60 seconds) and went through the same process plus an additional 30 seconds in relatively warmer water (15c) in the long trial. After two trials, participants were required to choose which one they wanted to repeat in a third time. Most of the participants chose the long trial instead of the short trial. Their responses supported the hypothesis of Peak-End evaluation [66]. In an example, participants were patients in a Toronto hospital. The patients reported both instant discomfort during the colonoscopy procedure and remembered disutility after the procedure. The results showed that the correlation between Peak-End average and remembered utility is 0.67. The correlation between duration and remembered utility through variability of duration was observed as 0.03 [62]. As demonstrated by the above experiments, respondents’ remembered utility of experience could be predicted by the average of peak and end instant utility and the duration of experiences was often neglected.

Ariely draw a similar conclusion by examining whether the final experience affects the overall retrospective evaluation: the final experience had more impacts on the retrospective evaluation [67]. The results in his study showed that the final pain intensity and its trend during the latter half of the experience had primary influence on the respondents’ retrospective evaluation. Duration was found to have little effect on the retrospective evaluation. The underlying explanation was based on the memory-related mechanism. Ariely explained that when the duration of that experience became longer, less nerves were activated and led to less noticeable experience.

Experienced utility (or process benefits) plays an important role in an individual’s choices. The peak and end instant utility should be weighted with greater weights when it is measured by retrospective method. The hypothesis of duration neglect demonstrates that duration of episode has few impacts on remembered utility associated with this episode. Several methods and measurements have been developed for application of experienced utility in empirical studies.

3.3.1 Methods of collecting experienced utility data

Subjective well-being is used in a growing body of literature to measure individual well-being and is usually interpreted as experienced utility [62]. Common methods of collecting information for experienced utility include Experience Sampling Method

(ESM) and Day Reconstruction Method (DRM).

ESM is developed to measure instant utility of selected moments [68,69]. The participants for collecting real time information wear an electronic diary (e.g., a palm pilot) that beeps at irregular intervals during a day. The respondents are asked to report what they are doing and evaluate the intensity of various feelings (e.g., happy, pain, etc.). One advantage of the ESM is that it avoids the problems of imperfect recall and duration neglect [70]. However, ESM is not a practical method because it is difficult to apply ESM in large samples due to high cost and infrequent activities are rarely sampled due to the procedure design [70].

DRM was put forward by Kahneman et al. [70] and it records retrospective reports on emotional states associated with specific activities. Respondents are invited to fill out a diary of time use of previous day. They describes what they are doing and how they are feeling during each episode on selected affect dimensions. To reduce errors and biases of recall, DRM is designed to elicit specific and recent memories by asking questions related to the context of each episode. For example, DRM asks respondents to answer structured questions such as "when it occurred", "where they were", and "with whom they interacted with". The intensity of their feelings are measured on a scale from 0 ("Not at all") to 6 ("Very much"). Nine affective categories, such as happy and angry, are described using adjectives. The zero point has a common meaning for different respondents. Though the DRM is a retrospective method recording emotional states, it appears to be successful in measuring experienced utility. Because it relies on a very short recall period and the design of the method minimizes the memory error. The validity is supported by several studies. For example, DRM could produce a complex pattern of diurnal variation in positive and negative affect similar to that in an ESM study [63]. DRM mood scores show similar diurnal patterns as those from previous studies and are feasible to administer in large-scale studies [71]. In addition, the reliability of DRM is verified by Krueger and Schkage (2008) by comparing the average experiences for a given activity at different times by various subjective well-being questions over a two-week period. The results show similar patterns of mean net affect across activities using these two methods. The hourly variation in ratings of "tired" in the ESM and DRM are remarkably similar, with minimum ratings at around noon in both methods [72].

A DRM-like method is used in the ATUS Subjective Well-being (SWB) module to collect respondents' feelings of selected episodes by using an abbreviated version of

DRM-type surveys [73]. ATUS SWB is the only federal government data source for providing the self-reported feelings related to day's events. The information of respondents' feeling, time use and the context of occurring activities is valuable for research on subjective well-being [74].

3.3.2 Existing measurements of experienced utility

Several measurements based on DRM have been developed to measure experienced utility. They include both cardinal measurements and ordinal measurements.

Net affect

Kahneman et al. (2004) proposes net affect as a simple formulation to measure the remembered utility. Net affect is imputed by the average of positive affect (PA) (e.g., happy, affectionate/friendly) minus the average of negative affect (NA) (e.g., stressed, depressed/blue). According to the definition of net affect, an individual's utility is described as:

$$U_i = \sum_j h_{ij} \mu_{ij} \tag{3.6}$$

where h_{ij} indicates the time that individual i spends on activity j and μ_{ij} is the net affective experience during duration j. Net affect is a cardinal measure of utility and has the underlying assumption that it can be compared across individuals.

U-index and P-index

U-index measures the proportion of time that an individual spends in a negative or unpleasant feeling [75]. The first step is to determine if an episode is unpleasant or pleasant by comparing the maximum intensity of negative and positive feeling. The episode is an unpleasant one if the maximum intensity of negative feelings is strictly greater than the maximum intensity of positive feelings and is coded as 1. In other cases (the most intense feeling is a positive emotion or the case of tie), the episode is coded as 0. The index from this process is referred to U-indicator and described as following:

U-indicator=1 if Max (Stress, Tiredness, Pain, Sad) > Max (Happy, Meaningful)

=0 otherwise (3.7)

Then U-index is defined as "the fraction of time that is spent in an unpleasant state" by Kahneman and Krueger [75] and is imputed by weighting the index with the duration of each activity to the total time spent for food-related actities. U-index is written as :

$$\text{U-index} = \text{U-indicator} \times \frac{duration}{totaltime} \tag{3.8}$$

Duration represents the duration of each episode and total time is the total time for food-related activities during the survey day. P-index (P represents pleasantness) is proposed in a study aimed to examine the link between attending religious service and affective well-being [76]. This measurement is opposite to U-index and measures the proportion of time during which the highest-rated affect is positive to the total time spent for the three randomly selected activities.

According to Kahneman and Krueger (2006), U-index has the advantages of being an ordinal measurement at the level of feelings and taking on cardinal properties as it is aggregated based on time. Several recent studies have utilized U-index to investigate the subjective well-being. For example, U-index is used to measure affective well-being for comparison of subjective well-being between two different countries [77].

DIFMAX

DIFMAX is an indicator of experienced happiness and used in a study analyzing the structure of well-being in two cities [78]. Kahneman defines DIFMAX for an episode as the happiness less the maximum of negative feeling (e.g., "tense", "depressed" and "angry"). The formulation of DIFMAX is as following:

$$\text{DIFMAX}\left(episode\right) = \text{"Happy"} - Max\left(\text{"Tense", "Depressed", "Angry"}\right) \qquad (3.9)$$

where each episode is weighed by its duration. DIFMAX ranges from -6 to +6 and reflects that an episode may be very aversive due to one of the most intense negative feelings. DIFMAX is a cardinal measurement and reflects the net experienced happiness, indicating that only "Happy" is considered as positive feeling for an activity. Meaningful is also an important positive feeling related to an activity and different from happy. Literature show that intense stress and anxiety are related to intense meaningfulness but lower intensity of happiness [79].

3.3.3 Limitation and extension of current measurements

The above affect measurements include different combinations of duration-weighted affective feelings. Net affect and DIFMAX are both cardinal measurements. They have been reported to be highly correlated in a study comparing the level of well-being in two cities (Columbus, Ohio vs. Rennes, France). The results manifest that the coefficient of correlation between net affect and DIFMAX is 0.95 over the 20277 episodes [78]. One problem with net affect and DIFMAX is that respondents may interpret intensity differently, making it difficult to compare across individuals.

Another limitation with these two measurements is that they utilize the average rating of negative feelings. However, the correlations between the negative feelings tend to be low and lead to underestimation of mean of negative feeling ratings [75,80]

U-index or P-index have an advantage that they are based on an ordinal ranking of emotional intensity within each episode. If one individual uses the range of 2 to 4 to indicate the intensity while another individual used the full range of 0 to 6 to report the intensity, the determination of a negative or positive episode is unaffected as long as they both employ the same personal interpretations of the scales [75]. Hence, U-index or P-index allows for interpersonal comparison even if the respondents' interpretations of intensity are different. There are some other desirable attributes of U-index from a psychological perspective. For example, a negative episode is a significant occurrence of the day because the predominant feeling for most people is usually positive [81]. Kahnaman also pointed that "one dominant negative emotion will probably color an entire episode" because the correlation among negative feelings were lower than that among positive feelings [75].

We choose U-index as one of the primary measurements in our study because it has desirable properties when comparing with other measurements. As is observed by Kahneman and Krueger, the positive emotion is the predominant feeling for most people during the most of time [75]. It seems that humans experience a positive state as a default state [81]. Negative feeling is important to subjective well-being because a negative feeling may produce avoidance [82]. Hence, we use U-indicator to reveal whether an episode is categorized as a negative one by the method in the imputation of U-index and examine the relationship between demographic and socio-economic factors and U-indicator.

Larsen and Diener argue that the intensity or magnitude of the experienced emotion is also an important aspect [83]. They observe that some individuals experience their emotions more mildly and only with minor fluctuations relative to other individuals. Previous studies have shown that individual difference in affect intensity is related to behavior consequences [84]. Intensity of the experienced well-being could not be revealed by U-index or U-indicator. This can be seen from the formula of U-indicator described in equation (3.15). An increase or decrease in both positive and negative affect may have no effect on U-index or U-indicator. Hence, neither of these measurements could provide information that if a respondent experiencing more intense emotions [85]. In the Well-being module, the intensity of each feeling is recorded from 0 (not feel at all) to 6 (very much). We calculate the percentage and frequency of the dominant feelings in each subsample to check which negative feeling(s) is the most frequent one (the most intense feeling among negative feelings and the most intense feeling among positive feelings). Overall, tired is the major of dominant negative feeling, followed by stress and pain. Accordingly, we propose U-intensity (U stands for unpleasant) as our third measurement, which includes the intensity of stress and tiredness. We examine the relationship between the most two frequently dominant negative feelings and the associated factors.

These three measurements provide us different dimensions of respondents' feelings. U-indictor and U-index emphasize the dominant feeling as being negative and its fraction of total time for food-related activities respectively. U-intensity reflects the intensity of feelings and two often dominant negative feelings: stress and tiredness (Table 3.1). Different demographic subgroups may exhibit different scopes and reactions on different measurements which inform diverse targeted policy designs.

3.4. Data

Data are obtained from American Time Use Survey (ATUS), which is designed to provide comprehensive information on time use and conducted by the Bureau of Labor Statistics (BLS). The ATUS uses a stratified, three-stage and nationally representative sample drawn from the households with completion of their final month of interviews of rotation groups from the Current Population Survey (CPS). Each respondent from the household members aged 15 or older has equal probability of being randomly selected. One person per household is interviewed about his or her time use with detailed information such as the type and duration of each activity. Primary activities during the day before the interview are collected along with demographic information of respondents.

The Well-being Module (WB Module, https://www.bls.gov/tus/wbdatafiles.htm) sponsored by the National Institute on Aging is a supplement to the ATUS and provides affective states during three randomly selected activities. Day Reconstruction Method (DRM) is adopted to collect individuals' time use and feelings of three randomly selected activities. According to DRM, each respondent fills out a detailed time diary of activities on the previous day. Activities like sleeping (0101xx), grooming (0102xx), and personal activities (0103xx) and don't know/can't remember (500106) are not eligible for WB module. The rest activities are supposed to be selected at random (These activities were required to last at least 5 minutes).

However, the last eligible activity in the time diary is excluded incorrectly due to a programming error, which was fixed on March, 2013. The time diary has the advantage of being more closely connected to the recalled emotional experiences of a day's actual events [80]. Specifically, the WB module asks the respondents, "*Please use a scale from 0 to 6, where a 0 means you did not experience this feeling at all and a 6 means the feeling was very strong*". For each selected episode, the intensity of six feelings ("happy", "meaningful", "tired", "stressed", "sad" and "pain") are rated. The Well-Being Supplement was initiated in 2010 and repeated in 2011 and 2013. The present analysis combines data from all three available waves of data collection. Analysis is conducted on the basis of available variables of interest. The study sample includes survey respondents selected in the Well-being module reporting feelings of at least one of food-related activities. Those who only report feelings of non-food-related activities were excluded from our analysis.

The activity coding lexicon in the ATUS is originally based on one used by the Australian 1997 time-use survey. After many revisions, the current coding is based on a 3-tiered system with 17 major categories (first-tier) and 2 additional levels of details (second-tier and third-tier). As focusing on the activities related to home-prepared food production, we searched the description of the activities for keywords like "food", "eating" and "cooking" to identify food-related activities. Grocery shopping and travel related to grocery shopping are vital to home food production and are included in this analysis. Among the 17 major categories, only category of "Eating and Drinking" is identified as food-related activities. Twenty-one sub-categories are identified as food-related activities among the third-tier activities and are classified into four major food activity groups (Supplementary Table 3.1). The present study includes two major food activity groups in our study: "food and drink preparation, presentation and cleanup" and "food purchasing" because they cover the major of home food production.

3.4.1 Dependent variables

To measure emotional wellbeing, we utilize the U-index (U for "undesirable" or "unpleasant") following Krueger and Khaneman (Krueger, Kahneman et al. 2009). As mentioned in Section 3, one advantage of U-index is that it depends on ordinal ranking of feelings' intensity within the respondent [77]. U-index combines the multidimensional affective experiences and time use associated with an activity to calculate the proportion of time with an unpleasant emotion as the dominant feeling.

Firstly, we obtain U-indicator (UI) by comparing the intensity of negative feelings with positive feelings. For each episode selected in the well-being module, if the most intense feeling for that episode is a negative one (e.g., tired, stressed, sad, or pain), this episode is classified as unpleasant and coded as one. If the most intense feeling is a positive one (e.g., happy, meaningful), the episode is coded as zero. In the case of tie, the episode is coded as zero (Krueger, Kahneman et al. 2009). The activity-level U-indicator is either one or zero. Secondly, we obtained the U-index for each activity by weighting the episode U-indicator with the duration of each activity over the total time related to food-related activities during the day for that individual [80]. The reason for selecting total time related to food-related activities is due to our focus on time related to food production. The U-index for an activity is between 0 and 1, which indicates the proportion of time spent on food-related activities in a negative mood. U-intensity includes rating of two negative feelings related to each activity with a range from 0 to 6.

We will check the robustness of the measurements of process benefits by using total waking time to calculate U-index in our analysis. In this case, U-index measures the proportion of total waking time in a negative feeling when conducting activities for home food production. Additionally, we use “happy” as the only positive feeling in the imputation of U-index or U-indicator to check if the results are robust from a perspective of pure happiness in home food production.

3.4.2 Explanatory variables

Household income is estimated by household income category and combines income of all household members during the last 12 months, including money from jobs, net income from business, farm or rent, pensions, dividends, and interests and so on. We use dummy indicator in our analysis as “lowincome” being 1 if income level is below the category of \$50000~\$100000, and is 0 otherwise (1=low income, 0=high income). The reason for choosing the income category of \$50000~\$100000 as a threshold is that the highest level of poverty thresholds for 2010 to 2013 ranges from \$48527 to \$51844 for different size of families and number of related children aged under 18 years [86]. Hence, the categories below \$50000~\$100000 cover most of the poverty thresholds in those three years. The income eligibility standards for participating in SNAP should be at or below 130 percent of the Federal poverty guidelines according to different catrgories [87]. Therefore, if it is below the \$50000~\$100000 category, the household is likely below the poverty threshold.

Whether food-related behaviors are different among ethnic groups is vital to exploring food-related behaviors for food and nutrition policymakers [88]. From a nutritional perspective, Sanjur (1982) proposed five major ethnic groups: Native Americans, Black Americans, Mexican Americans, Puerto Ricans and Asian Americans. Given availability, we use four ethnic groups in our study: white only, Black only, Asian only and other, with "Black only" as reference group in regression analysis.

Educational attainment is recorded by asking the respondent the following question: *"What is the highest level of school you have completed or the highest degree you have received?"* We combined the categories from "less than 1st grade" to "12th grade-no diploma" as the category of "Less than high school"; from "High school graduate" to "some college but no degree" as the category of "High school and some college"; and rest categories as "College and above". Group of "Less than high school" is used as reference group.

Marital Status is recoded as a four-category variable comprised of married, widowed, divorced/separated and never-married respondents with never-married as the reference group in regression analyses.

"Household size" measures the number of people living in the respondent's household. We also include the number of kids under 18 years old in the model because household size may affect the workload of home food production and number of children under 18 may affect the time pressure. We also include the following demographic characteristics: age and quadratic in age; a dummy variable for male respondents (1 =male, 0 =female).

Information related to the activity includes the person who the respondents act with during the activity, dummy variables for the activity occurring at time for breakfast or dinner and duration of the activity. These characteristics of an activity may affect the feeling related to this activity. For example, the time of day when the activity occurs plays a vital role in the level of tiredness. Previous studies show that the average value of tiredness show a V-shape during the day, indicating that the level of tiredness is lowest around noon [75]. Previous study show that involving children in food production is beneficial to healthy food intakes[89,90]. Hence, we include variable for indicating who the respondent interacts with and recode it as a three-category variable: alone, interact with family, and interact with other people. Occurrence of breakfast is defined as the start time of activity ranges from 6:00 to 8:00 in the morning (bkfast: 1=breakfast, 0=other time) and occurrence of dinner is defined as the start time of an activity ranges from 17:00-20:00 in the afternoon (dinner: 1=dinner, 0=other time). Duration in the survey is recorded in minutes/day and transformed to hours/day in the regression analyses.

3.4.3 Overall summary statistics

Individuals who perform more activities related to home food production, the probability that their food-related activities being selected in the Well-being module is higher. This indicates that, on average, individuals with one food-related activity may spend less time than those with two food-related activities. Hence, we focus on the analysis in cases of one, two and three food-related activities of those categories separately because the individuals in one subsample may behave differently from those in another subsample.

Table 3.2 reports the demographic composition of subsamples of respondents engaging one, two or three activities in categories of food production and food purchasing respectively. The left panel presents the composition of the respondents who perform the activities related to food production. The gender composition and percentage of black respondents are statistically different among the three subgroups of food production. The percentage of male respondents drops greatly from one to three activities, indicating that most of the respondents in the three-food-activity subsample are women. Similar trend is observed with the percentage of black respondents with the percentage of black respondents decreasing from 11% to 7%. The average age of respondents is increasing from 48.80 years to 53.67 years for one to three activities. No statistically significant difference of income level and education level is present among the three subgroups of food production. About a half of the respondents with activities selected in the Well-being module are married. The right panel of Table 3.2 presents the demographic composition of activities related to food purchasing. Subsample of three activities of food purchasing is not observed, indicating that people rarely engage grocery shopping or food purchasing for three times during a day. The difference between the percentage of male respondents and the percentage of female respondents is smaller than that of food production (e.g., 42% for male vs. 58% for female for one activity of food purchasing). On average, the respondents of food purchasing are at similar age to those who conduct food production (mean age of 47.61 and 59.09 years for respondents for one activity of food purchasing and food production respectively). The majority of respondents with selected activities of food purchasing are white (85% for one activity of food purchasing and 99% for two activities of food purchasing). The percentage of respondents of Asian and other race is relatively small (less than 5% in total) than that in the subsample of food production. No significant difference of income, education and marital status is manifested between one and two activities of food purchasing. The difference of demographic characteristics among subsamples and activity categories shown in Table 3.3 lend some support for conducting our analysis in subsamples. The different demographic composition for each subsamples may lead respondents in each sample act differently.

3.5. Empirical approach

As discussed in Section 2, the process benefits could be influenced by a vector of explanatory variables, X, including both individual and household factors. By maximizing the household utility function subject to the full constraint, the optimal goods and time allocation in our framework can be written as following:

$$x_f^* = x_f^*\left(p, w, I, D_i, D_h, D_z\right) \tag{3.10}$$

$$t_i^* = t_f^*\left(p, w, I, D_i, D_h, D_z\right) \qquad i = f, l, w \tag{3.11}$$

Accordingly, the marginal utility from time for food production is

$$\begin{aligned} MU_{t_f} &= MU_{t_f}\left(Z\left(x_f^*, t_f^*; D_Z\right), t_f^*, t_w^*, t_l^*; D_i, D_h\right) \\ &= MU_{t_f}\left(p, w, I, D_i, D_h, D_Z\right) \end{aligned} \tag{3.12}$$

Our strategy for analyzing the process benefits is to use equation 3. 12 as a reduced form model recognizing the determinants of process benefits. All regression analyses include year fixed effects, accounting for the identical yearly changes for each respondent. The analyses are performed at activity level (U-index, U-indicator, U-intensity of stress and tiredness) and provide us information of the relationship between the different measurements and demographic variables, and activity characteristics as well, such as the timing and duration of the activity.

For weighted U-index, the dependent variable is a fraction of the duration with negative feelings as the most intense emotion to the total duration of food-related activities and is in the range of [0, 1]. Figure 3.3 and Figure 3.4 present the histogram of the weighted U-index in the subsamples defined by the number of food-related activities in categories of “food and drink preparation, presentation and clean up” and “food purchasing”. It is shown that U-index in all cases is 0 for a large proportion of the sample and 1 for a small proportion. Hence, it is proper to estimate the reduced form model using the fractional logit model proposed by Papke and Wooldrige [91]. They argue that their approach is a superior to deal with potential problems caused by other methods. For example, the predictions of OLS regression may fall out of the unit interval. In addition, logit model requires the dependent variable to be 0 or 1.

Following Papke and Wooldridge, the expectation of weighted U-index (WUI) can be described as:

$$E\left(U - index_i \mid X_i\right) = G\left(X_i \beta\right) \tag{3.13}$$

where G(•) is a known function satisfying $0 < G\left(Z\right) < 1$ for all $z \in R$.

In our study, the latent model is specified as following and used in models of three measurements:

$$\begin{aligned} G\left(X;\beta\right) &= \beta_0 + \beta_1 AGE + \beta_2 AGE^2 + \beta_3 MALE + \beta_4 WHITE + \beta_5 ASIAN + \\ &\beta_6 OTHERRACE + \beta_7 LOWINCOME + \beta_8 HIGHSCHOOL + \beta_9 COLLEGE + \\ &\beta_{10} MARRIED + \beta_{11} WIDOWED + \beta_{12} DIVORCED + \beta_{13} BREAKFAST + \beta_{14} DINNER \\ &\beta_{15} WEEKEND + \beta_{16} HOUSEHOLDSIZE + \beta_{17}\ \mathrm{KIDS} + \beta_{18} WITHFAMILY + \\ &\beta_{19}\ \mathrm{WITHOTHER} + \beta_{20}\ \mathrm{YEAR\ 2012} + \beta_{21}\ \mathrm{YEAR\ 2013} \end{aligned} \tag{3.14}$$

Duration of an activity is not included in the latent model of U-index because the duration is used to impute the weight. But duration of each episode is included in cases of U-indicator and U-intensity. A quasi-maximum likelihood procedure is proper to estimate the parameters and the associated robust parameter covariance matrix. These fractional logit models are intended for exploring the general relationship between subjective well-being measured by weighted U-index and individual-level or household-level characteristics.

Further, we examined the relationship between the U-indicator (UI) and associated factors. The dependent variable (U-indicator) is binary: one if the maximum intensity of negative feelings (i.e., pain, sad, stress and tiredness) is strictly greater than the maximum intensity of positive feelings (i.e., happy and meaningful) and zero otherwise. The difference between the U-index and U-indicator is that the former measures the proportion of the duration in a negative feeling and the latter reveals that the dominant feeling during the activity is negative. We use logit regression to model U-indicator.

We next explore the relationship between U-intensity and associated factors in order to shed further light on how negative feelings are associated with the respondents' characteristics and socio-economic factors. In the ATUS Well-being module, the stress and tiredness are measured on an ordinal scale, ranging from 0 (not stressed/tired at all) to 6 (very stressed/tired). Ordered logit models are proper to model the intensity of stress and tiredness [92]. The signs of variables of high intensity are expected to be the same as that in estimation of U-index and U-indicator. But the signs of variables of low intensity are expected to be the opposite as that we have discussed in section 2.

Enough data is only available for model estimation for case of two activities related to food production using three measurements. We examined the between variation and within variation of the key variables and present the results in Supplementary Table 3.2. The within variations for those variables indicate that the observations may not be independent within individuals. Hence, we specify the estimation model with cluster option to allow for intragroup correlation.

3.6. U-index analysis

We first summarize the U-index and total duration and then report the results of model estimation of fractional logit model.

3.6.1 Statistics

Average U-index and total duration of all food-related activities with its standard deviation are presented in the lower panel Table 3.3 by characteristics of the respondents and by socio-economic variable (income level). U-index measures the percentage of time spent on food-related activities in a negative mood. Lower U-index indicates that people get more pleasure from food-related activities relative to people with higher U-index. U-index of 1 for an activity indicates that the respondent is in negative mood when he/she engages this activity. The differences in the U-index across subsamples within each category are relatively small except for two activities of food purchasing. However, the variation of total time allocation to food-related activities in the three subsamples varies greatly. The left panel summarizes average U-index and total duration of food-related activities for activities related to home food production. The total time for all food-related activities increases as the number of selected activities changes from one to three, except for activities performed by male, Asian or married respondents. Respondents aged 65 and more have the lowest U-index within each subgroup, indicating they are less likely to feel negatively for food production. Respondents aged 15-44 usually show higher percentage of time in a negative mood when conducting activities of food production. The U-index are similar between male and female respondents across all subsamples. However, female respondents spend more time on food production than male respondents do by an average of 27, 22 and 114 minutes in three subgroups respectively. Asian respondents spend the largest amount of time on one and two activities of food production. U-index for one activity of food production is the same across different races. Respondents of other race display higher U-index in two activities of food production, indicating respondents of other race in this subgroup spend a higher proportion of time in negative feeling. Respondents with some high school have slightly higher U-index than respondents with higher education do in case of one activity of food production, indicating that respondents with lower education are more likely to have lower process benefits in this subgroup. Married respondents show lower percentage of time in a negative mood and the largest amount of time on food-related activities in one and two activities of food production relative to respondents with other type of marital status, especially to divorced/separate people. The respondents with income over $50000 have lower U-index than the respondents with income below $50000, indicating that respondents with lower income may have less process benefits from home food production in case of one food production activity. U-indexes are the same between the two income groups in case of two or three activities. The right panel of Table 3.3 presents the average U-index and total duration of food-related activities for food-purchasing activities. The U-index and total time allocation for food purchasing presents different pattern from that for food production. Respondents with age of 65 and over spend more time in food-related activities compared to respondents of other age group and their U-index increases dramatically in case of two activities of food purchasing, indicating that respondents aged 65 and over are more likely to feel negative in this case. Female respondents have higher U-index and spend more time on food purchasing than male respondents. White respondents tend to have higher U-index, suggesting that they spend larger proportion of time in negative mood when engaging food purchasing. The U-index increases greatly from one activity to two activities of food purchasing for black respondent, suggestion black respondents are more likely to spend larger portion of time in negative feeling. Respondents with different levels of educations have similar U-index in case of one activity of food purchasing. But U-index rises greatly in case of two activities of food purchasing for respondents with some high school or college and above. Divorced/separated or never-married respondents have higher U-index and tend to spend less time in food purchasing. U-indexes for respondents with income over and below $50000 are quite close.

The average of U-index for each subgroup is shown in Table 3.4. Its highest value is in subsample of one activity of food production or two activities of food purchasing, suggesting that respondents in these subgroups are more likely to act in negative feelings. The decreasing U-index from one to three activities of food production indicates that respondents in the three-food-activity subsample may get more process benefits from activities of food production. However, respondents in the two-food-activity subsample have the highest U-index and may obtain more process disutility from activities of food purchasing.

3.6.2 Model estimation

Fractional regression is used to estimate the association between process benefits (measured by U-index) and demographic variables and socio-economic variables. The average marginal effects (AMEs) of fractional logit are presented in Table 3.5. Interpretations of all regressions are relative to the reference group of that categorical variable. Among respondents in one activity of food production, the age has a statistically significant negative effect on the U-index. This indicates that older respondents tends to spend larger proportion of time on food production in positive feelings. The AME of dummy variable of low income is positive, indicating that those with income below $50000 show higher U-index. The percentage of time spent on home-food production in a negative mood for individuals in the group of low income is higher than that for individuals with income over $50000. Married individuals have lower U-index relative to never-married respondents, indicating that married respondents may get more process benefits than never-married respondents may. The AMEs of dummy variables for breakfast, interaction with family and other people are all statistically negative. Those negative AMEs demonstrate that the U-index is lower when the activity happens at time for breakfast or weekend than it happens at other time. In addition, interaction with family or other people could reduce the proportion of time in a negative feeling compared to conducting the activity alone. The U-index increases if the activity happens at time for dinner compared to other time. In subgroup of two activities related to food production, age is negatively associated with U-index, indicating that older individuals might spend larger proportion of time in a positive mood. The U-index decreases then changing the female respondents to male respondents, indicating that more process benefits received by male respondents from home food production than that by female respondents. The AME of household size is negative and implies that an increase in household size leads to decrease U-index. In case of one activity of food purchasing, white respondents show higher U-index than that of black respondents, indicating that white respondents tend to get more process disutility from purchasing food. Married respondents show lower u-index than never-married individuals do, implying that these respondents tend to obtain more process benefits from food purchasing. The U-index of activities of food purchasing is higher at time for dinner, indicating that shopping for food purchase at dinner time may generate less process benefits than shopping at other time. Interacting with family or other people during activities of food purchasing may bring more process benefits and lead to lower U-index.

3.7. U-indicator analysis

The average of U-indicator for each subgroup is presented in Table 3.4. Similar to the trend of U-index, U-indicator decreases from one activity to three activities of food production. This suggests that the percentage of respondents with negative feeling as dominant emotion is highest in one activity of food production: about 13 percent of the activities are conducted in a negative feeling. About 15 percent of one-food activities of food purchasing are performed by respondents with dominant negative feeling, which is 10 percent lower than that in two-food subsample.

Table 3.6 shows the AMEs of logit model for one and two food-related activities. The first column presents the AMEs for one activity of food production. The AMEs of age, dummy variables for male, white and Asian are statistically significant and the signs are plausible. The effects of age and male are negative, indicating that older or male respondents are less likely to report negative feelings as the most intense feeling. For example, Table 3.1 shows that tiredness and stress are the most two frequent negative feelings associated with activities of food production. White ore Asian respondents are more likely to have negative feelings as the most intense emotion compared to black respondents. Getting married decreases the probability of a U-indicator as 1 relative to being never-married. The probability of U-indicator being 1 decreases if the activity of food production occurs at time for breakfast or at weekend and increases if this activity occurs at time for dinner. Interacting with someone else decreased the probability that the most intense feeling is negative for one activity relative to being alone during the activity. The sign of duration is opposite to our expectation. The negative AMEs indicate that an increase in the duration lowers the probability that negative feelings as being the most intense for food production. The second column presents the AMEs for case of two activities of food production. The AMEs of age, dummy variables of gender and dinner, and duration are significant and are similar to that in case of one-activity subsample. The AMEs indicate that an increase in age of respondents or time duration of the activity will lead to a rise in the probability of an episode being classified as a negative one falls. The AMEs of age in case of one activity of food purchasing are negative, indicating that older respondents are less likely to report negative feeling as dominant. Being a white respondent increases the probability that an activity is rated as negative compared to a black respondent. The probability of being in a negative feeling decreases when the activity occurs at time for breakfast and increases if the activity happens at time for dinner. The AMEs of indicator of interaction with others are significant and suggest that respondents are less likely to rate an activity as a negative one if they interact with someone else during food purchasing.

3.8. Analysis of U-intensity

We further examine two of the most intense negative feelings. The right panel of Table 3.4 shows the average value of U-intensity of feelings for activities of food production. Both U-intensity of stress and tiredness decrease from one to three activities of food production. Overall, the average intensity of tiredness is highest in the negative feelings across three subgroups. The mean values of pain, happiness and meaningfulness increases as the number of selected activities of food production increases. While the average ratings of sad present a decreasing trend. The left panel of Table 3.4 shows that the levels of stress are higher in two activities than that in one activity of food purchasing. The average score of being tired is the highest among all negative feelings and is higher in one activity of food purchasing than that in two activities of food purchasing. The mean values of intensity of other feelings, such as pain and sad, are lower in two activities of food purchasing than that in one activity of food purchasing.

3.8.1Analysis of stress

Figure 3.5 and Figure 3.6 show the frequency of stress intensity related to activities for home food production and food purchasing respectively. The frequency and proportion of activities conducted by respondents with low-income status increases dramatically from intensity of 0 to intensity of 6. Specifically, 58 percent of the activities of being rated as "not stressed at all" are reported by respondents with low-income status and 79% of the activities rated as "very stressed" are reported by respondents with low-income status in case of at least one activity for food production. Similar observations are present for the intensity of stress related to activities of food purchasing. In all cases, respondents with lower income are more likely to report higher level of stress in food purchasing activities.

We calculate the average marginal effects (AMEs) using ordered logit model and report these marginal effects for each subsample in Table 3.7, Table 3.8 and Table 3.9. The AMEs measures the average change in probability for a one-unit change in the explanatory variable. The average marginal effects across the seven level of stress intensity sum to zero for an explanatory variable [92]. Table 3.7 presents the AMEs for all explanatory variables in analyzing one activity of food production. The AMEs of age are only positive for the "intensity of 0", but negative for the other levels of stress intensity. The probability of "not stressed at all" increases and that of "very stressed" decreases as age increases. The AMEs for male respondents are positive for reporting "not stressed at all", but are negative for reporting intensity ranging from 1 to 6 relative to female respondents. White respondents have negative average AMEs for "not stressed at all" and positive AMEs for other intensity compared to black respondents. The AMEs for Asian respondents are only significant and positive for intensity of 1 and 2. The AMEs for respondents with high school or some college are positive for "not stressed at all" and negative for other intensity compared to respondents with education less than night school. The pattern of AMEs are similar across dummy variable of being divorced/ separated, the number of kids under the age of 18 in the household and the duration of the activity. Those AMEs are negative for intensity of 0 and positive for intensity ranging 1 to 6. The AMEs are positive for "not stressed at all" and negative for other levels of intensity for activities occur at weekends.

Table 3.8 presents the AMEs for all explanatory variables in analyzing two activities of food production. The AMEs of age, indicator of male, indicator of white, indicator of Asian and indicator of weekend are similar to AMEs in one activity of food production. The AMEs indicate that male or older respondents are more likely to report lower intensity of stress and less likely to report higher intensity of stress. The AMEs of indicator of low-income level are significant across stress intensity. They are negative for "not stressed at all" and positive for other levels of stress intensity. This indicates that the probability of “not stressed at all” falls if the respondents with high-income level change to respondents with lower income level. If the activity happens at weekend, lower level of stress are more likely to be reported. The AMEs of activity duration are not statistically significant in case of two activities of food production.

Table 3.9 shows the AMEs for one activity of food purchasing. The AMEs of age show that an increase in age are more likely to increase the probability of reporting low intensity of stress. The AMEs of gender variable are positive for intensity of 0 and negative for other intensity levels, which indicating the male respondents are more likely to rate the activity as “not stressed at all”, but less likely to report intensity of 1-6 compared to female respondents. The AMEs for indicator of white respondents suggest that the white respondents are less likely to report intensity of 0, but more likely to report intensities of 2-6 compared to black respondents.

3.8.2 Analysis of tiredness

Figure 3.7 and Figure 3.8 show the frequency of tiredness intensity related to activities for home food production and food purchasing respectively. The trend is quite similar as that of the intensity of stress. Respondents are more likely to get tired doing activities of food purchasing if they have lower level of income in all cases.

Tables 3.10 exhibits the AMEs of all dependent variables in the analysis of intensity of tiredness for one activity of food purchasing. The AMEs of age are positive for intensity of 0 and 1 and negative for other intensity levels. It indicates that the older respondents are more likely to report lower intensity of tiredness (e.g., 0 to 1), but less likely to report intensity of 2-6. The AMEs of gender dummy variable are positive for intensity of 0, 1 and 2 and negative for other intensity levels. This suggests that the male respondents are more likely to lower intensity of tiredness (e.g., 0-2), but less likely to report intensity of 3-6 compared to female respondents. The pattern of AMEs for indicator of white respondents and other race are similar. All are negative for intensity of 0-2 and positive for intensity of 3-6. The respondents of white and other race are more likely to report minor tiredness, but less likely to report greater tiredness for food production compared to black respondents. The AMEs for both indicator of weekend and that of breakfast are positive for intensity of 0, 1 and 2 and negative for other levels of intensity. This suggests that respondents are more likely to report being less tired if the activity occurs at weekend or breakfast. The pattern of AMEs for indicator of dinner are opposite to that of indicator of breakfast, indicating that respondents are more likely to feel notable level of tiredness if the activity happens at time for dinner.

Tables 3.11 shows the AMEs in the analysis of intensity of tiredness for two activities of food production. The AMEs of age are significant across all levels of intensity except for intensity of 1 and 2. The AMEs of dummy variable of male are positive for intensity of 0 and 1 and negative for intensity of 3-6. This reveals that the older or male respondents are less likely to be severely tired, but more likely to get mildly tired for food production in subsample of two activities. The AMEs of indicator of white are significant and negative for the intensity of 1 and negative for intensity of 4-6, demonstrating that the white respondents are less likely to rate the intensity of tiredness as 1 and more likely to rate the episode with higher level of tiredness. The AMEs of indicator of time for dinner are negative for intensity of 0 to 2 and positive for intensity ranging from 3 to 6. This demonstrates that respondents are more likely to be greatly tired if the activities occur at time for dinner. The pattern of AMEs of indicator of time for weekend are positive for intensity of 0-1 and are negative for intensity of 2-6. This suggests that respondents are more likely to get lightly tired if the activities take place at weekend. It is also shown that interacting with other people may decrease the probability of reporting “not tired at all” but increase the probability of reporting higher level of tiredness.

Table 3.12 presents the AMEs in case of one activity for food purchasing. The AMEs of indicator of male show that male respondents are more likely to report lower intensity of tiredness and less likely to report higher intensity of tiredness. In addition, the AMEs of indicator of dinner imply that respondents are more likely to get tired when the activities are performed at time for dinner.

3.9. Discussion

This is the first study to explore the relationship between process benefits associated with food-related activities and factors like socio-economic and demographics. Process benefits are critical in understanding the behavior related to home food production. They are also important in policy design as negative process benefits may attenuate the positive effects of policies going through resource allocation. We use U-index, U-indicator and U-intensity for measuring different dimensions of feelings associated with each episode and further investigate the reported subjective well-being by examining two major negative feelings, e.g., stress and tiredness related to activities. The results of this study provide direct evidence for the role of process benefits and its relationship with demographic and socio-economic factors. This indicates that subgroups with certain characteristics are more likely to obtain negative process benefits when doing activities related to food production.

We estimated the relationship within each subsample (respondents with one, two or three food-related activities being selected) respectively. Table 3.3 reports the total time for food-related activities. We can see a clear pattern that individuals spend more time on food-related activities when the number of selected activities in the Well-being module increases. This observation indicates that the behaviors of the respondents from each subsample may be different. From the summary statistics of each subsample, we can see that the subgroups are different in having different demographic characteristics. For example, the gender composition and race composition are different among the three subgroups in the category of food production. Hence, it is reasonable to analyze the association between process benefits and respondents' characteristics in each subsample.

The estimation results of different measurements show that the process benefits are indeed associated with some demographic characteristics, implying that some demographic subsample tend to have negative process benefits. For example the younger respondents are more likely to have less process benefits than older respondents. Female respondents are more likely to be in negative feeling when performing activities related to home food production. Never-married respondent tend to have lower process benefits relative to respondents with other type of marital status. Households with income below $50000 may receive lower process benefits from cooking than those with income greater than $50000. The above findings show that individuals with different demographic characteristics may receive different process benefits from activities related to home food productions. The results of U-intensity suggest that those type of subgroup are more likely to report high level of stress or tiredness. Hence, process benefits are vital and should not be neglected in the analysis of respondents' behavior in home food production. Further, these findings imply that shortfalls in food production activities are not simply a matter of resource shortfalls, but also reflect disutility associated from these activities. Therefore, this study provides a new and contributing explanation to the small effect of nutrition policies that target activities that require labor.

Economic assistance is usually offered to low-income family to help them receive nutritious meals. The results in this study reveal that low income level is positively associated with the fraction of time in negative feelings during one activity of food production. The average marginal effects show that respondents with income below $50000 spend 0.8% (AME of 0.0076 in Table 3.5) more of their time in a negative emotion when they conduct activities related to food production. This indicates that the respondents with income below $50000 receive lower or even negative process benefits from food production than that received by respondents with high-income level. The monetary support allocated to those with low-income level needs to compensate the lower process benefits first. To put it another way, the effects of nutrition programs (e.g., SNAP) are not enough for participants with process disutility associated with food production if process benefits are recognized in the traditional model. According to a report released by the United States Department of Agriculture, about 56.7% of the participants are female and white is the major race with a percentage of 36.7% [87]. The percentage of SNAP households lived in poverty is around 82% in 2015. We calculate the predicted probabilities for white female respondents for different income levels. Table 3.13 shows the predicted probabilities for the seven levels of intensity of stress evaluated for white female respondents. Theses probabilities for three subsamples indicate a strong likelihood that the respondents with income less than $50000 reporting a higher level of intensity. Respondents with income greater than $50000 are more likely to report "not stressed at all" in all three cases. Table 3.14 presents the predicted probabilities for different levels of intensity of tiredness. Respondents with income less than $50000 are less likely to report lower intensity of tiredness ranging from 0 to 2, but more likely to report the higher level of tiredness (intensity of 3-6). The predicted probabilities indicate that people with low income are more likely to report higher intensity of negative feeling, leading to a greater proportion of time in a negative emotion.

Sensitivity analysis for robust check are performed in two ways: firstly, we include happy as the only positive feeling and compare it with the maximum negative feeling to create U-indicator and U-index; secondly, we use total waking time to calculate the duration weight. The results are presented as Supplementary Table 3.3 and 3.4. Similar results are observed as those presented in the paper. Younger, female respondents tend to have lower process benefits. Respondents with lower income status are more likely to report negative feeling as the most intense feeling and spend larger proportion of time in a negative feeling when dong activities related to food production. When using happy as the only positive feeling, respondents with education less than high school have significantly lower process benefit.

Some implications are derived from this study for public health policy makers. The results in this indicate that greater resources are needed to help offset the negative process benefits. Strategies for improving diet quality for those with negative process benefits should focus on incorporating healthy, less labor-intensive home food. Economic incentive or assistance should combine with other strategies to improve the effectiveness of these policies. For example, nutrition education delivered by dietitians or culinary educators should motivate people to find joy in home food production. As mentioned in Section 2, education for respondents with positive process benefits should focus on information on local fresh produce or new recipes and that for respondents with negative process benefits should focus on motivation to increase home food production. Other strategies are in need to help those who have receive disutility and spend less time on home-food production. Information and knowledge to better identify healthy food environment outside the home by education may be a more effective strategy as well as providing economic incentives to eat healthy food away from home. From the analysis of intensity of negative feelings, it can be seen that instruments with ability of decreasing the burden of negative feelings will increase the process benefits for individuals with income less than $50000. Studies of subjective well-being also point that reducing the impact of negative emotion is easier than boosting the pleasure to improve the happiness[81]. The results in our study show that the U-index is lower when interacting with other during the activities related to food production, indicating that interaction with family or friends leads to more process benefits. Previous studies show that children who take part in meal preparation will consume more vegetables [89]. Involving children in activities related to food production is an effective strategy to promote the process benefits and healthier intakes.

There are several limitations should be considered. First, the self-reported intensity of feeling associated with the activity may be biased due to unreliability resulting from diary recall methods. Though the design of DRM is to minimize the recall biases, it is unknown to what extent the DRM actually eliminate the biases. For example, it has been claimed that the recalled enjoyment may be different from the actual feelings when engaging the activities [77]. Second, the feelings of one selected activity may be affected by previous activities and lead to inaccurate reported intensity of feeling associated with the selected activity. Third, the findings in this study are based upon the U.S. data, they may not be generalizable to other countries, especially when the culture difference plays a vital role in food production. Fourth, we cannot perform analysis for cases of three food-related activities due to not enough observations.

Further research should focus on examining what factors contribute to negative/positive process benefits associated with home food production for a targeted population and how to enhance positive process benefits to promote home food production with improvement in dietary quality as an ultimate objective.

3.10. References

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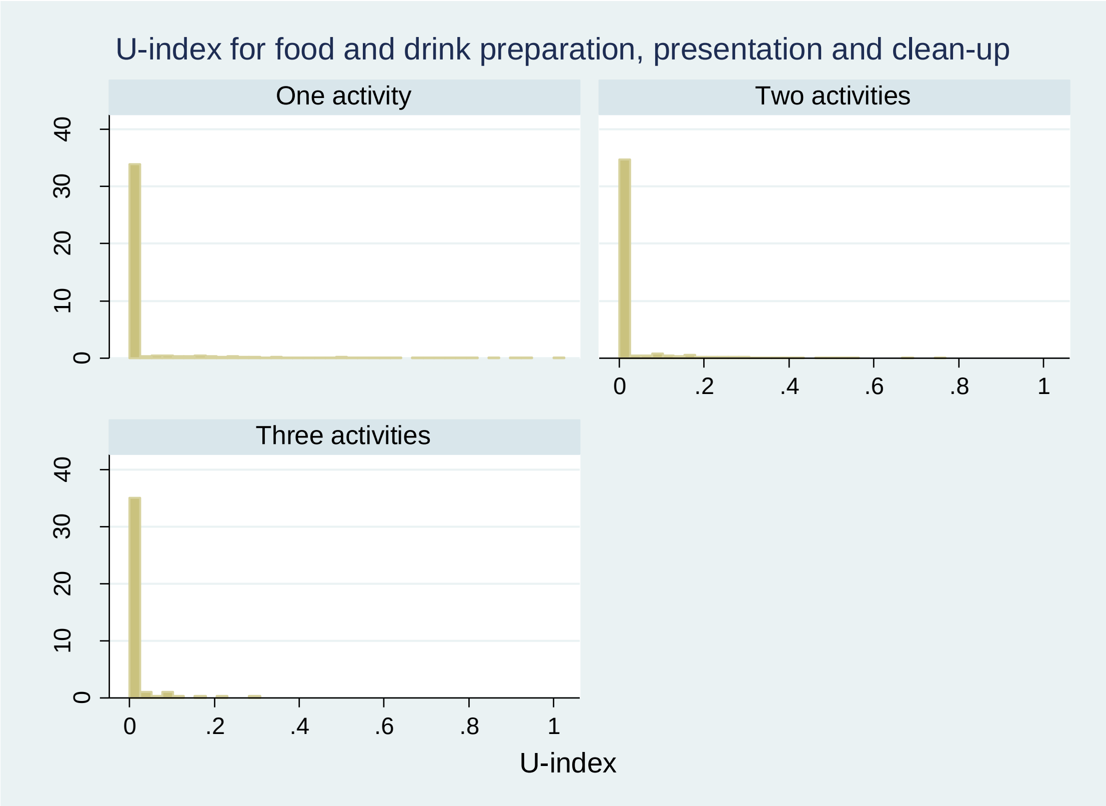

Figure 3.3. Distribution of U-index of actions in the category of food and drink preparation, presentation and clean up by number of food-related activities.

Figure 3.4. Distribution of U-index of actions in the category of food purchasing by number of food-related activities.

Figure 3.5. Frequency of stress intensity of activities in the category of food and drink preparation, presentation and clean up by income level.

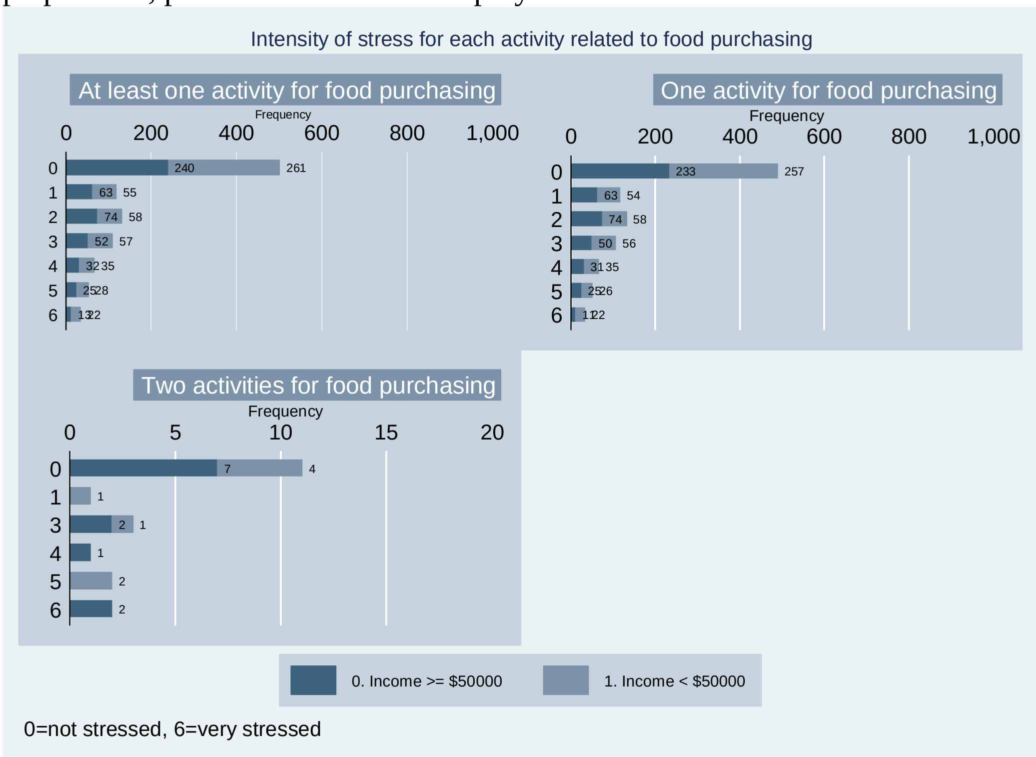

Figure 3.6. Frequency of stress intensity of activities in the category of food purchasing by income level.

Figure 3.7. Frequency of tiredness intensity of activities in the category of food and drink preparation, presentation and clean up by income level.

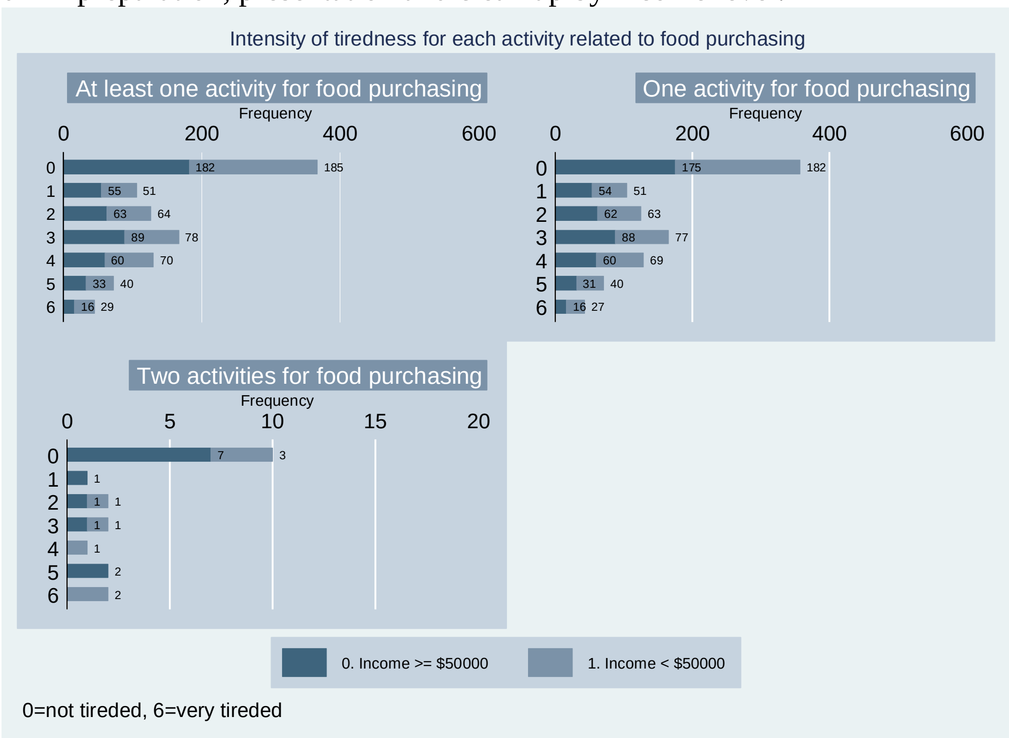

Figure 3.8. Frequency of tiredness intensity of activities in the category of food purchasing by income level.

Table 3.1. Percentage and frequency of the dominant feeling

Feeling	**Whole sample**	**Food & Drink Preparation, Presentation, & Clean-up**			**Food Purchasing**		
		One-food subsample	**Two-food subsample**	**Three-food subsample**	**One-food subsample**	**Two-food subsample**	**Three-food subsample**
	% (frequency)	**% (frequency)**	**% (frequency)**	**% (frequency)**	**% (frequency)**	**% (frequency)**	**% (frequency)**
Pain	40.85 (3812)	40.02 (2653)	44.11 (689)	52.78 (57)	39.88 (404)	45.00 (9)	- -
Sad	30.15 (2814)	29.57 (1960)	32.20 (503)	27.78 (30)	31.10 (315)	30.00 (6)	- -
Stress	43.71 (4079)	42.62 (2825)	44.11 (689)	33.33 (36)	51.23 (519)	50.00 (10)	- -
Tired	75.12 (7010)	75.65 (5015)	75.10 (1173)	72.22 (78)	72.06 (730)	70.00 (14)	- -
Happy	69.45 (6481)	69.35 (4597)	69.27 (1082)	74.07 (80)	70.09 (710)	60.00 (12)	- -
Meaning	70.25 (6556)	70.66 (4684)	71.38 (1115)	75.00 (81)	65.55 (664)	60.00 (12)	- -
Number of activities	9332	6629	1562	108	1013	20	

Note: The percentage and frequency is based on the emotional ratings associated with each activity

Table 3.2. Sample composition by demographic characteristics of survey respondents selected to report feelings during activities of food and drink preparation, presentation and clean up and food purchasing in the American Time Use Survey (ATUS) Well-Being Module, 2010, 2012 and 2013 [a]

Demographic variables	**Food and Drink preparation, presentation and clean-up**				**Food purchasing**			
	One-food subsample %	**Two-food subsample %**	**Three-food subsample %**	**P for difference**	**One-food subsample %**	**Two-food subsample %**	**Three-food subsample %**	**P for difference**
Sample Composition								
Sex								
Male	33	23	10	<0.001	42	46	-	0.5490
Female	67	77	90	<0.001	58	54	-	0.5490
Age	48.80[b] (17.80)[c]	52.02[b] (18.15)[c]	53.67[b] (21.04)[c]	0.4830	47.61[b] (16.34)[c]	52.09[b] (11.21)[c]	-	0.2384
Race								
White only	81	82	81	0.4576	85	99	-	0.3723
Black only	11	10	7	0.0134	10	1	-	0.6779
Asian only	5	6	12	0.4436	3	0	-	<0.001
Other	3	2	0	-	2	0	-	0.001
Income Level								
<$30000	32	34	38	0.6603	32	10	-	0.8977
$30000~$50000	22	20	31	0.2029	19	14	-	0.3905
$50000~$100000	29	30	22	0.5679	32	31	-	0.3154
>$100000	17	16	9	0.5379	17	45	-	0.5241
Education								
Some high school	15	17	31	0.0782	12	5	-	0.9824

Demographic variables	**Food and Drink preparation, presentation and clean-up**				**Food purchasing**			
	One-food subsample %	**Two-food subsample %**	**Three-food subsample %**	**P for difference**	**One-food subsample %**	**Two-food subsample %**	**Three-food subsample %**	**P for difference**
High school and some college	49	52	31	0.0891	50	72	-	0.3638
College and above	36	32	38	0.3010	38	23	-	0.3268
Marital Status							-	
Married	56	64	47	0.2216	56	49	-	0.5437
Widowed	8	10	14	0.2093	5	2	-	0.8611
Divorced/Separated	14	11	5	0.0891	15	49	-	0.5560
Never married	22	15	35	0.0510	24	0	-	<0.001
Number of respondents	6629	781	36		1013	10	-	
Statistics of dependent variable: Mean and Standard deviation								
U-index	0.03	0.02	0.01	<0.001	0.04	0.06	-	0.9652
	(0.11)	(0.07)	(0.04)		(0.11)	(0.13)	-	
U-indicator	0.13	0.11	0.10	0.0021	0.15	0.25	-	0.7388
	(0.34)	(0.32)	(0.30)		(0.36)	(0.44)	-	
U-intensity of Stress	1.24	1.15	0.90	0.0279	1.43	1.80	-	0.8445
	(1.72)	(1.67)	(1.47)		(1.78)	(2.31)	-	
U-intensity of tiredness	2.24	2.14	2.03	0.0004	2.00	1.85	-	0.5071
	(1.97)	(1.96)	(1.89)		(1.89)	(2.25)	-	
Other feelings								
Pain	1.07	1.12	1.57	0.1154	0.93	0.75	-	0.5511
	(1.75)	(1.77)	(1.89)		(1.62)	(1.12)	-	

Demographic variables	**Food and Drink preparation, presentation and clean-up**				**Food purchasing**			
	One-food subsample %	**Two-food subsample %**	**Three-food subsample %**	**P for difference**	**One-food subsample %**	**Two-food subsample %**	**Three-food subsample %**	**P for difference**
Sad	0.62	0.58	0.47	0.1649	0.61	0.25	-	0.0709
	(1.37)	(1.32)	(1.06)		(1.36)	(0.64)	-	
Happy	4.29	4.41	4.67	<0.001	3.99	3.80	-	0.7982
	(1.65)	(1.58)	(1.46)		(1.66)	(1.24)	-	
Meaning	4.25	4.34	4.43	0.0030	3.89	3.65	-	0.6534
	(1.93)	(1.91)	(2.08)		(1.93)	(1.50)	-	
Number of activities	6629	1562	108		1013	20	0	

[a] Percentage of the US population are adjusted for unequal probability of sampling by using Well-being module respondent weight
[b] Mean value
[c] Standard deviations in parentheses

Table 3.3. Average Process benefits and time duration for Food and Drink preparation, presentation and clean-up and food purchasing according to demographic variables by number of food-related activities in 2010, 2012 and 2013 Well-being Module [a]

Variable	**Food and Drink preparation, presentation and clean-up**						**Food purchasing [b]**			
	One-food subsample		Two-food subsample		Three-food subsample		One-food subsample		Two-food subsample	
	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities
Age group										
15-24	0.05	131.92	0.03	196.65	0.00	237.50	0.04	170.36	-	-
	(0.13)	(86.99)	(0.08)	(115.71)	(0.00)	(35.60)	(0.11)	(86.51)	-	-
25-44	0.03	161.87	0.02	203.83	0.03	259.64	0.05	194.84	0.07	195.33
	(0.11)	(95.05)	(0.08)	(104.99)	(0.06)	(226.80)	(0.13)	(96.84)	(0.17)	(127.29)
45-64	0.04	156.32	0.02	202.46	0.00	315.00	0.04	208.95	0.01	221.25
	(0.12)	(95.94)	(0.07)	(119.46)	(0.01)	(229.27)	(0.11)	(113.51)	(0.02)	(109.96)
65+	0.03	168.14	0.01	215.82	0.00	264.00	0.02	198.51	0.10	280.67
	(0.10)	(102.23)	(0.05)	(117.57)	(0.01)	(110.00)	(0.08)	(100.99)	(0.17)	(53.97)
Sex										
Female	0.04	168.29	0.02	211.36	0.01	286.25	0.04	211.20	0.07	286.20
	(0.11)	(99.83)	(0.07)	(115.68)	(0.04)	(198.75)	(0.11)	(107.74)	(0.13)	(117.32)
Male	0.03	140.97	0.02	189.26	0.01	172.25	0.04	181.99	0.04	176.40
	(0.12)	(87.61)	(0.06)	(103.99)	(0.03)	(62.71)	(0.11)	(95.66)	(0.14)	(46.23)
Race										
White only	0.03	160.76	0.02	203.11	0.01	281.58	0.05	199.97	0.03	230.33
	(0.11)	(95.55)	(0.07)	(108.54)	(0.04)	(201.47)	(0.12)	(97.94)	(0.10)	(109.34)

Variable	Food and Drink preparation, presentation and clean-up						Food purchasing [b]			
	One-food subsample		Two-food subsample		Three-food subsample		One-food subsample		Two-food subsample	
	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities
Black only	0.03	138.95	0.02	199.06	0.00	205.00	0.03	181.26	0.31	240.00
	(0.12)	(92.81)	(0.07)	(106.44)	(0.00)	(21.91)	(0.08)	(117.51)	(0.09)	(0.00)
Asian only	0.03	217.04	0.00	265.42	0.02	236.67	0.01	265.68	-	-
	(0.10)	(114.29)	(0.02)	(164.97)	(0.04)	(137.57)	(0.06)	(128.93)	-	-
Other	0.03	156.44	0.04	230.25	-	-	0.03	196.13	-	-
	(0.11)	(97.43)	(0.11)	(144.89)	-	-	(0.11)	(156.84)	-	-
Education										
Some high school	0.04	153.65	0.02	203.63	0.00	242.27	0.03	207.59	0.21	140.00
	(0.12)	(100.54)	(0.07)	(116.74)	(0.02)	(73.27)	(0.09)	(129.61)	(0.30)	(0.00)
High school and some college	0.03	154.78	0.02	208.21	0.02	280.27	0.05	196.88	0.01	246.83
	(0.12)	(96.73)	(0.08)	(122.78)	(0.06)	(256.60)	(0.13)	(105.76)	(0.02)	(128.23)
College and above	0.03	167.14	0.02	205.00	0.01	292.93	0.03	200.61	0.10	230.67
	(0.11)	(95.61)	(0.06)	(99.54)	(0.04)	(197.92)	(0.10)	(96.18)	(0.17)	(24.35)
Marital Status										
Married	0.03	177.13	0.01	216.24	0.01	214.83	0.03	219.66	0.04	206.50
	(0.10)	(98.46)	(0.06)	(104.75)	(0.04)	(75.96)	(0.09)	(106.02)	(0.12)	(81.80)
Widowed	0.03	156.23	0.02	213.63	0.00	317.50	0.02	189.48	0.00	350.00
	(0.10)	(98.01)	(0.07)	(137.10)	(0.00)	(118.20)	(0.07)	(91.00)	(0.00)	(0.00)
Divorced/Separated	0.05	140.24	0.02	177.68	0.01	459.50	0.05	179.07	0.12	241.33

Variable	Food and Drink preparation, presentation and clean-up						Food purchasing [b]			
	One-food subsample		Two-food subsample		Three-food subsample		One-food subsample		Two-food subsample	
	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities	Weighted U-Index	Total duration of food-related activities
	(0.14)	(93.50)	(0.06)	(95.11)	(0.02)	(344.59)	(0.13)	(95.31)	(0.16)	(136.85)
Never married	0.04	135.20	0.03	195.60	0.01	287.40	0.06	177.02	-	-
	(0.13)	(86.30)	(0.10)	(129.27)	(0.05)	(230.35)	(0.14)	(103.80)	-	-
Income										
Income≥$50000	0.03	165.37	0.02	210.76	0.01	246.45	0.04	203.05	0.06	202.33
	(0.10)	(92.92)	(0.06)	(112.55)	(0.02)	(90.53)	(0.11)	(101.46)	(0.12)	(102.70)
Income<$50000	0.04	155.20	0.02	199.36	0.01	293.04	0.04	195.79	0.05	274.75
	(0.13)	(99.89)	(0.07)	(108.62)	(0.04)	(223.15)	(0.12)	(105.82)	(0.15)	(94.27)
N	6629		1562		108		1013		20	

[a] U-index is imputed as proportion of time in negative emotional feeling by comparing the maximum intensity of negative feeling (e.g., tired, stressed, sad, or pain) with the maximum intensity of positive feeling (e.g., happy, meaningful). Total food-related duration is summation of time spent on all food-related activities during the survey day.

[b] no observation for three activities of food purchasing was observed

Table 3.4. The average of U-index, U-indicator and U-intensity, and other feelings in three subsamples of activities related to food production and food purchasing

Variable	**Food & Drink Preparation, Presentation, & Clean-up**			**Food Purchasing**		
	One-food subsample	Two-food subsample	Three-food subsample	One-food subsample	Two-food subsample	Three-food subsample
U-index	0.03	0.02	0.01	0.04	0.06	-
	(0.11)	(0.07)	(0.04)	(0.11)	(0.13)	-
U-indicator	0.13	0.11	0.10	0.15	0.25	-
	(0.34)	(0.32)	(0.30)	(0.36)	(0.44)	-
U-intensity of Stress	1.24	1.15	0.90	1.43	1.80	-
	(1.72)	(1.67)	(1.47)	(1.78)	(2.31)	-
U-intensity of tiredness	2.24	2.14	2.03	2.00	1.85	-
	(1.97)	(1.96)	(1.89)	(1.89)	(2.25)	-
Other feelings						
Pain	1.07	1.12	1.57	0.93	0.75	-
	(1.75)	(1.77)	(1.89)	(1.62)	(1.12)	-
Sad	0.62	0.58	0.47	0.61	0.25	-
	(1.37)	(1.32)	(1.06)	(1.36)	(0.64)	-
Happy	4.29	4.41	4.67	3.99	3.80	-
	(1.65)	(1.58)	(1.46)	(1.66)	(1.24)	-
Meaning	4.25	4.34	4.43	3.89	3.65	-
	(1.93)	(1.91)	(2.08)	(1.93)	(1.50)	-
N	6629	1562	108	1013	20	0

Table 3.5. Average marginal effects of fractional logit modeling the relationship between u-index and demographic and socioeconomic factors. Dependent variable is U-index.

Variable	One Activity of food and drink preparation, presentation and clean up	Two activities of food and drink preparation, presentation and clean up	One activity of food purchasing
Age	-0.0004***	-0.0005***	-0.0004
	(0.0001)	(0.0002)	(0.0002)
Male	-0.0049	-0.0099***	-0.0062
	(0.0031)	(0.0038)	(0.0075)
White	0.0039	0.0066	0.0237***
	(0.0040)	(0.0051)	(0.0077)
Asian	0.0024	-0.0067	-0.0043
	(0.0078)	(0.0064)	(0.0150)
Otherrace	-0.0023	0.0185	0.0001
	(0.0089)	(0.0134)	(0.0228)
Income <$50000	0.0076**	-0.0024	0.0046
	(0.0033)	(0.0044)	(0.0079)
High school & some college	-0.0059	-0.0072	0.0201
	(0.0047)	(0.0075)	(0.0129)
College and above	-0.0064	-0.0125	-0.0010
	(0.0052)	(0.0077)	(0.0126)
Married	-0.0075*	-0.0051	-0.0205*
	(0.0044)	(0.0059)	(0.0106)
Widowed	-0.0080	0.0069	-0.0239
	(0.0062)	(0.0095)	(0.0181)
Divorced/separated	0.0090	-0.0085	-0.0103
	(0.0056)	(0.0054)	(0.0121)
If time for breakfast	-0.0093**	0.0053	-0.0203
	(0.0041)	(0.0067)	(0.0190)
If time for dinner	0.0109***	0.0063	0.0268**
	(0.0034)	(0.0043)	(0.0115)
If weekend	-0.0046*	0.0020	0.0077
	(0.0028)	(0.0038)	(0.0072)
Household size	0.0013	-0.0082**	-0.0044
	(0.0020)	(0.0036)	(0.0051)
Number of household children < 18	-0.0030	-0.0001	0.0070
	(0.0027)	(0.0044)	(0.0063)
With family	-0.0117***	-0.0046	-0.0141*
	(0.0032)	(0.0044)	(0.0077)
With other people	-0.0181***	-0.0082	-0.0166*
	(0.0044)	(0.0057)	(0.0097)
Year of 2012	-0.0042	-0.0087**	0.0000
	(0.0035)	(0.0041)	(0.0083)
Year of 2013	-0.0059*	-0.0029	0.0013
	(0.0034)	(0.0052)	(0.0085)

Observations	6,506	1,538	996

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.6. Average marginal effects of Logit regression for the relationship between u-index and demographic and socioeconomic factors. Dependent variable is U-indicator.

Variable	One Activity of food and drink preparation, presentation and clean up	Two activities of food and drink preparation, presentation and clean up [a]	One activity of food purchasing
Age	-0.0009**	-0.0018***	-0.0016*
	(0.0004)	(0.0007)	(0.0009)
Male	-0.0381***	-0.0502***	-0.0270
	(0.0087)	(0.0189)	(0.0242)
White	0.0324***	0.0325	0.0563*
	(0.0112)	(0.0264)	(0.0295)
Asian	0.0486*	-0.0299	-0.0493
	(0.0252)	(0.0460)	(0.0498)
Otherrace	0.0175	0.0554	-0.0559
	(0.0285)	(0.0478)	(0.0591)
Income <$50000	0.0008	0.0014	-0.0012
	(0.0097)	(0.0222)	(0.0262)
High school & some college	-0.0124	-0.0289	0.0594
	(0.0138)	(0.0327)	(0.0438)
College and above	-0.0100	-0.0278	0.0014
	(0.0148)	(0.0353)	(0.0446)
Married	-0.0409***	-0.0363	-0.0398
	(0.0137)	(0.0302)	(0.0343)
Widowed	-0.0290	0.0583	-0.0705
	(0.0200)	(0.0504)	(0.0589)
Divorced/separated	0.0093	-0.0253	-0.0201
	(0.0162)	(0.0312)	(0.0385)
If time for breakfast	-0.0344***	0.0056	-0.0882*
	(0.0118)	(0.0244)	(0.0490)
If time for dinner	0.0425***	0.0336*	0.0567*
	(0.0099)	(0.0199)	(0.0334)
If weekend	-0.0152*	0.0140	0.0039
	(0.0084)	(0.0185)	(0.0239)
Household size	0.0008	-0.0091	-0.0017
	(0.0063)	(0.0156)	(0.0180)
Number of household children < 18	0.0029	-0.0115	0.0027
	(0.0078)	(0.0184)	(0.0209)
With family	-0.0505***	-0.0186	-0.0528*
	(0.0096)	(0.0198)	(0.0287)
With other people	-0.0780***	-0.0467	-0.0596*
	(0.0130)	(0.0293)	(0.0317)
Duration	-0.0259**	-0.1062***	0.0090
	(0.0108)	(0.0244)	(0.0211)
Year of 2012	-0.0259***	-0.0496**	-0.0009
	(0.0101)	(0.0208)	(0.0280)

Variable	**One Activity of food and drink preparation, presentation and clean up**	**Two activities of food and drink preparation, presentation and clean up [a]**	**One activity of food purchasing**
Year of 2013	-0.0177*	-0.0185	-0.0076
	(0.0103)	(0.0260)	(0.0269)
Observations	6,506	1,538	996

[a] multilevel logit model is utilized in case of two or more activities within the same individual. Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3.7. Average marginal effects of the relationship between the intensity of stress and demographic and socioeconomic factors in case of one activity of food and drink preparation, presentation and clean up. Dependent variable is intensity of stress.

Variable	**Stress intensity of 0**	**Stress intensity of 1**	**Stress intensity of 2**	**Stress intensity of 3**	**Stress intensity of 4**	**Stress intensity of 5**	**Stress intensity of 6**
Age	0.0016***	-0.0003***	-0.0004***	-0.0004***	-0.0003***	-0.0002***	-0.0001**
	(0.0005)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Male	0.0397***	-0.0040***	-0.0077***	-0.0092***	-0.0084***	-0.0055***	-0.0048***
	(0.0122)	(0.0013)	(0.0024)	(0.0028)	(0.0026)	(0.0017)	(0.0015)
White	-0.0331*	0.0035	0.0065*	0.0076*	0.0070*	0.0045*	0.0040*
	(0.0191)	(0.0022)	(0.0039)	(0.0044)	(0.0039)	(0.0025)	(0.0022)
Asian	-0.0553	0.0054*	0.0105*	0.0128	0.0119	0.0078	0.0069
	(0.0342)	(0.0031)	(0.0063)	(0.0079)	(0.0075)	(0.0051)	(0.0045)
Otherrace	-0.0458	0.0046	0.0088	0.0106	0.0097	0.0064	0.0056
	(0.0423)	(0.0038)	(0.0079)	(0.0098)	(0.0093)	(0.0062)	(0.0055)
Income <$50000	-0.0149	0.0014	0.0028	0.0035	0.0032	0.0021	0.0019
	(0.0134)	(0.0013)	(0.0025)	(0.0031)	(0.0029)	(0.0019)	(0.0017)
High school & some college	0.0509**	-0.0046***	-0.0095**	-0.0118**	-0.0111**	-0.0074**	-0.0065**
	(0.0215)	(0.0017)	(0.0038)	(0.0050)	(0.0048)	(0.0033)	(0.0030)
College and above	0.0251	-0.0020	-0.0045	-0.0058	-0.0056	-0.0038	-0.0034
	(0.0223)	(0.0016)	(0.0039)	(0.0052)	(0.0050)	(0.0034)	(0.0031)
Married	0.0189	-0.0019	-0.0036	-0.0044	-0.0040	-0.0026	-0.0023
	(0.0189)	(0.0018)	(0.0036)	(0.0044)	(0.0041)	(0.0027)	(0.0024)
Widowed	0.0366	-0.0039	-0.0072	-0.0085	-0.0077	-0.0050	-0.0044
	(0.0294)	(0.0033)	(0.0059)	(0.0068)	(0.0061)	(0.0039)	(0.0034)
Divorced/separated	-0.0384*	0.0029*	0.0068*	0.0089*	0.0087*	0.0058*	0.0052*
	(0.0217)	(0.0017)	(0.0039)	(0.0051)	(0.0049)	(0.0033)	(0.0030)
If time for breakfast	0.0031	-0.0003	-0.0006	-0.0007	-0.0007	-0.0004	-0.0004

Variable	Stress intensity of 0	Stress intensity of 1	Stress intensity of 2	Stress intensity of 3	Stress intensity of 4	Stress intensity of 5	Stress intensity of 6
	(0.0172)	(0.0017)	(0.0033)	(0.0040)	(0.0037)	(0.0024)	(0.0021)
If time for dinner	-0.0128	0.0012	0.0024	0.0030	0.0028	0.0018	0.0016
	(0.0129)	(0.0012)	(0.0024)	(0.0030)	(0.0028)	(0.0019)	(0.0016)
If weekend	0.0238**	-0.0023**	-0.0045**	-0.0055**	-0.0051**	-0.0034**	-0.0030**
	(0.0116)	(0.0011)	(0.0022)	(0.0027)	(0.0025)	(0.0017)	(0.0015)
Household size	0.0023	-0.0002	-0.0004	-0.0005	-0.0005	-0.0003	-0.0003
	(0.0086)	(0.0008)	(0.0016)	(0.0020)	(0.0018)	(0.0012)	(0.0011)
KidsNumber	-0.0254**	0.0024**	0.0048**	0.0059**	0.0055**	0.0036**	0.0032**
	(0.0104)	(0.0010)	(0.0020)	(0.0024)	(0.0023)	(0.0015)	(0.0013)
With family	-0.0076	0.0007	0.0015	0.0018	0.0016	0.0011	0.0010
	(0.0135)	(0.0013)	(0.0026)	(0.0031)	(0.0029)	(0.0019)	(0.0017)
With other people	-0.0251	0.0023	0.0047	0.0058	0.0055	0.0036	0.0032
	(0.0210)	(0.0017)	(0.0038)	(0.0049)	(0.0047)	(0.0031)	(0.0028)
Duration	-0.0223***	0.0021**	0.0042***	0.0052**	0.0048***	0.0032**	0.0028**
	(0.0086)	(0.0008)	(0.0016)	(0.0020)	(0.0019)	(0.0012)	(0.0011)
Year of 2012	0.0161	-0.0016	-0.0031	-0.0037	-0.0034	-0.0023	-0.0020
	(0.0138)	(0.0014)	(0.0027)	(0.0032)	(0.0030)	(0.0019)	(0.0017)
Year of 2013	-0.0043	0.0004	0.0008	0.0010	0.0009	0.0006	0.0006
	(0.0141)	(0.0013)	(0.0026)	(0.0033)	(0.0031)	(0.0020)	(0.0018)
Observations	6,492	6,492	6,492	6,492	6,492	6,492	6,492

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.8. Average marginal effects of the relationship between the intensity of stress and demographic and socioeconomic factors in case of two activities of food and drink preparation, presentation and clean up. Dependent variable is intensity of stress.

Variable	**Stress intensity of 0**	**Stress intensity of 1**	**Stress intensity of 2**	**Stress intensity of 3**	**Stress intensity of 4**	**Stress intensity of 5**	**Stress intensity of 6**
Age	0.0026**	-0.0003**	-0.0007**	-0.0006**	-0.0005**	-0.0003**	-0.0003**
	(0.0011)	(0.0001)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0001)
Male	0.0954***	-0.0114**	-0.0242***	-0.0211***	-0.0167***	-0.0126***	-0.0094**
	(0.0347)	(0.0049)	(0.0092)	(0.0077)	(0.0061)	(0.0047)	(0.0037)
White	-0.1057**	0.0136*	0.0273**	0.0232**	0.0181**	0.0135**	0.0100**
	(0.0466)	(0.0074)	(0.0129)	(0.0101)	(0.0076)	(0.0057)	(0.0044)
Asian	-0.1794**	0.0184**	0.0430**	0.0400**	0.0330**	0.0255**	0.0195*
	(0.0769)	(0.0077)	(0.0175)	(0.0175)	(0.0160)	(0.0125)	(0.0103)
Otherrace	0.0028	-0.0005	-0.0008	-0.0006	-0.0004	-0.0003	-0.0002
	(0.1090)	(0.0179)	(0.0304)	(0.0231)	(0.0169)	(0.0120)	(0.0087)
Income <$50000	-0.0796**	0.0083**	0.0193**	0.0178**	0.0145**	0.0112**	0.0085**
	(0.0358)	(0.0039)	(0.0089)	(0.0083)	(0.0068)	(0.0050)	(0.0040)
High school & some college	-0.0411	0.0049	0.0104	0.0091	0.0072	0.0055	0.0041
	(0.0534)	(0.0069)	(0.0138)	(0.0118)	(0.0092)	(0.0068)	(0.0051)
College and above	-0.0738	0.0080	0.0180	0.0164	0.0134	0.0102	0.0078
	(0.0575)	(0.0071)	(0.0148)	(0.0129)	(0.0102)	(0.0075)	(0.0057)
Married	0.0752	-0.0077*	-0.0181	-0.0168	-0.0138	-0.0107	-0.0081
	(0.0500)	(0.0046)	(0.0116)	(0.0113)	(0.0096)	(0.0076)	(0.0060)
Widowed	-0.0622	0.0033	0.0125	0.0142	0.0129	0.0107	0.0085
	(0.0699)	(0.0036)	(0.0136)	(0.0159)	(0.0148)	(0.0126)	(0.0103)
Divorced/separated	0.0056	-0.0004	-0.0012	-0.0013	-0.0011	-0.0009	-0.0007
	(0.0535)	(0.0042)	(0.0119)	(0.0121)	(0.0105)	(0.0083)	(0.0065)

Variable	**Stress intensity of 0**	**Stress intensity of 1**	**Stress intensity of 2**	**Stress intensity of 3**	**Stress intensity of 4**	**Stress intensity of 5**	**Stress intensity of 6**
If time for breakfast	0.0228	-0.0024	-0.0056	-0.0051	-0.0041	-0.0032	-0.0024
	(0.0369)	(0.0041)	(0.0092)	(0.0083)	(0.0066)	(0.0050)	(0.0038)
If time for dinner	0.0035	-0.0004	-0.0008	-0.0008	-0.0006	-0.0005	-0.0004
	(0.0272)	(0.0028)	(0.0065)	(0.0061)	(0.0050)	(0.0039)	(0.0029)
If weekend	0.0743**	-0.0073**	-0.0177**	-0.0167**	-0.0138**	-0.0107**	-0.0081**
	(0.0312)	(0.0031)	(0.0076)	(0.0072)	(0.0060)	(0.0047)	(0.0038)
Household size	-0.0249	0.0025	0.0060	0.0056	0.0046	0.0035	0.0027
	(0.0209)	(0.0021)	(0.0050)	(0.0047)	(0.0039)	(0.0030)	(0.0023)
KidsNumber	0.0087	-0.0009	-0.0021	-0.0020	-0.0016	-0.0012	-0.0009
	(0.0259)	(0.0026)	(0.0062)	(0.0058)	(0.0048)	(0.0037)	(0.0028)
With family	0.0010	-0.0001	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001
	(0.0303)	(0.0031)	(0.0073)	(0.0068)	(0.0056)	(0.0043)	(0.0033)
With other people	-0.0312	0.0029	0.0073	0.0070	0.0059	0.0046	0.0035
	(0.0504)	(0.0042)	(0.0114)	(0.0114)	(0.0098)	(0.0077)	(0.0060)
Duration	-0.0058	0.0006	0.0014	0.0013	0.0011	0.0008	0.0006
	(0.0228)	(0.0023)	(0.0055)	(0.0051)	(0.0042)	(0.0032)	(0.0025)
Year of 2012	-0.0098	0.0010	0.0024	0.0022	0.0018	0.0014	0.0010
	(0.0344)	(0.0036)	(0.0084)	(0.0077)	(0.0063)	(0.0048)	(0.0037)
Year of 2013	-0.0277	0.0027	0.0066	0.0062	0.0051	0.0040	0.0030
	(0.0387)	(0.0037)	(0.0092)	(0.0088)	(0.0073)	(0.0056)	(0.0043)
Observations	1,533	1,533	1,533	1,533	1,533	1,533	1,533

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3.9. Average marginal effects of the relationship between the intensity of stress and demographic and socioeconomic factors in case of one activity of food purchasing. Dependent variable is intensity of stress.

Variable	Stress intensity of 0	Stress intensity of 1	Stress intensity of 2	Stress intensity of 3	Stress intensity of 4	Stress intensity of 5	Stress intensity of 6
Age	0.0026**	-0.0004***	-0.0007**	-0.0006**	-0.0004*	-0.0003	-0.0002
	(0.0012)	(0.0001)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
Male	0.0694**	-0.0034*	-0.0128**	-0.0175**	-0.0141**	-0.0126**	-0.0090**
	(0.0299)	(0.0018)	(0.0058)	(0.0077)	(0.0062)	(0.0055)	(0.0041)
White	-0.1059**	0.0075	0.0213**	0.0265**	0.0204**	0.0178**	0.0124**
	(0.0456)	(0.0050)	(0.0105)	(0.0115)	(0.0083)	(0.0073)	(0.0048)
Asian	0.0810	-0.0119	-0.0198	-0.0193	-0.0129	-0.0103	-0.0068
	(0.0721)	(0.0114)	(0.0179)	(0.0171)	(0.0114)	(0.0090)	(0.0061)
Otherrace	-0.1572	0.0076	0.0289*	0.0394	0.0320	0.0288	0.0206
	(0.0985)	(0.0055)	(0.0151)	(0.0248)	(0.0225)	(0.0219)	(0.0168)
Income <$50000	-0.0303	0.0013	0.0054	0.0076	0.0063	0.0057	0.0041
	(0.0333)	(0.0014)	(0.0059)	(0.0084)	(0.0069)	(0.0063)	(0.0046)
High school & some college	0.0464	-0.0017	-0.0081	-0.0116	-0.0097	-0.0089	-0.0064
	(0.0614)	(0.0016)	(0.0100)	(0.0154)	(0.0133)	(0.0125)	(0.0092)
College and above	0.0202	-0.0005	-0.0033	-0.0051	-0.0043	-0.0040	-0.0029
	(0.0631)	(0.0012)	(0.0101)	(0.0158)	(0.0137)	(0.0129)	(0.0095)
Married	-0.0197	0.0010	0.0037	0.0049	0.0040	0.0035	0.0025
	(0.0452)	(0.0025)	(0.0086)	(0.0114)	(0.0090)	(0.0080)	(0.0056)
Widowed	0.0234	-0.0017	-0.0047	-0.0058	-0.0045	-0.0039	-0.0027
	(0.0809)	(0.0063)	(0.0166)	(0.0201)	(0.0154)	(0.0133)	(0.0093)
Divorced/separated	-0.0626	0.0021	0.0109	0.0157	0.0131	0.0120	0.0087
	(0.0463)	(0.0022)	(0.0083)	(0.0118)	(0.0098)	(0.0089)	(0.0064)
If time for breakfast	-0.0241	0.0008	0.0041	0.0060	0.0051	0.0047	0.0034
	(0.1000)	(0.0022)	(0.0163)	(0.0250)	(0.0216)	(0.0201)	(0.0149)

Variable	**Stress intensity of 0**	**Stress intensity of 1**	**Stress intensity of 2**	**Stress intensity of 3**	**Stress intensity of 4**	**Stress intensity of 5**	**Stress intensity of 6**
If time for dinner	-0.0529	0.0014*	0.0089	0.0133	0.0113	0.0104	0.0076
	(0.0386)	(0.0008)	(0.0060)	(0.0098)	(0.0086)	(0.0082)	(0.0061)
If weekend	0.0465	-0.0018	-0.0082	-0.0117	-0.0097	-0.0088	-0.0064
	(0.0305)	(0.0012)	(0.0054)	(0.0077)	(0.0065)	(0.0059)	(0.0045)
Household size	0.0164	-0.0007	-0.0029	-0.0041	-0.0034	-0.0031	-0.0022
	(0.0196)	(0.0009)	(0.0035)	(0.0049)	(0.0041)	(0.0037)	(0.0027)
KidsNumber	-0.0404	0.0017	0.0072	0.0101	0.0083	0.0076	0.0054
	(0.0253)	(0.0012)	(0.0046)	(0.0064)	(0.0054)	(0.0048)	(0.0035)
With family	-0.0233	0.0009	0.0041	0.0059	0.0049	0.0044	0.0032
	(0.0371)	(0.0013)	(0.0065)	(0.0093)	(0.0078)	(0.0071)	(0.0052)
With other people	0.0087	-0.0004	-0.0016	-0.0022	-0.0018	-0.0016	-0.0011
	(0.0442)	(0.0024)	(0.0083)	(0.0111)	(0.0089)	(0.0079)	(0.0056)
Duration	-0.0338	0.0014	0.0061	0.0085	0.0070	0.0063	0.0046
	(0.0300)	(0.0013)	(0.0054)	(0.0075)	(0.0062)	(0.0057)	(0.0042)
Year of 2012	0.0336	-0.0017	-0.0062	-0.0084	-0.0068	-0.0061	-0.0044
	(0.0352)	(0.0019)	(0.0066)	(0.0089)	(0.0072)	(0.0064)	(0.0047)
Year of 2013	-0.0067	0.0002	0.0011	0.0017	0.0014	0.0013	0.0009
	(0.0342)	(0.0011)	(0.0058)	(0.0086)	(0.0072)	(0.0066)	(0.0048)
Observations	995	995	995	995	995	995	995

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.10. Average marginal effects of the relationship between the intensity of tiredness and demographic and socioeconomic factors in case of one activity of food and drink preparation, presentation and clean up. Dependent variable is intensity of tiredness.

Variable	Tiredness intensity of 0	Tiredness intensity of 1	Tiredness intensity of 2	Tiredness intensity of 3	Tiredness intensity of 4	Tiredness intensity of 5	Tiredness intensity of 6
Age	0.0026***	0.0002***	-0.0001	-0.0006***	-0.0009***	-0.0007***	-0.0006***
	(0.0004)	(0.0000)	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Male	0.0735***	0.0068***	0.0009*	-0.0143***	-0.0258***	-0.0214***	-0.0198***
	(0.0101)	(0.0009)	(0.0005)	(0.0021)	(0.0036)	(0.0029)	(0.0027)
White	-0.0659***	-0.0056***	-0.0002	0.0132***	0.0228***	0.0186***	0.0171***
	(0.0178)	(0.0012)	(0.0007)	(0.0040)	(0.0060)	(0.0046)	(0.0040)
Asian	0.0019	0.0001	-0.0001	-0.0004	-0.0006	-0.0005	-0.0004
	(0.0296)	(0.0017)	(0.0011)	(0.0067)	(0.0098)	(0.0073)	(0.0064)
Otherrace	-0.0973***	-0.0096**	-0.0024	0.0179***	0.0343**	0.0294**	0.0277**
	(0.0375)	(0.0048)	(0.0032)	(0.0057)	(0.0136)	(0.0130)	(0.0130)
Income <$50000	-0.0107	-0.0011	-0.0003	0.0019	0.0038	0.0033	0.0031
	(0.0107)	(0.0011)	(0.0003)	(0.0019)	(0.0038)	(0.0033)	(0.0031)
High school & some college	-0.0032	-0.0003	-0.0001	0.0006	0.0012	0.0010	0.0009
	(0.0171)	(0.0017)	(0.0005)	(0.0031)	(0.0061)	(0.0052)	(0.0050)
College and above	0.0015	0.0002	0.0000	-0.0003	-0.0005	-0.0005	-0.0004
	(0.0177)	(0.0018)	(0.0005)	(0.0032)	(0.0063)	(0.0054)	(0.0051)
Married	0.0116	0.0012	0.0003	-0.0021	-0.0041	-0.0035	-0.0033
	(0.0154)	(0.0016)	(0.0005)	(0.0028)	(0.0055)	(0.0047)	(0.0045)
Widowed	0.0107	0.0011	0.0003	-0.0019	-0.0038	-0.0033	-0.0031
	(0.0242)	(0.0024)	(0.0006)	(0.0045)	(0.0086)	(0.0073)	(0.0069)
Divorced/separated	-0.0176	-0.0020	-0.0008	0.0029	0.0063	0.0057	0.0055
	(0.0172)	(0.0020)	(0.0008)	(0.0029)	(0.0062)	(0.0056)	(0.0054)

Variable	**Tiredness intensity of 0**	**Tiredness intensity of 1**	**Tiredness intensity of 2**	**Tiredness intensity of 3**	**Tiredness intensity of 4**	**Tiredness intensity of 5**	**Tiredness intensity of 6**
If time for breakfast	0.0307**	0.0029**	0.0005**	-0.0059*	-0.0108**	-0.0090**	-0.0084**
	(0.0149)	(0.0013)	(0.0002)	(0.0030)	(0.0052)	(0.0042)	(0.0039)
If time for dinner	-0.0795***	-0.0094***	-0.0042***	0.0132***	0.0291***	0.0259***	0.0249***
	(0.0099)	(0.0014)	(0.0009)	(0.0017)	(0.0038)	(0.0035)	(0.0035)
If weekend	0.0422***	0.0044***	0.0013***	-0.0076***	-0.0151***	-0.0130***	-0.0123***
	(0.0094)	(0.0010)	(0.0004)	(0.0018)	(0.0034)	(0.0029)	(0.0028)
Household size	0.0010	0.0001	0.0000	-0.0002	-0.0004	-0.0003	-0.0003
	(0.0069)	(0.0007)	(0.0002)	(0.0012)	(0.0024)	(0.0021)	(0.0020)
KidsNumber	-0.0081	-0.0008	-0.0002	0.0014	0.0029	0.0025	0.0024
	(0.0083)	(0.0009)	(0.0003)	(0.0015)	(0.0030)	(0.0026)	(0.0024)
With family	0.0025	0.0003	0.0001	-0.0004	-0.0009	-0.0008	-0.0007
	(0.0112)	(0.0012)	(0.0004)	(0.0020)	(0.0040)	(0.0034)	(0.0033)
With other people	0.0234	0.0022	0.0004*	-0.0044	-0.0082	-0.0069	-0.0065
	(0.0175)	(0.0016)	(0.0002)	(0.0034)	(0.0061)	(0.0051)	(0.0047)
Duration	-0.0072	-0.0007	-0.0002	0.0013	0.0026	0.0022	0.0021
	(0.0081)	(0.0008)	(0.0003)	(0.0015)	(0.0029)	(0.0025)	(0.0024)
Year of 2012	0.0127	0.0013	0.0004	-0.0023	-0.0045	-0.0039	-0.0037
	(0.0113)	(0.0011)	(0.0003)	(0.0020)	(0.0040)	(0.0034)	(0.0033)
Year of 2013	0.0048	0.0005	0.0002	-0.0008	-0.0017	-0.0015	-0.0014
	(0.0114)	(0.0012)	(0.0004)	(0.0020)	(0.0041)	(0.0036)	(0.0034)
Observations	6,486	6,486	6,486	6,486	6,486	6,486	6,486

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.11. Average marginal effects of the relationship between the intensity of tiredness and demographic and socioeconomic factors in case of two activities of food and drink preparation, presentation and clean up. Dependent variable is intensity of tiredness.

Variable	Tiredness intensity of 0	Tiredness intensity of 1	Tiredness intensity of 2	Tiredness intensity of 3	Tiredness intensity of 4	Tiredness intensity of 5	Tiredness intensity of 6
Age	0.0027**	0.0001	-0.0001	-0.0006**	-0.0009**	-0.0007**	-0.0005**
	(0.0011)	(0.0001)	(0.0001)	(0.0003)	(0.0004)	(0.0003)	(0.0003)
Male	0.1121***	0.0052***	-0.0027	-0.0265***	-0.0374***	-0.0287***	-0.0221***
	(0.0312)	(0.0015)	(0.0023)	(0.0080)	(0.0102)	(0.0077)	(0.0062)
White	-0.0790	-0.0039**	0.0015	0.0183	0.0265*	0.0206*	0.0160*
	(0.0483)	(0.0017)	(0.0027)	(0.0124)	(0.0157)	(0.0114)	(0.0083)
Asian	0.0255	0.0004	-0.0017	-0.0067	-0.0079	-0.0055	-0.0040
	(0.0820)	(0.0013)	(0.0060)	(0.0218)	(0.0251)	(0.0175)	(0.0128)
Otherrace	-0.0883	-0.0047	0.0012	0.0201	0.0298	0.0235	0.0183
	(0.0874)	(0.0063)	(0.0037)	(0.0183)	(0.0304)	(0.0255)	(0.0209)
Income <$50000	-0.0378	-0.0024	-0.0002	0.0080	0.0131	0.0108	0.0086
	(0.0289)	(0.0018)	(0.0006)	(0.0061)	(0.0099)	(0.0082)	(0.0067)
High school & some college	-0.0610	-0.0028	0.0016	0.0144	0.0203	0.0155	0.0119
	(0.0481)	(0.0017)	(0.0025)	(0.0121)	(0.0156)	(0.0116)	(0.0086)
College and above	-0.0874*	-0.0047**	0.0010	0.0197	0.0296*	0.0234*	0.0183*
	(0.0500)	(0.0021)	(0.0025)	(0.0124)	(0.0164)	(0.0124)	(0.0095)
Married	0.0104	0.0007	0.0001	-0.0022	-0.0036	-0.0030	-0.0024
	(0.0421)	(0.0029)	(0.0006)	(0.0086)	(0.0148)	(0.0123)	(0.0100)
Widowed	-0.0083	-0.0006	-0.0002	0.0016	0.0029	0.0025	0.0020
	(0.0620)	(0.0047)	(0.0015)	(0.0121)	(0.0219)	(0.0188)	(0.0154)
Divorced/separated	0.0235	0.0015	0.0001	-0.0050	-0.0081	-0.0067	-0.0053
	(0.0450)	(0.0029)	(0.0007)	(0.0096)	(0.0156)	(0.0128)	(0.0102)
If time for breakfast	0.0253	0.0015	-0.0001	-0.0055	-0.0087	-0.0070	-0.0056
	(0.0340)	(0.0019)	(0.0005)	(0.0077)	(0.0116)	(0.0091)	(0.0071)
If time for dinner	-0.0692***	-0.0053**	-0.0017	0.0137***	0.0247***	0.0209***	0.0169***

Variable	Tiredness intensity of 0	Tiredness intensity of 1	Tiredness intensity of 2	Tiredness intensity of 3	Tiredness intensity of 4	Tiredness intensity of 5	Tiredness intensity of 6
	(0.0220)	(0.0021)	(0.0014)	(0.0045)	(0.0081)	(0.0070)	(0.0062)
If weekend	0.0832***	0.0059***	0.0013	-0.0170***	-0.0293***	-0.0244***	-0.0197***
	(0.0271)	(0.0023)	(0.0014)	(0.0057)	(0.0099)	(0.0083)	(0.0070)
Household size	0.0158	0.0010	0.0001	-0.0033	-0.0055	-0.0045	-0.0037
	(0.0218)	(0.0015)	(0.0003)	(0.0046)	(0.0076)	(0.0063)	(0.0051)
KidsNumber	-0.0193	-0.0013	-0.0002	0.0040	0.0067	0.0055	0.0044
	(0.0255)	(0.0017)	(0.0004)	(0.0053)	(0.0089)	(0.0073)	(0.0059)
With family	-0.0043	-0.0003	-0.0000	0.0009	0.0015	0.0012	0.0010
	(0.0270)	(0.0017)	(0.0001)	(0.0058)	(0.0094)	(0.0076)	(0.0060)
With other people	-0.0787**	-0.0070	-0.0037	0.0136**	0.0284**	0.0256*	0.0216*
	(0.0380)	(0.0043)	(0.0035)	(0.0056)	(0.0141)	(0.0139)	(0.0127)
Duration	-0.0145	-0.0010	-0.0001	0.0030	0.0050	0.0042	0.0033
	(0.0138)	(0.0009)	(0.0002)	(0.0029)	(0.0048)	(0.0040)	(0.0032)
Year of 2012	0.0172	0.0011	-0.0000	-0.0037	-0.0059	-0.0048	-0.0038
	(0.0307)	(0.0019)	(0.0003)	(0.0067)	(0.0106)	(0.0085)	(0.0067)
Year of 2013	-0.0185	-0.0014	-0.0004	0.0037	0.0065	0.0055	0.0045
	(0.0321)	(0.0024)	(0.0008)	(0.0063)	(0.0114)	(0.0097)	(0.0079)
Observations	1,530	1,530	1,530	1,530	1,530	1,530	1,530

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.12. Average marginal effects of the relationship between the intensity of tiredness and demographic and socioeconomic factors in case of one activity of food purchasing. Dependent variable is intensity of tiredness.

Variable	Tiredness intensity of 0	Tiredness intensity of 1	Tiredness intensity of 2	Tiredness intensity of 3	Tiredness intensity of 4	Tiredness intensity of 5	Tiredness intensity of 6
Age	0.0017	0.0001	-0.0001	-0.0004	-0.0006	-0.0004	-0.0003
	(0.0011)	(0.0001)	(0.0001)	(0.0003)	(0.0004)	(0.0003)	(0.0002)
Male	0.1317***	0.0088***	-0.0058**	-0.0335***	-0.0462***	-0.0326***	-0.0224***
	(0.0265)	(0.0024)	(0.0025)	(0.0074)	(0.0098)	(0.0072)	(0.0054)
White	-0.0529	-0.0032*	0.0025	0.0133	0.0182	0.0130	0.0090
	(0.0422)	(0.0019)	(0.0030)	(0.0111)	(0.0140)	(0.0096)	(0.0067)
Asian	-0.0602	-0.0038	0.0027	0.0150	0.0209	0.0150	0.0104
	(0.0697)	(0.0055)	(0.0031)	(0.0170)	(0.0247)	(0.0182)	(0.0131)
Otherrace	-0.0314	-0.0016	0.0018	0.0081	0.0106	0.0074	0.0050
	(0.0953)	(0.0058)	(0.0048)	(0.0241)	(0.0328)	(0.0233)	(0.0161)
Income <$50000	-0.0245	-0.0019	0.0007	0.0059	0.0088	0.0065	0.0046
	(0.0294)	(0.0023)	(0.0009)	(0.0071)	(0.0105)	(0.0078)	(0.0055)
High school & some college	0.0097	0.0010	-0.0000	-0.0022	-0.0036	-0.0028	-0.0020
	(0.0472)	(0.0048)	(0.0002)	(0.0105)	(0.0176)	(0.0138)	(0.0101)
College and above	0.0491	0.0039	-0.0013	-0.0117	-0.0176	-0.0131	-0.0093
	(0.0497)	(0.0048)	(0.0010)	(0.0113)	(0.0184)	(0.0143)	(0.0103)
Married	-0.0046	-0.0003	0.0001	0.0011	0.0016	0.0012	0.0008
	(0.0354)	(0.0027)	(0.0012)	(0.0087)	(0.0126)	(0.0092)	(0.0064)
Widowed	0.0852	0.0030	-0.0063	-0.0227	-0.0279	-0.0187	-0.0125
	(0.0855)	(0.0021)	(0.0088)	(0.0238)	(0.0265)	(0.0169)	(0.0112)
Divorced/separated	-0.0396	-0.0037	0.0005	0.0092	0.0146	0.0111	0.0080
	(0.0391)	(0.0038)	(0.0010)	(0.0091)	(0.0144)	(0.0111)	(0.0079)
If time for breakfast	-0.0422	-0.0041	0.0003	0.0095	0.0156	0.0121	0.0088
	(0.0621)	(0.0072)	(0.0012)	(0.0129)	(0.0237)	(0.0193)	(0.0146)
If time for dinner	-0.1210***	-0.0146***	-0.0025	0.0252***	0.0469***	0.0379***	0.0280***

Variable	**Tiredness intensity of 0**	**Tiredness intensity of 1**	**Tiredness intensity of 2**	**Tiredness intensity of 3**	**Tiredness intensity of 4**	**Tiredness intensity of 5**	**Tiredness intensity of 6**
	(0.0309)	(0.0055)	(0.0031)	(0.0058)	(0.0136)	(0.0118)	(0.0101)
If weekend	0.0350	0.0028	-0.0009	-0.0084	-0.0126	-0.0094	-0.0066
	(0.0261)	(0.0022)	(0.0008)	(0.0063)	(0.0095)	(0.0071)	(0.0050)
Household size	0.0228	0.0018	-0.0007	-0.0055	-0.0081	-0.0060	-0.0043
	(0.0172)	(0.0014)	(0.0006)	(0.0042)	(0.0062)	(0.0046)	(0.0033)
KidsNumber	-0.0309	-0.0024	0.0009	0.0074	0.0110	0.0081	0.0058
	(0.0228)	(0.0018)	(0.0008)	(0.0055)	(0.0082)	(0.0061)	(0.0043)
With family	-0.0527*	-0.0045	0.0011	0.0125*	0.0191	0.0143	0.0102
	(0.0319)	(0.0031)	(0.0010)	(0.0075)	(0.0119)	(0.0090)	(0.0066)
With other people	-0.0196	-0.0014	0.0008	0.0049	0.0069	0.0050	0.0034
	(0.0373)	(0.0028)	(0.0013)	(0.0092)	(0.0133)	(0.0097)	(0.0067)
Duration	0.0255	0.0020	-0.0007	-0.0061	-0.0091	-0.0067	-0.0048
	(0.0273)	(0.0021)	(0.0009)	(0.0066)	(0.0098)	(0.0073)	(0.0050)
Year of 2012	0.0183	0.0012	-0.0008	-0.0046	-0.0064	-0.0046	-0.0031
	(0.0313)	(0.0020)	(0.0014)	(0.0079)	(0.0109)	(0.0078)	(0.0054)
Year of 2013	-0.0366	-0.0033	0.0006	0.0085	0.0134	0.0102	0.0073
	(0.0306)	(0.0028)	(0.0008)	(0.0072)	(0.0112)	(0.0087)	(0.0061)
Observations	995	995	995	995	995	995	995

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3.13. Predicted probabilities of intensity of stress for white female respondents by income level lower than $50000 and higher than $50000

Variable	**Stress intensity of 0**	**Stress intensity of 1**	**Stress intensity of 2**	**Stress intensity of 3**	**Stress intensity of 4**	**Stress intensity of 5**	**Stress intensity of 6**
One Activity of food and drink preparation, presentation and clean up							
Income ≥ $50000	0.5476***	0.1111***	0.1099***	0.0918***	0.0681***	0.0394***	0.0321***
	(0.0109)	(0.0040)	(0.0043)	(0.0042)	(0.0037)	(0.0027)	(0.0024)
Income < $50000	0.5326***	0.1124***	0.1126***	0.0953***	0.0714***	0.0417***	0.0341***
	(0.0102)	(0.0040)	(0.0042)	(0.0042)	(0.0038)	(0.0029)	(0.0026)
Observations	6,492	6,492	6,492	6,492	6,492	6,492	6,492
Two activities of food and drink preparation, presentation and clean up							
Income ≥ $50000	0.5972***	0.0951***	0.1208***	0.0768***	0.0512***	0.0347***	0.0242***
	(0.0286)	(0.0089)	(0.0106)	(0.0088)	(0.0071)	(0.0065)	(0.0053)
Income < $50000	0.5149***	0.1019***	0.1397***	0.0956***	0.0671***	0.0471***	0.0338***
	(0.0254)	(0.0090)	(0.0113)	(0.0100)	(0.0085)	(0.0072)	(0.0068)
Observations	1,533	1,533	1,533	1,533	1,533	1,533	1,533
One activity of food purchasing							
Income ≥ $50000	0.4577***	0.1200***	0.1403***	0.1158***	0.0728***	0.0566***	0.0368***
	(0.0281)	(0.0104)	(0.0122)	(0.0120)	(0.0097)	(0.0089)	(0.0071)
Income < $50000	0.4273***	0.1199***	0.1447***	0.1235***	0.0797***	0.0631***	0.0416***
	(0.0260)	(0.0104)	(0.0120)	(0.0125)	(0.0105)	(0.0097)	(0.0078)
Observations	995	995	995	995	995	995	995

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.14. Predicted probabilities of intensity of tiredness for white female respondents by income level lower than $50000 and higher than $50000

Variable	**Tiredness intensity of 0**	**Tiredness intensity of 1**	**Tiredness intensity of 2**	**Tiredness intensity of 3**	**Tiredness intensity of 4**	**Tiredness intensity of 5**	**Tiredness intensity of 6**
One Activity of food and drink preparation, presentation and clean up							
Income ≥ $50000	0.2941***	0.0830***	0.1326***	0.1701***	0.1524***	0.0937***	0.0741***
	(0.0089)	(0.0035)	(0.0042)	(0.0049)	(0.0053)	(0.0044)	(0.0040)
Income < $50000	0.2839***	0.0817***	0.1318***	0.1716***	0.1562***	0.0972***	0.0776***
	(0.0082)	(0.0034)	(0.0042)	(0.0048)	(0.0052)	(0.0044)	(0.0042)
Observations	6,486	6,486	6,486	6,486	6,486	6,486	6,486
Two activities of food and drink preparation, presentation and clean up							
Income ≥ $50000	0.3387***	0.0737***	0.1237***	0.1806***	0.1418***	0.0844***	0.0571***
	(0.0247)	(0.0077)	(0.0095)	(0.0118)	(0.0122)	(0.0099)	(0.0081)
Income < $50000	0.3025***	0.0704***	0.1219***	0.1869***	0.1551***	0.0962***	0.0670***
	(0.0199)	(0.0074)	(0.0095)	(0.0115)	(0.0119)	(0.0102)	(0.0096)
Observations	1,530	1,530	1,530	1,530	1,530	1,530	1,530
One activity of food purchasing							
Income ≥ $50000	0.3107***	0.1028***	0.1282***	0.1784***	0.1465***	0.0825***	0.0509***
	(0.0228)	(0.0098)	(0.0107)	(0.0132)	(0.0136)	(0.0106)	(0.0084)
Income < $50000	0.2880***	0.0996***	0.1272***	0.1829***	0.1557***	0.0901***	0.0565***
	(0.0227)	(0.0096)	(0.0107)	(0.0132)	(0.0144)	(0.0117)	(0.0097)
Observations	995	995	995	995	995	995	995

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Supplementary Table 3.1: Activities related to home-prepared food production according to description of three tier coding lexicon.

Major categories of food-related activities	**6-tier code**	**Activity description**
Food & Drink Preparation, Presentation, & Clean-up	20104	Storing interior household items, inc. food
	20201	Food and drink preparation
	20202	Food presentation
	20203	Kitchen and food clean-up
	20299	Food & drink prep, presentation, & clean-up, n.e.c.*
	150201	Food preparation, presentation, clean-up
Eating and Drinking	110101	Eating and drinking
	110199	Eating and drinking, n.e.c.*
	110201	Waiting associated w/eating & drinking
	110281	Waiting associated w/eating & drinking
	110299	Waiting associated with eating & drinking, n.e.c.*
	50202	Eating and drinking as part of job
	50301	Income-generating hobbies, crafts, and food
Food Purchasing	70101	Grocery shopping
Travel related to food activities	180202	Travel related to food & drink prep., clean-up, & presentation
	180701	Travel related to grocery shopping
	180703	Travel related to purchasing food (not groceries)
	181101	Travel related to eating and drinking
	181199	Travel related to eating and drinking, n.e.c.*

* n.e.c.: not elsewhere classified

Supplementary Table 3.2. The overall, between and within variance of key variables in cases of more than one food-related activities.

Variable	**Category of variance**	**Two activities of food production**			**Three activities of food production**			**Two activities of food purchasing**		
		Mean	Standard deviation	Obs.	Mean	Standard deviation	Obs.	Mean	Standard deviation	Obs.
Alone	Overall	0.59	0.4924	1562	0.49	0.5022	108	0.55	0.5104	20
	Between		0.4125	781		0.3693	36		0.4972	10
	Within		0.2691	2		0.3441	3		0.1622	2
With family	Overall	0.33	0.4721	1562	0.38	0.4876	108	0.40	0.5026	20
	Between		0.3990	781		0.3750	36		0.4595	10
	Within		0.252	2		0.3157	3		0.2294	2
With other people	Overall	0.08	0.2674	1562	0.13	0.3375	108	0.05	0.2236	20
	Between		0.2238	781		0.2903	36		0.1581	10
	Within		0.1465	2		0.1765	3		0.1622	2
Duration	Overall	0.59	0.663	1562	0.67	0.8899	108	0.56	0.4215	20
	Between		0.5037	781		0.6903	36		0.3910	10
	Within		0.4317	2		0.5696	3		0.1814	2
At time for breakfast	Overall	0.13	0.3385	1562	0.19	0.3903	108	0	0	20
	Between		0.2346	781		0.2174	36		0	10
	Within		0.2441	2		0.3255	3		0	2
At time for dinner	Overall	0.31	0.4626	1562	0.24	0.4295	108	0.10	0.3078	20
	Between		0.3213	781		0.2470	36		0.3162	10
	Within		0.3329	2		0.3530	3		0	2
U-index	Overall	0.02	0.0692	1562	0.01	0.0423	108	0.06	0.1308	20
	Between		0.0539	781		0.0265	36		0.1120	10

Variable	Category of variance	Two activities of food production			Three activities of food production			Two activities of food purchasing		
		Mean	Standard deviation	Obs.	Mean	Standard deviation	Obs.	Mean	Standard deviation	Obs.
	Within		0.0434	2		0.0332	3		0.0724	2
Intensity of happiness	Overall	4.41	1.5831	1548	4.67	1.4588	105	3.80	1.2397	20
	Between		1.3783	778		1.0541	35		1.1832	10
	Within		0.7916	2		1.0190	3		0.4588	2
Intensity of meaningfulness	Overall	4.34	1.9117	1541	4.43	2.0754	102	3.65	1.4965	20
	Between		1.7060	777		1.9155	35		1.1797	10
	Within		0.8778	2		1.0049	3		0.9597	2
Intensity of pain	Overall	1.12	1.7722	1556	1.57	1.8905	108	0.75	1.1180	20
	Between		1.6880	781		1.7828	36		1.1365	10
	Within		0.5536	2		0.6744	3		0.1622	2
Intensity of sad	Overall	0.58	1.3234	1555	0.47	1.0630	108	0.25	0.6387	20
	Between		1.1919	780		0.8706	36		0.6346	10
	Within		0.5729	2		0.6215	3		0.1622	2
Intensity of stress	Overall	1.15	1.6688	1557	0.90	1.4657	108	1.80	2.3079	20
	Between		1.4915	781		1.2365	36		2.1499	10
	Within		0.7484	2		0.8050	3		0.9733	2
Intensity of tiredness	Overall	2.14	1.9572	1553	2.03	1.8917	108	1.85	2.2542	20
	Between		1.7537	781		1.5499	36		2.2242	10
	Within		0.8732	2		1.1050	3		0.6283	2

Supplementary Table 3.3. Average marginal effects of fractional logit modeling the relationship between u-index and demographic and socioeconomic factors when only happy is considered as positive feeling. Dependent variable is weighted U-index.

Variable	One Activity of food and drink preparation, presentation and clean up	Two activities of food and drink preparation, presentation and clean up	One activity of food purchasing
Age	-0.0005***	-0.0004**	-0.0004
	(0.0002)	(0.0002)	(0.0003)
Male	-0.0077*	-0.0205***	-0.0045
	(0.0041)	(0.0056)	(0.0091)
White	-0.0054	0.0027	0.0109
	(0.0057)	(0.0079)	(0.0114)
Asian	-0.0010	0.0036	0.0097
	(0.0107)	(0.0162)	(0.0295)
Otherrace	-0.0185*	0.0276	0.0081
	(0.0106)	(0.0246)	(0.0324)
Income <$50000	0.0148***	0.0086	0.0137
	(0.0044)	(0.0065)	(0.0095)
High school & some college	-0.0134**	0.0027	0.0089
	(0.0064)	(0.0086)	(0.0162)
College and above	-0.0172**	0.0001	-0.0080
	(0.0069)	(0.0093)	(0.0164)
Married	-0.0125**	-0.0144	-0.0319**
	(0.0061)	(0.0094)	(0.0146)
Widowed	-0.0063	0.0022	-0.0362*
	(0.0087)	(0.0130)	(0.0210)
Divorced/separated	0.0136*	-0.0115	-0.0107
	(0.0074)	(0.0091)	(0.0156)
If time for breakfast	-0.0152***	-0.0037	-0.0154
	(0.0050)	(0.0071)	(0.0219)
If time for dinner	0.0103**	0.0031	0.0114
	(0.0043)	(0.0056)	(0.0125)
If weekend	-0.0033	-0.0076	-0.0106
	(0.0037)	(0.0055)	(0.0095)
Household size	0.0005	-0.0071	-0.0034
	(0.0028)	(0.0049)	(0.0062)
Number of household children < 18	-0.0044	0.0026	0.0057
	(0.0035)	(0.0055)	(0.0077)
With family	-0.0075*	-0.0099	-0.0072
	(0.0045)	(0.0062)	(0.0103)
With other people	-0.0153**	0.0013	-0.0232*
	(0.0063)	(0.0112)	(0.0120)
Year of 2012	-0.0086*	-0.0048	-0.0095
	(0.0045)	(0.0063)	(0.0104)
Year of 2013	-0.0084*	-0.0040	-0.0064
	(0.0045)	(0.0068)	(0.0105)

Observations	6,506	1,538	996

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Supplementary Table 3.4. Average marginal effects of Logit regression for the relationship between U-index and demographic and socioeconomic factors when only happy is considered as positive feeling. Dependent variable is U-indicator.

Variable	One Activity of food and drink preparation, presentation and clean up	Two activities of food and drink preparation, presentation and clean up	One activity of food purchasing
Age	-0.0013***	-0.0011	-0.0010
	(0.0004)	(0.0009)	(0.0011)
Male	-0.0527***	-0.1000***	-0.0275
	(0.0110)	(0.0248)	(0.0286)
White	0.0192	0.0467	0.0057
	(0.0148)	(0.0339)	(0.0391)
Asian	0.0572*	0.0053	-0.0577
	(0.0316)	(0.0584)	(0.0788)
Otherrace	0.0205	0.0808	-0.0061
	(0.0364)	(0.0796)	(0.1108)
Income <$50000	0.0233*	0.0394	0.0375
	(0.0123)	(0.0286)	(0.0318)
High school & some college	-0.0169	0.0215	0.0370
	(0.0167)	(0.0357)	(0.0522)
College and above	-0.0125	0.0403	-0.0153
	(0.0180)	(0.0394)	(0.0542)
Married	-0.0380**	-0.0846*	-0.0665
	(0.0168)	(0.0433)	(0.0428)
Widowed	-0.0116	0.0434	-0.1070
	(0.0250)	(0.0644)	(0.0681)
Divorced/separated	0.0312	-0.0498	-0.0302
	(0.0192)	(0.0450)	(0.0470)
If time for breakfast	-0.0272*	0.0256	-0.0579
	(0.0153)	(0.0315)	(0.0676)
If time for dinner	0.0406***	0.0183	0.0223
	(0.0121)	(0.0242)	(0.0378)
If weekend	-0.0254**	-0.0094	-0.0285
	(0.0105)	(0.0243)	(0.0291)
Household size	-0.0050	-0.0080	0.0007
	(0.0077)	(0.0189)	(0.0208)
Number of household children < 18	0.0051	0.0007	0.0164
	(0.0096)	(0.0231)	(0.0256)
With family	-0.0479***	-0.0364	-0.0406
	(0.0125)	(0.0255)	(0.0347)
With other people	-0.0713***	-0.0584	-0.0985***
	(0.0180)	(0.0386)	(0.0368)
Duration	-0.0120	-0.0197	-0.0114
	(0.0092)	(0.0182)	(0.0245)
Year of 2012	-0.0389***	-0.0317	-0.0390
	(0.0125)	(0.0275)	(0.0333)

Year of 2013	-0.0255**	-0.0062	-0.0349
	(0.0128)	(0.0317)	(0.0328)
Observations	6,506	1,538	996

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Supplementary Table 3.5. Average marginal effects of fractional logit modeling the relationship between U-index and demographic and socioeconomic factors using total waking time for imputation of U-index. Dependent variable is weighted U-index.

Variable	One Activity of food and drink preparation, presentation and clean up	Two activities of food and drink preparation, presentation and clean up	One activity of food purchasing
Age	-0.0000	-0.0001**	-0.0001
	(0.0000)	(0.0000)	(0.0001)
Male	-0.0015***	-0.0018***	-0.0019
	(0.0005)	(0.0006)	(0.0015)
White	0.0007	0.0006	0.0029
	(0.0006)	(0.0010)	(0.0022)
Asian	0.0018	-0.0000	-0.0014
	(0.0013)	(0.0022)	(0.0037)
Otherrace	-0.0003	0.0005	-0.0050**
	(0.0015)	(0.0014)	(0.0022)
Income <$50000	0.0009*	-0.0004	0.0002
	(0.0005)	(0.0008)	(0.0017)
High school & some college	-0.0005	-0.0017	0.0037
	(0.0007)	(0.0015)	(0.0028)
College and above	-0.0010	-0.0025	0.0001
	(0.0008)	(0.0015)	(0.0027)
Married	-0.0006	-0.0001	-0.0020
	(0.0007)	(0.0010)	(0.0021)
Widowed	-0.0017*	0.0016	-0.0046
	(0.0009)	(0.0016)	(0.0034)
Divorced/separated	0.0008	-0.0008	-0.0007
	(0.0009)	(0.0009)	(0.0022)
If time for breakfast	-0.0014*	-0.0001	-0.0042
	(0.0008)	(0.0009)	(0.0036)
If time for dinner	0.0014***	0.0016**	0.0031
	(0.0005)	(0.0007)	(0.0021)
If weekend	0.0004	0.0006	0.0016
	(0.0005)	(0.0007)	(0.0015)
Household size	0.0005	-0.0012**	-0.0019
	(0.0003)	(0.0006)	(0.0012)
Number of household children < 18	-0.0006	0.0004	0.0028*
	(0.0004)	(0.0006)	(0.0015)
With family	-0.0009*	-0.0009	-0.0003
	(0.0005)	(0.0007)	(0.0017)
With other people	-0.0011	-0.0012	-0.0024
	(0.0008)	(0.0011)	(0.0020)
Year of 2012	-0.0002	-0.0015*	0.0008
	(0.0006)	(0.0008)	(0.0019)
Year of 2013	-0.0006	-0.0006	0.0003

	(0.0005)	(0.0009)	(0.0017)
Observations	6,506	1,538	996

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1