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## **The time patterns of carbohydrate intake in UK adults – the National Dietary and Nutrition Survey (NDNS) 2008/09-2015/16 programme**

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*Submitted in part fulfillment of the requirements  
for the degree of MSc in Medical Statistics*

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# Declaration of Authorship

I, Chaochen WANG, declare that this thesis titled, “The time patterns of carbohydrate intake in UK adults – the National Dietary and Nutrition Survey (NDNS) 2008/09-2015/16 programme” and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a MSc degree on Medical Statistics at this University.
- No part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

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Date:

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*“All models are wrong, but some are useful.”*

George E. P. Box





## *Abstract*

The National Dietary and Nutrition Survey (NDNS) database of detailed four-day food diaries was used to ...



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# List of Abbreviations

|             |  |
|-------------|--|
| <b>AIC</b>  | <b>Akaike Information Criterion</b>                |
| <b>BMI</b>  | <b>Body Mass Index</b>                             |
| <b>BIC</b>  | <b>Bayesian Information Criterion</b>              |
| <b>CI</b>   | <b>Confidence Interval</b>                         |
| <b>DM</b>   | <b>Diabetes Mellitus</b>                           |
| <b>EM</b>   | <b>Expectation Maximization</b>                    |
| <b>FSA</b>  | <b>Food Standards Agency</b>                       |
| <b>A1c</b>  | <b>Haemoglobin A1c: Glycated hemoglobin</b>        |
| <b>LCA</b>  | <b>Latent Class Analysis</b>                       |
| <b>MAFF</b> | <b>Ministry of Agriculture, Fisheries and Food</b> |
| <b>MLCA</b> | <b>Multilevel Latent Class Analysis</b>            |
| <b>ML</b>   | <b>Maximum Likelihood</b>                          |
| <b>NDNS</b> | <b>the National Dietary and Nutrition Survey</b>   |
| <b>OR</b>   | <b>Odds Ratio</b>                                  |
| <b>PHE</b>  | <b>Public Health England</b>                       |
| <b>PSUs</b> | <b>Primary Sampling Units</b>                      |
| <b>WC</b>   | <b>Waist Circumference</b>                         |





# Chapter 1

## Introduction

### Background

The widely accepted standard these days seems to be that we eat three times a day. However, whether this is really an ideal temporal eating pattern for everyone has never been answered with evidence. More importantly, the actual temporal patterns of eating in the population, proportions of people who actually manage/fail to follow this so-called doctrine have not been described thoroughly.

The importance of the circadian rhythm in regulating physiological responses has been recognised for long, while the impact of which on nutrition and metabolism is still largely unknown (Johnston, 2014; Asher and Sassone-Corsi, 2015).

Although nutritional studies have extensively examined the influence of the quantity and quality of dietary and nutrients intake and their alteration on morbidity and mortality, investigations on temporal eating patterns and their effects are still scarce. Some recent evidence have found that meal timing is associated with a wide variety of health outcomes. Skipping breakfast is associated with higher risk of type 2 diabetes (Uemura et al., 2015). Shift workers have a higher risk of developing metabolic syndrome (De Bacquer et al., 2009) and type 2 diabetes (Pan et al., 2011). Evening intake of energy is positively associated with overweight/obesity (Almoosawi et al., 2016).

More recently, discernible temporal eating patterns that differed by sociodemographic and eating profiles were revealed by latent class analysis using nutrition survey data (Leech et al., 2017; Mansukhani and Palla, 2018). Based on total energy consumption, the presence of 3 groups of eaters: grazers, early eaters, and late eaters were identified. So far, the temporal eating patterns were only based on averaging the total energy intake calculated from one or two days dietary recall, and therefore could not capture the day-to-day variation in temporal eating patterns.

(some review of articles about carbohydrate eating)

## **The National Dietary and Nutrition Survey (NDNS)**

The National Diet and Nutrition Survey (NDNS) programme (NatCen Social Research, 2018) was initially established in 1992 and started off as a joint initiative between the Ministry of Agriculture, Fisheries and Food (MAFF) and the Department of Health. In 2008, a new continuous cross-sectional survey was started, the NDNS Rolling Programme (RP). The NDNS RP is funded by Public Health England (PHE), an executive agency of the Department of Health, and the UK Food Standards Agency (FSA). The survey covers a representative sample of around 1000 people per year. Fieldwork began in 2008 and is now beginning its (y)ear. NDNS provides essential evidence on the diet and nutrition of the UK population to enable PHE to identify and address nutritional issues in the population and monitor progress towards public health nutrition objectives.

The NDNS RP has now completed and analysed its eighth year. The sample was randomly drawn from a list of all the addresses, clustered into postcode sectors from across the UK. Overall, for years 1-8 combined, a sample of 39,300 addresses was selected from 799 (year 1-4), 323 (year 5-6), and 316 (year 7-8) postcode sectors. At each address, one household was selected at random (in cases where there were two or more households). For each household, either an adult and a child, or a child only, was selected to participate.

These individuals were asked to keep a four-day diary on their food and drink consumption on consecutive days. An interview and a nurse visit were also conducted to collect information regarding height and weight, smoking and drinking habits, physical activity, blood pressure, prescribed medicines, dietary supplements, fasting blood sample, and 24-hour urine sample.

## **Aims and objectives**

Our goal is to explore and make use of the NDNS RP (2008/09-2015/16) database to describe and identify the potential relationship between the timing of eating within the day and specific nutrient-carbohydrate intake. We aimed at finding time patterns of consumption of carbohydrate and defining latent groups in the UK adults. Subsequently, an additional potential aim, is to investigate the association between eating time patterns with diabetes and obesity.

## Chapter 2

# Methods

### Dietary diary collected in the NDNS RP

Participants were asked to keep a record of everything eaten or drunk over four consecutive days. Interviewers undertook three visits with each participant. At the first visit, the interviewer explained the method followed a protocol, taking participants through the sections in the diary including how to describe details of food and drink and portion size and an example day. The second was a brief visit to check for compliance, answer questions or deal with problems and review the diary to identify and edit possible omissions and missing detail. The third visit was to collect the diary and again review and edit possible omissions.

In the diary, participants were asked to record portion sizes in household measures (e.g. one tablespoon of beans, one Kit Kat finger-size), or for packaged foods to note the weight indicated on the packet. For homemade dishes, participants were asked to record on a separate page in the diary the individual ingredients and quantities for the whole dish along with a brief description of the cooking method and how much of dish they had consumed. In addition to details of what and how much was eaten, participants recorded for each eating occasion; when was it, where they were, who they were eating with. An example, used as guidance for participants, of a food diary for one day is shown in **Appendix C**.

### Definition of carbohydrate intake

Detailed dairy checking was performed to code and convert the food consumption into energy and nutrients intake. Intakes of nutrients were calculated from the food consumption records using a specially adapted Nutrient Databank (Smithers, 1993), which was originally developed by the Ministry of Agriculture, Fisheries and Food (MAFF) for the Dietary and Nutritional Survey of British Adults. Further details of data coding and editing are outlined in Appendix A of the NDNS official reports

(Department of Health, 2018). Specifically, the main variables that we adopted in the current analysis were defined as:

- Total Energy intake = (protein(gramme)  $\times$  17) + (fat(gramme)  $\times$  37) + (carbohydrate(gramme)  $\times$  16) + (alcohol(gramme)  $\times$  29) kJ;
- Carbohydrate intake = total sugars (gramme) + starch (gramme);

Time across a typical survey day was divided into 7 time slots in the dietary diary of NDNS RP: 6 am to 9 am, 9 am to 12 noon, 12 noon to 2 pm, 2 pm to 5 pm, 5 pm to 8 pm, 8 pm to 10 pm, and 10 pm to 6 am. To produce a sequence of discrete responses regarding the carbohydrate intake we are interested, the energy consumption within each time slot over the four days of survey for each participant were calculated. The percentages of energy that contributed by carbohydrate within each time slot were then estimated. Since we planned to apply latent class analysis (LCA) in the current study, in which the observed indicators for latent classes must be categorical, we then dichotomised the responses according to the carbohydrate contribution to the energy intake at cut-off value of 50%, i.e. if within a time slot there is any energy intake occurred, carbohydrate consumption was categorised into whether it's energy contribution was lower or higher/equal to 50% of total energy intake within that time slot. Consequently, for each day of the recording, there were 7 data points generated by the diary, each data point included one of the following responses:

- Not eating any food (Energy intake = 0 kJ);
- Eating, and carbohydrate contributed less than 50% of the total energy intake;
- Eating, and carbohydrate contributed higher or equal to 50% of the total energy intake.

## Survey Data

### Survey selection method

The NDNS RP participants were drawn from the UK Postcode Address File, a list of all the addresses in the UK. The addresses were clustered into Primary Sampling Units (PSUs), small geographical areas, based on postcode sectors, randomly selected from across the UK. A list of 27 or 28 addresses was then randomly selected from each PSU.

Overall, for years 1 to 8 combined, a sample of 39,300 addresses was selected from 1,438 PSUs. The sampling selection process was:

- Randomly select PSUs from the Postcode Address File;
- Randomly select 27 or 28 addresses in that postcode area;
- Randomly select one household at that address;
- Selected addresses were randomly allocated to one of two groups to determine whether an adult (aged 19 years or older) and a child (aged 1.5 to 18 years), or a child only, were selected for interview.

## Response rates

The response rates for completion of the dietary diary (three or four days) were 56%, 53%, 53%, for years 1 to 4, 5 to 6, and 7 to 8, respectively. A total of 6,155 adults aged 19 years and over were kept in our analyses.

## Strata and weightings

It is necessary to apply weighting factors to the data collected in the NDNS RP for two reasons: to remove any bias in the observed results which may be due to differences in the probability of households and individuals being selected to take part; and to attempt to reduce differential non-response bias by age, sex and geographical region.

The strata that used to calibrate proportions in the sample include: age-group (1.5-3, 4-6, 7-10, 11-15, 16-18, 19-24, 25-29, 30-39, 40-49, 50-59, 60-64, 65-69, and over 70 years); sex (men or women); and regions (Northern Ireland, Scotland, Wales, and the nine regions of England).

Two steps of weighting system are designed in the NDNS RP to assure that the combined sample will be representative of the UK population:

1. An overall selection weight, which is the product of the address, dwelling unit, catering(household) unit, and individual selection weights, was generated to correct for the unequal selection probabilities. These weights are the inverse of the selection probabilities at each level of the random sampling process and they can be used to compensate for differences in the chance of selection of an individual.
2. An iterative procedure was used to adjust the selection weights until the distribution of the weighted sample matched that of the population for age-group, sex and geographical region. Population distributions were taken from the mid-year population estimates (Office for National Statistics, 2018).

Another two sets of weights were generated to correct for differential non-response (either due to refusal or inability) to 1) nurse visit, and 2) giving a blood sample. Response rates to the nurse visit among those completed a dietary diary was approximately 75%, to blood sample in adults were 51%, 57%, and 50% for years 1 to 4, 5 to 6, and 7 to 8, respectively. In creating the nurse/blood sample weight, a logistic regression model was used by the NDNS RP study team to model the relationship between response to nurse visit/giving blood sample and a set of predictor variables (socio-demographic, participant and catering/household unit characteristics). The model generated a predicted probability for each participant, which is the probability would agree to a nurse visit/provide blood sample, given the characteristics of the individual and the household unit. Participants with characteristics associated with non-response were under-represented in the sample and therefore receive a low predicted probability. The inverse of these predicted probabilities were used as a set of non-response weights so that participants with a low predicted probability got a larger weight, increasing their representation in the sample. Then the nurse/blood sample weights were re-scaled so that the sum of the weights equalled the number of participants who had a nurse visit/who provided a blood sample. The final nurse/blood weights should therefore make the sample participants representative of all eligible persons in the population.

Further details of the weighting system developed by the NDNS RP are described in the Appendix B of the reports published by Public Health England (PHE) (Bates et al., 2014; Roberts et al., 2018; Department of Health, 2018).

### **Socio-demographic status, lifestyle, physical activity, anthropometric measurements and biochemical analyses**

Computer assisted personal interviews were conducted for the selected individuals by trained interviewers to collect background information on smoking habits (current, past, never smokers), ethnicity (white, non-white), education level, living with a partner or not and other socio-demographic related variables. Participants also had their height, weight, blood pressure, waist circumferences (WC) measured by the nurses.

Specifically, blood pressure was measured in a sitting position using an automated, validated machine, the Omron HEM907, after a five minute rest. The means of second and third readings, taken at one minute intervals, were used in the current report. Hypertension was defined as with systolic blood pressure of 140 mmHg or above, and/or diastolic blood pressure of 90 mmHg or above, and/or taking any medication specifically to reduce blood pressure.

A self-completion questionnaire - the Recent Physical Activity Questionnaire (Besson et al., 2009) (RPAQ, developed by the MRC Epidemiology Unit Cambridge) was used to estimate physical activity from year 2 of the survey. The RPAQ was designed to assess usual physical activity in the last month in four domains: home, work, commuting to work, and leisure activities. Detailed descriptions of the assessment of adult physical activity in the NDNS RP and the processing of data are available in Appendices G and V of the published reports (Bates et al., 2014; Roberts et al., 2018; Department of Health, 2018).

Blood samples were stored at 4 °C, and sent directly by post to the Department of Haematology and Department of Clinical Biochemistry and Immunology, Addenbrooke's Hospital, Cambridge within two hours of their collection. Serum samples were obtained by centrifugation of the coagulated blood sample. Serum total, High Density Lipoprotein (HDL) and Low Density Lipoprotein (LDL) cholesterol, triglycerides, blood glucose, haemoglobin A1C were measured. A1C value of 6.5% was used as the cut off point for diagnosing diabetes.

Body mass index (BMI) was calculated as weight in kilograms and weight in kilograms divided by height in square meters. BMI was then categorised into less than 25 kg/m<sup>2</sup> (normal weight), 25 to 30 kg/m<sup>2</sup> (overweight), and higher or equal to 30 kg/m<sup>2</sup> (obese).

## **Ethics approval**

Ethics approval for the survey was obtained from the Oxfordshire A Research Ethics Committee. The letters of approval for the original submission and subsequent substantial amendments, together with approved documents, were sent to all Local Research Ethics Committees covering areas where fieldwork was being conducted. Research governance approval was sought for all participating NHS laboratories and obtained where required by the Research and Development Committee for each laboratory. Ethics approval for the current project was obtained from the MSc Research Ethics Committee of London School of Hygiene & Tropical Medicine (LSHTM MSc Ethics Ref: 15624).

## Statistical methods

### Latent Class Analysis (LCA)

Latent class analysis is a statistical technique that identifies categorical latent (unobserved) class variables on the basis of observed categorical variables (Collins and Lanza, 2010). It belongs to the family of latent variable models, and is directly analogous to the factor analysis model. The major difference is that the latent variable in LCA is categorical, not continuous as in factor analysis. The basic assumptions in LCA are independent observations, and local independence, as shown in the fundamental expression of a typical LCA model:

$$P(U_{i1} = s_1, U_{i2} = s_2, \dots, U_{ik} = s_K) = \sum_{t=1}^T P(C_i = t) \prod_{k=1}^K P(U_{ik} = s_k | C_i = t) \quad (2.1)$$

Where,

- $P(U_{i1} = s_1, U_{i2} = s_2, \dots, U_{ik} = s_k)$  is the probability of observing a particular vector of responses;
- $P(C_i = t)$  is the probability that a randomly selected  $i$ th observation will be in class  $t$ ;
- $P(U_{ik} = s_k | C_i = t)$  is the probability of a particular observed response pattern  $U_{ik} = s_k$  conditional on membership in latent class  $t$ .

Equation 2.1 indicates that responses for an observation to the measuring variables are independent of one another given its membership in latent class  $t$ . However, in the NDNS RP data set, the assumption of independent observations is violated. Each individual completed their dietary diary for four consecutive days, their diary recordings were later converted into four sequences of categorical responses reflecting the type of carbohydrate consumption at each time slot of the day. The four observed sequences (observed days) are nested in the participants and therefore are not independent. This nested data structure requires multilevel techniques.

### Multilevel Latent Class Analysis (MLCA)

Multilevel latent class analysis accounts for the nested structure of the data by allowing latent class intercepts to vary across level 2 units and thereby examining if and how level 2 units influence the level 1 latent classes. These random intercepts allow the probability of membership in a particular level 1 (observation days) latent class to vary across level 2 units (e.g., here in the current context are the



individuals). Essentially this allows the probability that an observation day will belong to a particular day level latent class to vary across individual levels.

### Parametric approach

Proposed by Vermunt (Vermunt, 2003; Vermunt, 2008) and Asparouhov and Muthén (Muthén and Asparouhov, 2009), a traditional, parametric approach can be applied using a logistic regression model. For example, let's assume that there are two types of observation days in the dietary survey—high and low carbohydrate eating days. In an unconditional logistic regression model, the probability of the outcome (i.e. an observed high carbohydrate eating day vs. a low carbohydrate eating day) is constant within individual level which means for each person throughout his/her survey there is some probability of following a high carbohydrate eating day. A random effect model considers the individuals (level 2) to be drawn from the adult population in the UK, and the probability of the outcome (i.e. high carbohydrate eating days) across individuals is considered to be a random variable (Snijders and Bosker, 2011).

Thus, for a binary outcome  $C_{ij} = 0, 1$  (low = 0 or high = 1 carbohydrate eating days), where  $i$  denotes the observation days ( $i = 1, 2, 3, 4$ ), and  $j$  denotes the individual ( $j = 1, 2, \dots, 6155$ ). The 2-level random intercept logistic regression model can be expressed as:

$$\begin{aligned} \text{logit}[P(C_{ij} = 1)] &= \beta_{0j} + \beta_1 x_{ij} && \text{(day level)} \\ \beta_{0j} &= \gamma_0 + \gamma_1 w_j + u_{0j} && \text{(individual level)} \\ \Rightarrow P(C_{ij} = 1) &= \frac{\exp(\gamma_0 + \beta_1 x_{ij} + \gamma_1 w_j + u_{0j})}{1 + \exp(\gamma_0 + \beta_1 x_{ij} + \gamma_1 w_j + u_{0j})} \end{aligned} \quad (2.2)$$

Where we define:

- $P(C_{ij} = 1)$  as the probability that the randomly selected  $i$ th observation day of  $j$ th individual is a high carbohydrate eating day;
- $\beta_{0j}$  as the random intercept, for outcome  $C_{ij} = 1$ ;
- the random deviation of the individuals  $u_{0j}$  are assumed be normally distributed (i.e.  $u_{0j} \sim N(0, \sigma_{u_0}^2)$ ), the magnitude of the  $u_{0j}$  variance ( $\sigma_{u_0}^2$ ) indicates the influence of the individuals (level 2);
- $x_{ij}, w_j$  is the predictors for day level (weekdays or weekends) and individual level, such as age, and sex.

Same framework can be used to consider random effects in an LCA model, but instead of saying that  $C_{ij}$  is either low or high carbohydrate eating days as if we already know, it is now replaced by a latent variable  $G_{ij}$  which indicates the typologies of carbohydrate eating patterns. Then we can use the day level data to assess the log-odds of belonging to  $k$ th type of carbohydrate eating pattern on a specific day of survey, and we allow the log-odds to vary across individuals. Therefore, for some persons the log-odds of having a  $k$ th type of carbohydrate eating pattern during the survey can be high, but for the other persons, the log-odds of following the  $k$ th type of carbohydrate eating pattern can be low.

If the day level LCA model (carbohydrate eating pattern typologies) is best defined by  $T(T \geq 2)$  latent classes, then  $T - 1$  random intercept will be specified by a two-level multinomial logistic regression model. Similar to the typical LCA models, the latent class variable in a MLCA is defined by multiple observed indicators (here is defined by the responses of eating carbohydrate within each time slots, throughout 4 consecutive days of survey period). Considering the latent class indicators are indicator variables ( $U_{ijk}$ ), the MLCA model can be written as follows:

$$P(U_{ij1} = s_1, U_{ij2} = s_2, \dots, U_{ijk} = s_K) = \sum_{t=1}^T P(G_{ij} = t) \prod_{k=1}^K P(U_{ijk} = s_k | G_{ij} = t) \quad (2.3)$$

Where,

- $U_{ijk}$  represents the response of eating carbohydrate (one of the following: not eating any food,  $< 50\%$  of the energy, or  $\geq 50\%$  of the energy) on  $i$ th day of the survey ( $i \in (1, 2, 3, 4)$ ) in  $j$ th individual at the  $k$ th time slot of the day ( $k \in (1, 2, 3, \dots, 7)$ );
- $G_{ij}$  denotes the latent class membership for  $j$ th individuals on  $i$ th day of the survey, the total number of day level latent class is  $T$ ;
- $P(U_{ijk} = s_k | G_{ij} = t)$  is the probability of a specific response pattern, conditional on membership in latent class  $t$ .

The  $P(G_{ij} = t)$  in equation 2.3 is what we have already defined in equation 2.2:

$$P(G_{ij} = t) = \frac{\exp(\gamma_0 + \beta_1 x_{ij} + \gamma_1 w_j + u_{0j})}{1 + \exp(\gamma_0 + \beta_1 x_{ij} + \gamma_1 w_j + u_{0j})} \quad (2.4)$$

### Non-Parametric approach

Since the parametric approach discussed above can be extremely computationally demanding (Van Horn et al., 2008; Vermunt, 2008), an alternative approach is using

a non-parametric MLCA (Davidian et al., 2008). In this approach, separate latent class models are specified for level 1 (observation days) and level 2 (individuals). Similar with the parametric MLCA approach, there are  $T - 1$  random intercepts, where  $T$  is the number of level 1 latent classes. However, rather than assuming the random intercepts following a normal distribution, the non-parametric MLCA assumes a multinomial (discrete) distribution of the level 2 latent classes. This approach is less computationally demanding compared with the parametric approach. These level 2 (individual) latent classes reflect differences in the probability of belonging to a specific day level latent class, so that individuals that contain observation days with similar probabilities for the level 1 latent classes will be grouped together. The non-parametric MLCA model can be defined as follows:

$$P(C_{ij} = t | CB_j = m) = \frac{\exp(\gamma_{tm})}{\sum_{r=1}^T \exp(\gamma_{rm})} \quad (2.5)$$

Where,

- $CB_j$  is individual level latent class membership for  $j$ th individual;
- $\gamma_{tm}$  is day level and individual level indicators.

According to Finch and French's simulation study (Finch and French, 2014), non-parametric approach generally resulted in more accurate recovery of the underlying latent structure of the data at both levels and provided better latent class model. Specifically, we are interested in exploring both meaningful individual (level 2) latent classes and the daily carbohydrate consumption classification. Therefore, non-parametric MLCA was employed 1) to identify latent classes of observation days (level 1) based on the subjects' responses to the 4-day food and drink diary and 2) to form distinct latent classes of individuals (level 2) based on the distribution of observation-level latent classes within individuals.

## Strategy of conducting MLCA in the current analysis

To identify the best-fitting model, we used the following sequential modelling strategy (Henry and Muthén, 2010):

- Firstly, we ignored the multilevel structure of the data and estimated a series of traditional LC models to determine the number of classes at the observational-level;
- Next, a series of MLCA models were fitted to account for the multi-level structure of the data. In these models, the number of observational-level classes was based on the best fitting LCA model from the first step, and the

LCA model at the individual level was estimated to identify the number of individual level latent classes;

- Thirdly, when number of individual level latent classes is defined based on the previous stage, observational-level classes was modified (one class lower and one class higher than in the second step), to see the effect of changing level 1 classes and confirm the best fitting model.

The number of classes in either level 1 were determined by 1) the evaluation of model fit indices, including the Akaike information criterion (AIC), Bayesian information criterion (BIC), adjusted Bayesian information criterion (aBIC) where smaller values indicate better, and entropy which is a statistic that summarizes latent class probabilities where values near 1 indicate better latent class separation; 2) the Lo-Mendell-Rubin Likelihood Ratio Test (LMR-LRT) (Lo, Mendell, and Rubin, 2001; Nylund, Asparouhov, and Muthén, 2007) which compare  $q$  vs.  $q - 1$  class models, where  $q$  is the number of latent classes and 3) pattern interpretability. In the step of performing multilevel LCA, where LMR-LRT is available, same rules of model fit indices and pattern interpretability were used to determine the optimal combination of latent classes in observation day level and individual level. MLCA models were fitted in Mplus 7.4 (Muthén and Muthén, 2017), the Mplus codes and outputs are shown in **Appendix B**.

### **Characteristics of day level latent classes and individual level latent classes**

Day level latent classes identified by the first step of MLCA were tabulated according to day of week and also whether the diary was recorded during weekdays or not. A contingency table giving the frequency of responses across the 7 time slots of the survey days was produced. Descriptive statistics for the dietary day level recordings according to the latent class memberships were presented. Pearson  $\chi^2$  test was used to compare the distribution of categorical variables. One-way Analysis of Variance (ANOVA) was used to compare the means across the multiple groups for continuous variables.

Person level point estimates and 95% confidence intervals (CIs) were determined by applying individual, nurse visiting, and blood sample weights accordingly which accounted for the probability of participant selection and the clustered survey design. Descriptive statistics for sample characteristics are presented as weighted means (95% CI) or weighted percentages (95%CI). After examining the distribution of the data, the following variables were log-transformed to improve normality:

blood glucose, A1C, TC, LDL, HDL, TG, and average physical activity duration per day. Weighted geometric means (95% CI) were used for all log-transformed variables. For continuous variables, the *F* test was used to determine differences between latent classes with Bonferroni correction to account for multiple testing across > 2 classes. For categorical variables, differences between latent classes were assessed using the adjusted Pearson  $\chi^2$  test for survey data.

### **Association between individual level latent classes and the prevalence of hypertension, obesity, and diabetes**

Associations between individual level carbohydrate eating classes and the prevalence of hypertension, obesity as well as diabetes were explored in men and women separately. Point estimates of weighted means and proportions and 95%CI of the characteristics were determined by applying either nurse visiting weights (for outcomes of hypertension, BMI, and WC) or blood sample weights (for outcomes of DM) accordingly. Similarly, the *F* test (for continuous variables) and adjusted Pearson  $\chi^2$  test (for categorical variables) were used to determine sex-specific differences by hypertension status, BMI categories, and DM diagnosis.

Logistic regression models (for hypertension, and diabetes), and linear regression model (for WC, BMI), were used to test for associations between individual level carbohydrate eating classes and hypertension, diabetes, obesity, and WC, separately.

For the multiple regression models, model fitting strategies are as follows:

1. The crude association between the carbohydrate eating groups and the outcomes was first examined.
2. Potential confounders of the association between carbohydrate eater groups (exposure) and the outcomes were selected depending on the descriptive statistics conducted above, ie. those are associated with both the exposure and the outcome and not on the causal pathway were selected as potential confounders. Those are strongly related with the outcomes but may not associated with carbohydrate eating groups may reduce the standard errors and so improve the precisions are also considered.
3. Confounding and/or interaction effect from each of the potential factors were checked one by one.
4. A preliminary model that includes all of the variables suggested to be confounders in the previous step was established.

5. The remaining variables were added to the preliminary model one by one to see if any of them may be a confounder in condition of the presence of the other covariates.
6. For logistic regression models under survey data, goodness-of-fit (calibration) was assessed using the adapted `svylogitgof` command in Stata (Archer and Lemeshow, 2006). Other diagnostics for regular logistic regression models, such as estimating the pseudo- $R^2$ , AIC or BIC, checking the standardized Pearson residuals, or covariate pattern residuals are currently not available for weighted survey data.
7. For linear regression models (WC, BMI), assumption of independent observations is violated as soon as we weighted the sample. General checking such as QQ plots of the residuals (normality), plotting the residuals against fitted values (constant variance) are not available as well. Outliers, leverage, and Cook's distance cannot be checked either, however, samples with extreme weightings (if exist) are checked by removing them and refit the models as a sensitivity analysis.
8. Since under survey design data, the sampling-weighted least squares are not maximum likelihood, it would not be possible to compare models using likelihood ratio test. Instead, adjusted Wald tests with  $p < 0.05$  were used as criteria for variable inclusion in the final model, and a useful tool to decide whether quadratic and cubic terms of continuous variables are necessary in improving the fitting of model.

Data manipulation and preparation (**Appendix A**) were done in R version 3.5.1 (R core Team, 2018). All statistical analyses, except for MLCA models, were performed with `svyset` command as implemented in Stata software version 15.1 (StataCorp LLC, 2017). All  $p$  values were two-sided.

## Chapter 3

# Results

### Model selection, and interpretation

A series of traditional LCA of the responses to carbohydrate intake within 7 time slots of day was first examined. These initial analyses ignored the clustering of observation days within participants of the survey. **Table 3.1** shows the latent class solutions for one to five classes (see rows under the Fixed effects model section). The BIC declines with the number of day level classes increases. However, the improvement of BIC dropped to less than 1000 from 3 classes to 4 classes solutions (658.9) and from 4 classes to 5 classes solutions (361.7). Entropy index indicates that the 4 classes model could explain about 51% percent of the data, while  $p$  values of Lo-Mendell-Rubun LRT suggest that the more classes we fit, the better model we will have until up to 6 classes ( $p = 0.06$  and is not shown in the table). From the parsimony point of view, we extended the model with random effects building on 2 classes, 3 classes and 4 classes solutions.

The results of the random effect included models are presented in **Table 3.1** under the Random effects model section. It is obvious that the BIC improves with the addition of the random effects which account for the nested structure of the data. Entropy indicates that 4 classes in individual level and 2 classes in the day level may be the best solution mathematically. However, after these solutions were checked in more details, the potentially most substantively interpretable model was found to be the  $3 \times 3$  random effect model, which is the model with 3 latent classes in the day level, and 3 latent classes in the individual level. We must emphasize that different researchers may have made decision slightly different from ours, we provided the descriptions and figures for other solutions in the **Appendix xxx** for reference.

In the  $3 \times 3$  random effect model solution we have chosen, there were 39.5%, 20.4%, and 40.1% observations classified into 3 latent groups in the day level. The overall

counts and percentages for each responses within every time slot and the distributions of the solution are presented in **Table 3.2**. The trajectories illustrating the change of the probabilities of each response to carbohydrate eating during the hours of the day are shown separately by the three types of days in **Figure 3.1**.

TABLE 3.1: Fit criteria for each model specification.

| Model                       | Number of day level classes |             |             |             |             |
|-----------------------------|-----------------------------|-------------|-------------|-------------|-------------|
|                             | 1 class                     | 2 classes   | 3 classes   | 4 classes   | 5 classes   |
| <b>Fixed effects model</b>  |                             |             |             |             |             |
| No. of free parameters      | 14                          | 29          | 44          | 59          | 74          |
| Log-likelihood              | -173793.306                 | -172669.771 | -172039.204 | -171633.941 | -171377.292 |
| BIC                         | 347728.092                  | 345632.608  | 344523.060  | 343864.121  | 343502.409  |
| Lo-Mendell-Rubun LRT        | –                           | < 0.0001    | < 0.0001    | < 0.0001    | < 0.0001    |
| Entropy                     | 1                           | 0.310       | 0.392       | 0.510       | 0.481       |
| <b>Random effects model</b> |                             |             |             |             |             |
| 2 individual level classes  |                             |             |             |             |             |
| No. of free parameters      |                             | 59          | 89          | 119         |             |
| Log-likelihood              |                             | -169331.132 | -168700.96  | -168366.193 |             |
| BIC                         |                             | 339258.502  | 338301.338  | 337934.968  |             |
| Entropy                     |                             | 0.581       | 0.569       | 0.555       |             |
| 3 individual level classes  |                             |             |             |             |             |
| No. of free parameters      |                             | 89          | 134         | 179         |             |
| Log-likelihood              |                             | -166936.279 | -166348.815 | -166062.761 |             |
| BIC                         |                             | 334771.968  | 334051.799  | 333934.448  |             |
| Entropy                     |                             | 0.677       | 0.630       | 0.644       |             |
| 4 individual level classes  |                             |             |             |             |             |
| No. of free parameters      |                             | 119         | 179         |             |             |
| Log-likelihood              |                             | -165441.731 | -164845.696 |             |             |
| BIC                         |                             | 332086.045  | 331500.318  |             |             |
| Entropy                     |                             | 0.729       | 0.659       |             |             |

Note:

**Abbreviation:** No, number; BIC, Bayesian information criterion; Entropy, a pseudo-r-squared index;

Lo-Mendel-Rubin LRT, likelihood ratio test comparing  $q$  classes models with  $q - 1$  classes models.

Class 1 days (**Figure 3.1-A**) were given the name of "high carbohydrate day" since in these days of survey, the probabilities of carbohydrate contributed higher or equal to 50% of the energy consumed were always higher than that in the other two types of days. Specifically, high carbohydrate days were characterised with probabilities of over 0.6 in time slots between 6 am to 9 am, 9 am to 12 am, and also 2 pm to 5 pm, during which the time slots may be interpreted as breakfast, morning snack, and afternoon snack time periods for many participants. Moreover, even during late night time period, such as 8 pm to 10 pm, and 10 pm to 6 am time slots, the probabilities of having higher carbohydrate contained food were still as high as 0.412, and 0.246, respectively.



TABLE 3.2: Day level latent class solution for three classes LCA model.  
(No individual level model)

| Time slots of  | Responses to        |          |      | Class 1<br>(39.5%)         | Class 2<br>(20.4%)        | Class 3<br>(40.1%)   |
|----------------|---------------------|----------|------|----------------------------|---------------------------|----------------------|
| the day        | carbohydrate intake | <i>n</i> | (%)  | High carbo-<br>hydrate day | Low carbo-<br>hydrate day | Regular<br>meals day |
| 6 am – 9 am    |                     |          |      |                            |                           |                      |
|                | Not eating any food | 7655     | 31.2 | 0.129                      | 0.450                     | 0.320                |
|                | Carbohydrate < 50%* | 4500     | 18.4 | 0.130                      | 0.267                     | 0.128                |
|                | Carbohydrate ≥ 50%† | 12328    | 50.4 | 0.741                      | 0.283                     | 0.552                |
| 9 am – 12 am   |                     |          |      |                            |                           |                      |
|                | Not eating any food | 5447     | 22.2 | 0.237                      | 0.079                     | 0.401                |
|                | Carbohydrate < 50%  | 7227     | 29.5 | 0.158                      | 0.492                     | 0.173                |
|                | Carbohydrate ≥ 50%  | 11809    | 48.2 | 0.605                      | 0.429                     | 0.426                |
| 12 noon – 2 pm |                     |          |      |                            |                           |                      |
|                | Not eating any food | 4783     | 19.5 | 0.156                      | 0.356                     | 0.019                |
|                | Carbohydrate < 50%  | 11112    | 45.4 | 0.405                      | 0.413                     | 0.560                |
|                | Carbohydrate ≥ 50%  | 8588     | 35.1 | 0.439                      | 0.231                     | 0.421                |
| 2 pm – 5 pm    |                     |          |      |                            |                           |                      |
|                | Not eating any food | 6926     | 28.3 | 0.130                      | 0.123                     | 0.659                |
|                | Carbohydrate < 50%  | 8277     | 33.8 | 0.249                      | 0.602                     | 0.076                |
|                | Carbohydrate ≥ 50%  | 9280     | 37.9 | 0.621                      | 0.276                     | 0.266                |
| 5 pm – 8 pm    |                     |          |      |                            |                           |                      |
|                | Not eating any food | 3043     | 12.4 | 0.114                      | 0.199                     | 0.034                |
|                | Carbohydrate < 50%  | 14240    | 58.2 | 0.516                      | 0.590                     | 0.639                |
|                | Carbohydrate ≥ 50%  | 7200     | 29.4 | 0.370                      | 0.211                     | 0.328                |
| 8 pm – 10 pm   |                     |          |      |                            |                           |                      |
|                | Not eating any food | 8722     | 35.6 | 0.322                      | 0.291                     | 0.480                |
|                | Carbohydrate < 50%  | 8898     | 36.3 | 0.266                      | 0.551                     | 0.212                |
|                | Carbohydrate ≥ 50%  | 6863     | 28.0 | 0.412                      | 0.158                     | 0.308                |
| 10 pm – 6 am   |                     |          |      |                            |                           |                      |
|                | Not eating any food | 16295    | 66.6 | 0.680                      | 0.590                     | 0.751                |
|                | Carbohydrate < 50%  | 4144     | 16.9 | 0.074                      | 0.294                     | 0.101                |
|                | Carbohydrate ≥ 50%  | 4044     | 16.5 | 0.246                      | 0.115                     | 0.148                |

Note:

**Abbreviation:** LCA, latent class analysis

\* Carbohydrate < 50% indicates that within the time slot, carbohydrate contributed < 50% total energy intake.

† Carbohydrate ≥ 50% indicates that within the time slot, carbohydrate contributed ≥ 50% total energy intake.

Class 2 days (**Figure 3.1-B**) were named as "low carbohydrate day" because first of all, in these days the possibility of participants skipping breakfast was 0.45. And after 9 am, within low carbohydrate days, the probability of having food contained lower carbohydrate (contributed less than 50% of total energy intake), was always higher than having higher carbohydrate contained food. In these days, participants also turned to have morning snacks (with only 0.079 possibility of not eating any food and similar probabilities of having either high or low carbohydrate

contained food). This phenomenon may also be interpreted as having a long and late breakfast (brunch) in these mornings. The probability of not eating any food was the lowest for low carbohydrate days during the midnight time slot (10 pm to 6 am), with probability of 0.590 compared with 0.680 and 0.751 in the class 1 and class 3 days, respectively.

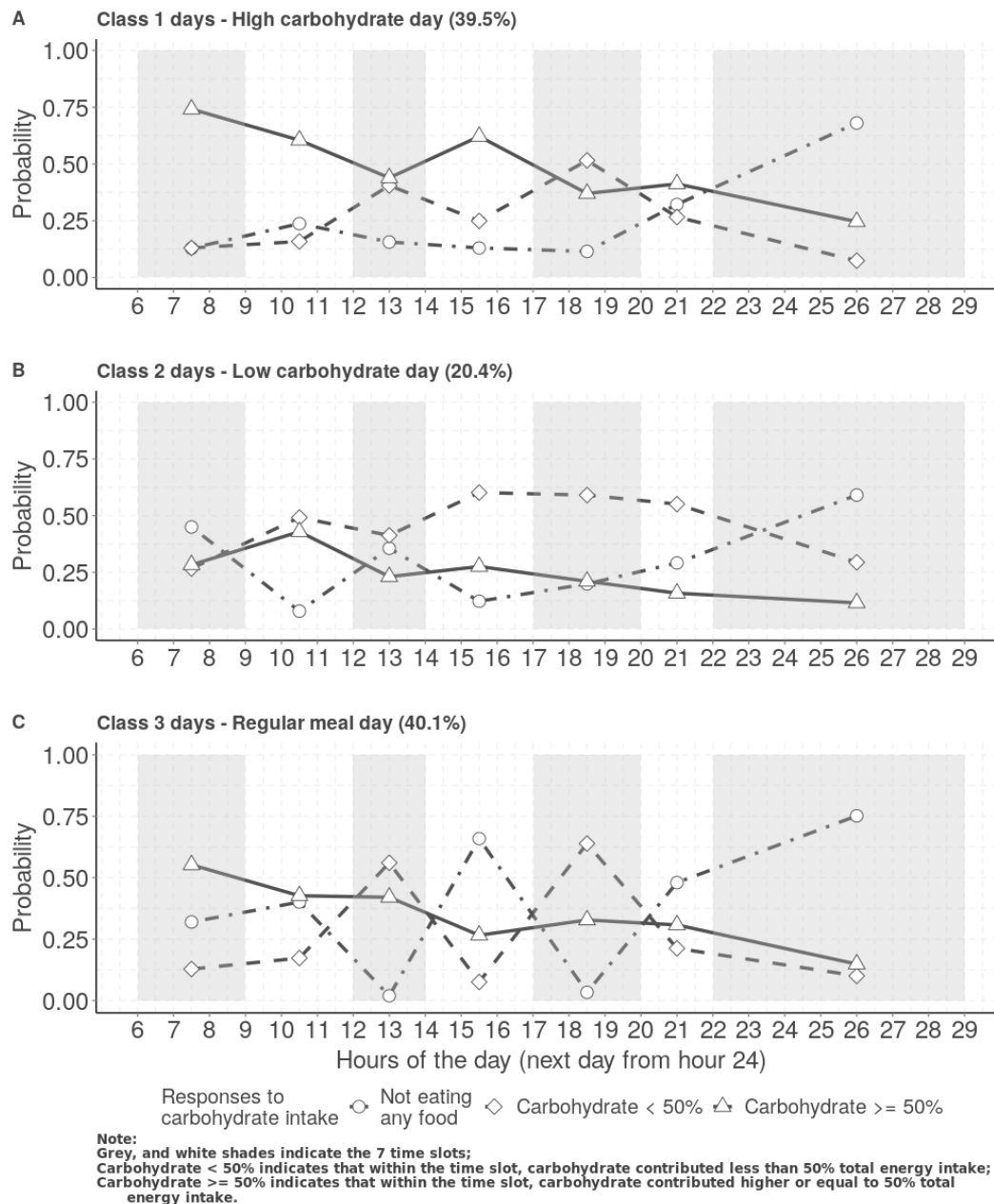


FIGURE 3.1: Day Level Latent Classes Solution.

Class 3 days (**Figure 3.1-C**) were called "regular meals day" due to the following reasons: 1) participants' dietary recordings showed that in these days there was almost 0 possibility of not eating any food at lunch (0.019 between 12 noon and 2

TABLE 3.3: Means (standard deviations), and counts (%) of the characteristics of different types of days according to carbohydrate intake.

|                                       | High carbo-<br>hydrate day | Low carbo-<br>hydrate day | Regular<br>meals day | <i>P</i> value* |
|---------------------------------------|----------------------------|---------------------------|----------------------|-----------------|
| Counts (%)                            | 9667 (39.5)                | 5002 (20.4%)              | 9814 (40.1%)         |                 |
| Country (%)                           |                            |                           |                      | < 0.001         |
| England                               | 5627 (58.2)                | 2972 (59.4)               | 5291 (53.9)          |                 |
| Northern Ireland                      | 1194 (12.4)                | 527 (10.5)                | 1400 (14.3)          |                 |
| Scotland                              | 1527 (15.8)                | 813 (16.3)                | 1774 (18.1)          |                 |
| Wales                                 | 1318 (13.6)                | 690 (13.8)                | 1349 (13.7)          |                 |
| Day of Week (%)                       |                            |                           |                      | < 0.001         |
| Monday                                | 1303 (13.5)                | 715 (14.3)                | 1370 (14.0)          |                 |
| Tuesday                               | 1266 (13.1)                | 674 (13.5)                | 1290 (13.1)          |                 |
| Wednesday                             | 1225 (12.7)                | 740 (14.8)                | 1233 (12.6)          |                 |
| Thursday                              | 1272 (13.2)                | 752 (15.0)                | 1425 (14.5)          |                 |
| Friday                                | 1458 (15.1)                | 797 (15.9)                | 1479 (15.1)          |                 |
| Saturday                              | 1537 (15.9)                | 703 (14.1)                | 1495 (15.2)          |                 |
| Sunday                                | 1605 (16.6)                | 621 (12.4)                | 1522 (15.5)          |                 |
| Weekend, Yes (%)                      | 3142 (32.5)                | 1324 (26.5)               | 3017 (30.7)          | < 0.001         |
| Total energy (kJ)                     | 7539.98 (2875.87)          | 7160.22 (2922.15)         | 7439.68 (2978.91)    | < 0.001         |
| Carbohydrate (g)                      | 222.79 (89.84)             | 209.70 (86.17)            | 206.59 (84.42)       | < 0.001         |
| Protein (g)                           | 71.36 (29.79)              | 69.55 (30.20)             | 73.29 (32.94)        | < 0.001         |
| Fat (g)                               | 65.44 (33.27)              | 63.94 (33.76)             | 67.24 (34.73)        | < 0.001         |
| Alcohol (g)                           | 11.76 (27.31)              | 8.85 (24.25)              | 13.80 (33.00)        | < 0.001         |
| Total sugars (g)                      | 98.63 (56.03)              | 88.03 (50.50)             | 86.39 (50.96)        | < 0.001         |
| Starch (g)                            | 124.07 (55.84)             | 121.59 (56.13)            | 120.11 (54.62)       | < 0.001         |
| Non-milk extrinsic sugar <sup>†</sup> | 59.45 (49.31)              | 50.07 (43.41)             | 50.41 (44.84)        | < 0.001         |
| Fruit (g)                             | 107.40 (137.97)            | 103.15 (129.08)           | 92.76 (126.02)       | < 0.001         |
| Yellow Red Green Vegetables (g)       | 26.52 (46.44)              | 26.84 (47.99)             | 26.16 (45.99)        | 0.681           |

Note:

\* *P* values were obtained from Pearson  $\chi^2$  test for categorical variables, and one-way ANOVA comparing the means in multiple groups for continuous variables;

<sup>†</sup> Non-milk extrinsic sugar is defined as: additionally added free sugar, such as table sugar, honey, glucose, fructose and glucose syrups, sugars added to food and sugars in fruit juices.

pm) and dinner (0.034 between 5 pm and 8 pm); 2) the probabilities of not eating during morning snack time (9 am to 12 am) and afternoon snack time (2 pm to 5 pm) were also the highest among the three types of days (0.401 and 0.659). 3) during these days, participants may have some high carbohydrate contained food between 8 pm and 10 pm (0.308), but the probability of not eating any food during 10 pm to 6 am next morning was 0.751, the highest among the three types of days.

### Features of the three carbohydrate eating time patterns

The details of the characteristics of the three types of carbohydrate eating time pattern were listed in **Table 3.3**. Specifically, regular meals day turned to be recorded slightly more often in Northern Ireland, and Scotland. In terms of day of week distribution in the three types of days, there is strong evidence ( $p < 0.001$ ) that high carbohydrate days appeared more frequently in weekends (32.5%) compared with low carbohydrate day (26.5%) and regular meals day (30.7%).

As expected, consumption of total energy (7539.98 kJ), total carbohydrate (222.79 g), total sugar (98.63 g), starch (124.07 g), and non-milk extrinsic sugar (59.45 g) were highest among high carbohydrate days (all  $p < 0.001$ ). On the other hand, the consumption of protein (73.29 g), total fat (67.24 g), and alcohol (13.80 g) were the highest in the so-called regular meals days. Moreover, in high carbohydrate days, participants turned to consume the highest amount of fruit (107.40 g). There was no evidence of any difference for the consumption of yellow, red, or green vegetables across the three types of days ( $p = 0.681$ ).

### Individual level LCA solution

In the random effect models we utilized the non-parametric approach, in which we added a level 2 (individual level) latent classes based on the random means from the level 1 (day level) latent class solution. The results of the individual level LCA solution for 2 and 3 classes are presented in **Figure 3.2**, and **3.3**.

With two individual level latent classes (**Figure 3.2**), one individual class is comprised of individuals with a relatively slightly higher proportion of having "low carbohydrate day" (22.1%) compared to the other (17.4%). This class represents nearly 65% of the individuals. However, we believe these individual classes are not very distinguishable to each other.

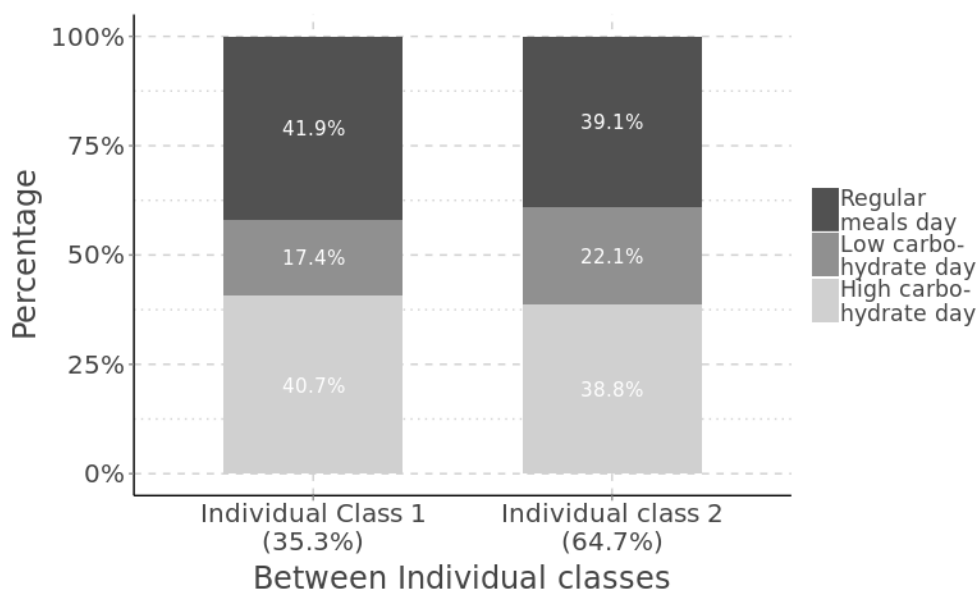


FIGURE 3.2: Multilevel Latent Class Solution, 3 classes in day level, 2 classes in individual level.

With three individual level latent classes (**Figure 3.3**), a low-carbohydrate eaters class, a moderate-carbohydrate eaters class, and a high-carbohydrate eaters class emerges. 43.1% participants were identified as high-carbohydrate eaters, in these individuals, about 50% of the days (2 out of 4 days) of their dietary diary could be classified as having high carbohydrate days. Nearly 1 out of 4 days of their dietary diary were either "regular meals day" or "low carbohydrate day". 28.1% participants fell into the low carbohydrate eaters class in the left hand side of **Figure 3.3**, their recordings of food intake showed that in more than 60% of their days, they were having "regular meals" which was characterised as with highest amount of fat and alcohol consumptions as already described in **Table 3.3**. Moderate carbohydrate eaters have comparable proportions (42.0% vs. 40.0%) of having high carbohydrate days and regular meals day, 18.0% of their dietary diary were identified as low carbohydrate days.

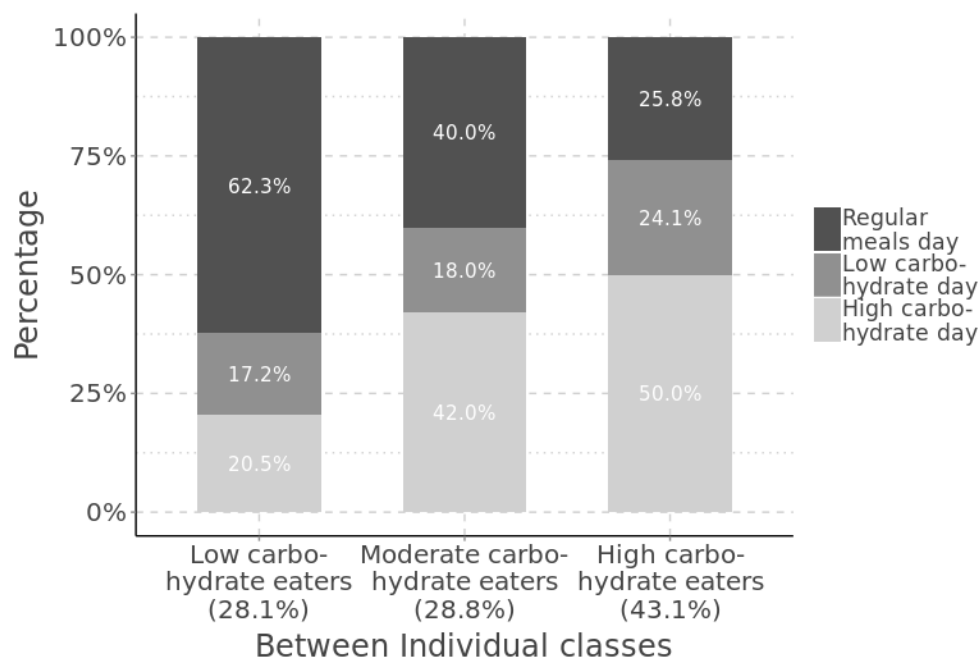


FIGURE 3.3: Multilevel Latent Class Solution, 3 classes in day level, 3 classes in individual level.

The social-demographic characteristics of the UK adults according to their individual level latent class membership are shown in **Table 3.4**. Moderate carbohydrate eaters were relatively younger ( $p < 0.001$ ), and slightly less from England ( $p = 0.007$ ). Gender distribution across the three types of carbohydrate eaters was fairly even ( $p = 0.119$ ). Distribution of the carbohydrate eater types turned out to be changing with the year of survey. Low carbohydrate eaters represented 32.5% of the population in the first year of survey, but later dropped to lower than 30% (lowest in

the third year, 22.6%) until the most recent year. Proportion of high carbohydrate eaters increased from 41.2% to the highest (50.6%) in the second year of the survey, but then started to decline to 38.4% in the 8th year of survey ( $p = 0.015$ ). There was no evidence of difference in employment status across three types of carbohydrate eaters. However, strong evidence suggested that high carbohydrate eaters had the highest proportion (61.3%) of living with a partner ( $p < 0.001$ ); moderate carbohydrate eaters had the lowest average income (27180.8 £/year), highest proportion of non-white population (20.5%), and lower education level (23.3% with degree of higher education) compared with either low or high carbohydrate eaters.

Weighted means, percentages of anthropometric measurements, average of main nutrients intake, as well as biochemical characteristic profiles according to the latent carbohydrate eater groups are given in **Table 3.5**. Low carbohydrate eaters had higher mean BMI (27.8 kg/m<sup>2</sup>) and larger mean WC (98.9/89.9 cm in men/women) compared with 27.2, 27.3 kg/m<sup>2</sup>, and 95.9/88.7 (men/women), 98.1/87.2 (men/women) cm in moderate and high carbohydrate eaters. Moderate carbohydrate eaters had the highest prevalence of being a current smoker (27.8%), shortest time of daily physical activity (geometric mean: 0.87 hours/day), and the lowest prevalence of hypertension (20.2%).

Average total energy intake over the 4 days of dietary survey was the highest (7985.8 kJ) in the low carbohydrate eaters group. As expected, the mean of total carbohydrate intake was 203.8 g, 218.3 g, and 233.4 g for low, moderate, and high carbohydrate eaters, respectively. Energy contribution from carbohydrate was close to 50% in the high carbohydrate eaters, but was only 40.6% in the low carbohydrate eaters. It is noteworthy that low carbohydrate eaters consumed the highest average amount of protein (79.9 g, 17.2% of total energy), fat (74.7g, 35.4% of total energy), and alcohol (20.8 g, 6.8% of total energy).

From the results of blood tests, 6.9% of low carbohydrate eaters were found to be diabetic (diagnosed by A1C > 6.5%), while the percentages of diabetes in the moderate and high carbohydrate eaters were 3.5%, and 4.1% ( $p < 0.011$ ), respectively. Although there was some evidence ( $p = 0.027$ ) that fasting blood glucose level may be slightly higher in non-diabetic low carbohydrate eaters, the geometric mean for A1C was probably lower in moderate carbohydrate eaters (4.72, 95%CI: 5.39, 5.47). Cholesterol, HDL, and LDL were all lower in the moderate carbohydrate eaters, while no evidence of any difference of TG was found across three types of carbohydrate eaters.

TABLE 3.4: Weighted means, percentages, and 95% CIs of the social-demographic characteristics by carbohydrate eating latent class memberships in the UK adults.  
(NDNS RP 2008/09-2015/16, sample size = 6155)

| Variables                          | Low carbo-<br>hydrate eaters<br>(n = 1730) | Moderate carbo-<br>hydrate eaters<br>(n = 1772) | High carbo-<br>hydrate eaters<br>(n = 2653) | P value * |
|------------------------------------|--|---|---|-----------|
| Total (%)                          | 28.4 (26.9, 29.9)                          | 28.7 (27.1, 30.3)                               | 43.0 (41.3, 44.7)                           |           |
| Country (%)                        |  |   |   | 0.007     |
| England                            | 84.5 (81.7, 86.9)                          | 82.0 (79.3, 84.5)                               | 84.7 (82.3, 86.8)                           |           |
| Northern Ireland                   | 2.1 (1.6, 2.8)                             | 4.2 (3.2, 5.6)                                  | 2.2 (1.7, 3.0)                              |           |
| Scotland                           | 9.1 (7.0, 11.8)                            | 8.6 (6.7, 11.1)                                 | 8.0 (6.3, 10.2)                             |           |
| Wales                              | 4.3 (3.3, 5.6)                             | 5.1 (4.0, 6.4)                                  | 5.1 (4.0, 6.4)                              |           |
| Age (years)                        | 51.0 (49.9, 52.1)                          | 40.3 (39.1, 41.6)                               | 51.7 (50.7, 52.7)                           | < 0.001   |
| Sex (%)                            |  |   |   | 0.119     |
| Men                                | 50.0 (46.9, 53.1)                          | 50.2 (47.0, 53.5)                               | 46.6 (44.0, 49.1)                           |           |
| Women                              | 50.0 (46.9, 53.1)                          | 49.8 (46.5, 53.0)                               | 53.4 (50.9, 56.0)                           |           |
| Survey years (% in rows)           |  |   |   | 0.015     |
| 1                                  | 32.5 (28.4, 36.9)                          | 26.3 (21.9, 31.2)                               | 41.2 (36.6, 46.0)                           |           |
| 2                                  | 26.8 (22.6, 31.3)                          | 22.6 (18.6, 27.3)                               | 50.6 (45.8, 55.4)                           |           |
| 3                                  | 22.6 (18.8, 26.9)                          | 33.7 (28.6, 39.2)                               | 43.6 (38.7, 48.7)                           |           |
| 4                                  | 27.9 (24.1, 32.2)                          | 27.6 (23.8, 31.8)                               | 44.4 (40.2, 48.7)                           |           |
| 5                                  | 27.9 (24.2, 32.0)                          | 28.7 (24.4, 33.5)                               | 43.3 (38.2, 48.6)                           |           |
| 6                                  | 28.0 (24.0, 32.4)                          | 31.5 (26.9, 36.6)                               | 40.5 (35.8, 45.3)                           |           |
| 7                                  | 29.1 (25.2, 33.4)                          | 29.0 (24.5, 34.0)                               | 41.8 (37.1, 46.7)                           |           |
| 8                                  | 31.1 (27.3, 35.3)                          | 30.5 (25.9, 35.5)                               | 38.4 (34.1, 42.8)                           |           |
| Paid employment <sup>†</sup> (%)   |  |   |   | 0.907     |
| Yes                                | 40.3 (37.0, 43.6)                          | 40.8 (37.1, 44.5)                               | 39.8 (37.1, 42.6)                           |           |
| No                                 | 59.7 (56.4, 63.0)                          | 59.2 (55.5, 62.9)                               | 60.2 (57.4, 62.9)                           |           |
| Live with partner <sup>‡</sup> (%) |  |   |   | < 0.001   |
| Yes                                | 56.9 (53.6, 60.1)                          | 38.4 (35.2, 41.8)                               | 61.3 (58.7, 63.7)                           |           |
| No                                 | 43.1 (39.9, 46.4)                          | 61.6 (58.2, 64.8))                              | 38.7 (36.3, 41.3)                           |           |
| Household income, £/year           | 36558.5<br>(34800.2, 38316.8)              | 27180.8<br>(25597.9, 28763.7)                   | 32171.6<br>(31024.9, 33318.2)               | < 0.001   |
| Ethnicity (%)                      |  |   |   |           |
| White                              | 94.2 (92.4, 95.6)                          | 79.5 (76.4, 82.3)                               | 91.9 (90.1, 93.4)                           | < 0.001   |
| Non-White                          | 5.8 (4.4, 7.6)                             | 20.5 (17.7, 23.6)                               | 8.1 (6.6, 9.9)                              |           |
| Education (%)                      |  |   |   |           |
| Degree or higher                   | 29.0 (26.1, 32.1)                          | 23.3 (20.5, 26.3)                               | 26.2 (24.1, 28.5)                           | 0.019     |
| Lower than degree                  | 71.0 (67.9, 73.9)                          | 76.7 (73.7, 79.5)                               | 73.8 (71.5, 75.9)                           |           |

Note:

**Abbreviations:** CI, confidence intervals; NDNS RP, national dietary and nutrition survey rolling programme.  
Variables were weighted by individual weights.

\* For continuous variables, the *F* test was used to determine differences between latent classes with Bonferroni correction to account for multiple testing across > 2 classes. For categorical variables, differences between latent classes were assessed using the adjusted Pearson  $\chi^2$  test for survey data.

<sup>†</sup> Paid employment was defined as being in paid employment during the last 4 weeks prior to the survey.

<sup>‡</sup> Live with partner was defined as either living with a married husband/wife or a legally recognised civil partnership.

TABLE 3.5: Weighted means, percentages, and 95% CIs of the anthropometric measurements, average main nutrients intake and biochemical characteristics by carbohydrate eating latent class memberships in the UK adults. (NDNS RP 2008/09-2015/16, sample size = 6155)

| Variables                             | Low carbo-<br>hydrate eaters<br>(n = 1730) | Moderate carbo-<br>hydrate eaters<br>(n = 1772) | High carbo-<br>hydrate eaters<br>(n = 2653) | P value * |
|---------------------------------------|--|---|---|-----------|
| BMI (kg/m <sup>2</sup> )              | 27.8 (27.4, 28.2)                          | 27.2 (26.7, 27.7)                               | 27.3 (26.9, 27.6)                           | 0.006     |
| WC (cm)                               |  |   |   |           |
| Men                                   | 98.9 (97.4, 100.5)                         | 95.9 (94.1, 97.8)                               | 98.1 (96.9, 99.2)                           | 0.056     |
| Women                                 | 89.9 (88.7, 91.3)                          | 88.7 (87.1, 90.3)                               | 87.2 (86.1, 88.2)                           | 0.005     |
| Smoking status (%)                    |  |   |   |           |
| Current                               | 20.4 (18.0, 23.0)                          | 27.8 (25.0, 30.9)                               | 17.1 (15.4, 19.0)                           | < 0.001   |
| Ex-smoker                             | 29.3 (26.5, 32.2)                          | 16.8 (14.6, 19.2)                               | 26.1 (24.9, 28.3)                           |           |
| Never                                 | 50.3 (47.2, 52.2)                          | 55.4 (52.2, 58.6)                               | 56.8 (54.3, 59.3)                           |           |
| Physical activity (hours/day) ¶       | 1.08 (0.97, 1.19)                          | 0.87 (0.77, 0.97)                               | 1.07 (0.98, 1.16)                           | 0.005     |
| Hypertension <sup>†</sup> , Yes (%)   | 33.8 (30.2, 37.5)                          | 20.2 (17.0, 24.0)                               | 30.9 (26.9, 31.0)                           | < 0.001   |
| Total energy intake (kJ)              | 7985.8<br>(7823.3, 8146.3)                 | 7341.8<br>(7825.3, 8146.3)                      | 7677.0<br>(7555.8, 7799.8)                  | < 0.001   |
| Carbohydrate intake (g)               | 203.8<br>(199.8, 207.8)                    | 218.3<br>(212.9, 223.7)                         | 233.4<br>(229.6, 237.2)                     | < 0.001   |
| Carbohydrate percent <sup>‡</sup> (%) | 40.6 (40.2, 41.0)                          | 47.3 (46.8, 47.8)                               | 48.3 (47.9, 48.6)                           | < 0.001   |
| Protein intake (g)                    | 79.9 (77.9, 81.8)                          | 69.3 (67.6, 71.0)                               | 73.7 (72.5, 74.8)                           | < 0.001   |
| Protein percent (%)                   | 17.2 (16.9, 17.5)                          | 16.3 (16.0, 16.6)                               | 16.5 (16.3, 16.6)                           | < 0.001   |
| Fat intake (g)                        | 74.7 (73.1, 76.4)                          | 63.8 (62.1, 65.5)                               | 65.7 (64.4, 67.0)                           | < 0.001   |
| Fat percent (%)                       | 35.4 (34.9, 35.8)                          | 32.5 (32.1, 32.9)                               | 32.0 (31.7, 32.3)                           | < 0.001   |
| Alcohol intake (g)                    | 20.8 (18.3, 23.2)                          | 10.7 (9.4, 11.9)                                | 8.9 (8.1, 9.8)                              | < 0.001   |
| Alcohol percent (%)                   | 6.8 (6.3, 7.4)                             | 3.8 (3.4, 4.3)                                  | 3.2 (2.9, 3.4)                              | < 0.001   |
| Glucose (mmol/l)                      | 5.17 (5.12, 5.23)                          | 5.05 (4.99, 5.13)                               | 5.10 (5.05, 5.15)                           | 0.027     |
| A1C (%)                               | 5.47 (5.44, 5.51)                          | 5.43 (5.39, 5.47)                               | 5.50 (5.48, 5.53)                           | 0.010     |
| DM §                                  | 6.9 (5.0, 9.3)                             | 3.5 (2.3, 5.3)                                  | 4.1 (2.9, 5.6)                              | 0.011     |
| TC (mmol/l)                           | 4.95 (4.84, 5.05)                          | 4.72 (4.62, 4.83)                               | 4.95 (4.87, 5.03)                           | 0.001     |
| HDL (mmol/l)                          | 1.39 (1.35, 1.43)                          | 1.32 (1.28, 1.35)                               | 1.39 (1.36, 1.42)                           | 0.003     |
| LDL (mmol/l)                          | 2.88 (2.79, 2.97)                          | 2.77 (2.68, 2.86)                               | 2.93 (2.86, 3.00)                           | 0.024     |
| TG (mmol/l)                           | 1.14 (1.08, 1.19)                          | 1.11 (1.05, 1.17)                               | 1.10 (1.06, 1.15)                           | 0.629     |

**Abbreviations:** CI, confidence intervals; NDNS RP, national dietary and nutrition survey rolling programme; BMI body mass index; WC, waist circumference; A1C, haemoglobin A1c; DM, diabetes mellitus; TC, total cholesterol, HDL, high density lipoproteins; LDL, low density lipoproteins; TG, triglycerides.

Glucose, A1C, TC, HDL, LDL, TG, and physical activity were expressed in geometric means (95% CI) because the data were positively skewed.

Variables from the blood tests (glucose and A1C) were weighted by blood sample weights, the other variables were weighted by nurse visiting weights. Glucose and A1C levels are estimated in subgroups of people without diabetes.

\* For continuous variables, the *F* test was used to determine differences between latent classes with Bonferroni correction to account for multiple testing across > 2 classes. For categorical variables, differences between latent classes were assessed using the adjusted Pearson  $\chi^2$  test for survey data.

¶ Physical activity was calculated as mean time spent at moderate or vigorous physical activity including both work-related and recreational activities during the most recent month before the survey.

† Hypertension was defined as either systolic blood pressure  $\geq 140$  mmHg or diastolic blood pressure  $\geq 90$  mmHg, or under treatment for hypertension.

‡ Carbohydrate percent indicates the percentage of energy from carbohydrate in total energy intake.

§ DM was defined by A1C > 6.5%.



## Association between individual level latent classes and hypertension, and obesity.

### Hypertension

**Table 3.6** presents the characteristics of men and women participants in the NDNS RP 2008/09-15/16 by hypertension status. The weighted prevalences of hypertension were 30.4% in men and 27.5% in women. Among both sexes, there were strong evidence of differences by hypertension status for age, education level, living with a partner or not, smoking status, BMI, WC, and prevalence of diabetes ( $p < 0.01$ ). Differences were also found for carbohydrate eating patterns defined previously, total energy intake, as well as total carbohydrate intake ( $p < 0.001$ ). No difference was found among either men or women for geographic location, and ethnicity. Strong evidence of difference was found in women for average household income (32741.5 £/year in non-hypertensive vs. 27862.0 £/year in hypertensive,  $p < 0.001$ ), and physical activity level (geometric mean: 0.81 hours/day in non-hypertensive compared with 0.53 hours/day in hypertensive,  $p < 0.001$ ) but not in men.

The sex-specific associations of carbohydrate eating patterns with hypertension with or without diabetes are shown in **Table 3.7**. In the crude models, moderate carbohydrate eaters had statistically significant lower odds of having hypertension than low carbohydrate eaters in both men and women irrespective to diabetes status. Among men, after adjustment for selected confounders, which includes: age, live with partner or not, education level, BMI, smoking status, and total energy intake, the odds ratio (OR) comparing moderate carbohydrate eaters was 0.68 (95% CI: 0.43, 1.07) and remained borderline significant ( $p = 0.093$ ). 95% CI of the OR became narrower (OR: 0.64, 95% CI: 0.41, 1.01,  $p = 0.054$ ) when BMI was replaced with WC in model 2. When diabetic men were excluded in the models, the ORs (95%CI) for moderate and high carbohydrate eaters compared with low carbohydrate eaters were 0.65 (0.41, 1.03) and 0.73 (0.51, 1.06), respectively. The negative associations between carbohydrate eaters patterns were still observed in women, however, without any statistical evidence in the full adjusted models.

### Obesity (BMI and WC)

**Table 3.9** shows the characteristics for participants according to their obesity status stratified by sex. The survey design-weighted prevalence for being overweight and obese in the UK adults were estimated to be 43.4% and 25.7% in men, and 30.9% and 27.4% in women. As expected, WC increased significantly with the elevated BMI level in both men and women. Strong evidence of differences by obesity level

TABLE 3.6: Weighted means, percentages, and 95 % CIs of the characteristics by hypertension status in the UK adults.  
(NDNS RP 2008/09-2015/16, sample size = 6155)

|                                  | Men (n = 2537)             |                            |          | Women (n = 3618)           |                            |          |
|----------------------------------|----------------------------|----------------------------|----------|----------------------------|----------------------------|----------|
|                                  | Non-hypertensive           | Hypertensive               | P value* | Non-hypertensive           | Hypertensive               | P value* |
| Weighted prevalence (%)          | 69.6 (66.6, 72.5)          | 30.4 (27.5, 33.4)          |          | 72.5 (69.8, 75.0)          | 27.5 (25.0, 30.2)          |          |
| Age (years)                      | 43.2 (41.7, 44.7)          | 59.9 (58.0, 61.7)          | < 0.001  | 43.9 (42.7, 45.1)          | 64.9 (63.4, 66.5)          | < 0.001  |
| Country (%)                      |                            |                            | 0.109    |                            |                            | 0.631    |
| England                          | 84.7 (80.9, 87.2)          | 85.4 (81.2, 88.8)          |          | 84.0 (81.0, 86.6)          | 83.5 (79.1, 87.0)          |          |
| Northern Ireland                 | 3.3 (2.2, 4.8)             | 1.6 (0.8, 3.1)             |          | 2.5 (1.9, 3.5)             | 2.6 (1.5, 4.3)             |          |
| Scotland                         | 8.6 (6.3, 11.7)            | 7.1 (4.6, 10.9)            |          | 8.7 (6.5, 11.7)            | 7.9 (5.1, 11.8)            |          |
| Wales                            | 3.9 (2.7, 5.6)             | 5.9 (4.0, 8.5)             |          | 4.7 (3.7, 6.0)             | 6.1 (4.3, 8.6)             |          |
| Ethnicity (%)                    |                            |                            | 0.534    |                            |                            | 0.126    |
| White                            | 89.6 (86.5, 92.0)          | 91.1 (86.2, 94.4)          |          | 85.7 (82.7, 88.3)          | 90.2 (85.0, 93.7)          |          |
| Non-white                        | 10.4 (8.0, 13.5)           | 8.9 (5.6, 13.8)            |          | 14.3 (11.7, 17.3)          | 9.8 (6.3, 15.0)            |          |
| Education (%)                    |                            |                            | 0.006    |                            |                            | < 0.001  |
| Degree or higher                 | 30.3 (26.6, 34.2)          | 21.5 (17.3, 26.5)          |          | 33.0 (29.9, 36.3)          | 19.7 (15.8, 24.3)          |          |
| Lower than Degree                | 69.7 (65.8, 73.4)          | 78.5 (73.5, 82.7)          |          | 67.0 (63.7, 70.1)          | 80.3 (75.7, 84.2)          |          |
| Household income £/year          | 34006.5 (31972.9, 36040.1) | 32280.5 (29875.6, 34685.4) | 0.284    | 32741.5 (31009.9, 34473.1) | 27862.0 (25557.0, 30167.0) | < 0.001  |
| Live with partner†, Yes, (%)     | 56.1 (51.8, 61.4)          | 66.6 (61.3, 71.5)          | 0.002    | 48.7 (45.1, 52.3)          | 58.9 (53.6, 63.9)          | 0.002    |
| Smoking status                   |                            |                            | < 0.001  |                            |                            | < 0.001  |
| Current                          | 19.7 (16.6, 23.1)          | 12.9 (9.5, 17.2)           |          | 15.2 (13.1, 17.6)          | 8.5 (6.2, 11.6)            |          |
| Ex-smoker                        | 24.2 (21.1, 27.6)          | 38.8 (33.4, 44.5)          |          | 21.6 (19.1, 24.4)          | 32.2 (27.3, 37.4)          |          |
| Never                            | 56.2 (52.1, 60.1)          | 48.3 (42.7, 54.0)          |          | 63.2 (60.1, 66.2)          | 59.3 (54.0, 64.4)          |          |
| Physical activity (hours/day) †  | 1.52 (1.33, 1.72)          | 1.29 (1.08, 1.53)          | 0.134    | 0.81 (0.73, 0.89)          | 0.53 (0.42, 0.64)          | < 0.001  |
| BMI (kg/m²)                      | 26.8 (26.4, 27.2)          | 29.5 (28.9, 29.9)          | < 0.001  | 26.4 (26.1, 26.8)          | 29.8 (29.2, 30.5)          | < 0.001  |
| WC (cm)                          | 95.0 (93.9, 96.2)          | 104.6 (103.2, 106.1)       | < 0.001  | 85.7 (84.8, 86.6)          | 95.7 (94.2, 97.2)          | < 0.001  |
| DM§ (%)                          | 3.7 (2.4, 5.7)             | 12.6 (8.9, 17.5)           | < 0.001  | 1.8 (1.0, 3.3)             | 7.9 (5.1, 11.9)            | < 0.001  |
| Carbohydrate eating patterns (%) |                            |                            | < 0.001  |                            |                            | < 0.001  |
| Low                              | 28.3 (24.8, 32.2)          | 37.1 (32.0, 42.5)          |          | 26.9 (24.1, 29.9)          | 32.0 (27.2, 37.2)          |          |
| Moderate                         | 30.8 (26.9, 35.0)          | 19.3 (15.3, 24.1)          |          | 29.6 (26.4, 33.0)          | 18.4 (14.5, 22.9)          |          |
| High                             | 40.8 (36.9, 44.9)          | 43.6 (38.2, 49.2)          |          | 43.5 (40.3, 46.8)          | 49.7 (44.1, 55.2)          |          |
| Total energy intake (kJ)         | 9021.4 (8791.9, 9251.0)    | 8366.2 (8094.9, 8637.4)    | < 0.001  | 6802.6 (6681.1, 6924.0)    | 6396.7 (6217.1, 6576.2)    | < 0.001  |
| Carbohydrate intake (g)          | 259.2 (252.9, 265.3)       | 235.3 (227.8, 242.8)       | < 0.001  | 198.0 (194.2, 201.8)       | 184.5 (178.8, 190.1)       | < 0.001  |

Note:

**Abbreviations:** CI, confidence intervals; NDNS RP, national dietary and nutrition survey rolling programme; BMI body mass index; WC, waist circumference.

Variables are weighted by nurse visiting weights.

\* Significant sex-specific differences by hypertension status assessed using an *F* test for continuous variables or design-adjusted Pearson  $\chi^2$  test.

† Live with partner was defined as either living with a married husband/ wife or a legally recognised civil partnership.

‡ Physical activity was calculated as mean time spent at moderate or vigorous physical activity including both work-related and recreational activities.

§ DM was defined by A1C > 6.5%.

were found for age, total energy intake, and carbohydrate intake in both sexes. Specifically, education level ( $p = 0.022$  for men,  $< 0.001$  for women), average household income ( $p = 0.011$  for men,  $< 0.001$  for women) were lower with increasing BMI. Living with partner or not was strongly positively associated with obesity in men but not in women. Men with obesity were found to have the lowest proportion of never being a smoker (47.9 %), and the highest proportion of being ex-smoker (32.9%). Association between smoking status and obesity in women was only with very weak evidence ( $p = 0.042$ ) but similar pattern as in men was also observed. No difference was found for length of physical activity across obesity levels in men,

TABLE 3.7: ORs (95%CI) of carbohydrate eating patterns with hypertension in the UK adults, with or without diabetes .  
(NDNS RP 2008/09-2015/16, sample size = 6155)

| Model                                | Carbohydrate eating patterns |                   |                 |                   |                 |
|--------------------------------------|------------------------------|-------------------|-----------------|-------------------|-----------------|
|                                      | Low                          | Moderate          | <i>P</i> value* | High              | <i>P</i> value* |
| <b>Men (n = 2537)</b>                |                              |                   |                 |                   |                 |
| <b>Hypertension</b>                  |                              |                   |                 |                   |                 |
| Crude model                          | 1                            | 0.48 (0.33, 0.70) | $< 0.001$       | 0.82 (0.59, 1.13) | 0.217           |
| Model 1 <sup>†</sup>                 | 1                            | 0.68 (0.43, 1.07) | 0.093           | 0.80 (0.56, 1.15) | 0.227           |
| Model 2                              | 1                            | 0.64 (0.41, 1.01) | 0.054           | 0.75 (0.53, 1.08) | 0.124           |
| <b>Hypertension in non-diabetics</b> |                              |                   |                 |                   |                 |
| Crude model                          | 1                            | 0.49 (0.33, 0.73) | $< 0.001$       | 0.82 (0.59, 1.14) | 0.241           |
| Model 1 <sup>†</sup>                 | 1                            | 0.69 (0.43, 1.09) | 0.110           | 0.78 (0.54, 1.14) | 0.197           |
| Model 2                              | 1                            | 0.65 (0.41, 1.03) | 0.066           | 0.73 (0.51, 1.06) | 0.096           |
| <b>Women (n = 3618)</b>              |                              |                   |                 |                   |                 |
| <b>Hypertension</b>                  |                              |                   |                 |                   |                 |
| Crude model                          | 1                            | 0.52 (0.36, 0.75) | $< 0.001$       | 0.96 (0.72, 1.28) | 0.773           |
| Model 1 <sup>†</sup>                 | 1                            | 0.79 (0.45, 1.39) | 0.415           | 0.89 (0.61, 1.30) | 0.552           |
| Model 2                              | 1                            | 0.78 (0.45, 1.36) | 0.384           | 0.88 (0.62, 1.26) | 0.483           |
| <b>Hypertension in non-diabetics</b> |                              |                   |                 |                   |                 |
| Crude model                          | 1                            | 0.51 (0.35, 0.74) | $< 0.001$       | 0.98 (0.73, 1.31) | 0.875           |
| Model 1 <sup>†</sup>                 | 1                            | 0.79 (0.44, 1.42) | 0.435           | 0.89 (0.61, 1.29) | 0.534           |
| Model 2                              | 1                            | 0.79 (0.45, 1.39) | 0.415           | 0.87 (0.61, 1.25) | 0.452           |

Note:

**Abbreviations:** OR, odds ratio; CI, confidence interval; BMI, body mass index; WC, waist circumference; NDNS RP, national dietary and nutrition survey rolling programme.

Diabetes was defined by A1C  $> 6.5\%$ . BMI was replaced with WC in Model 2s, other covariates remained the same with the corresponding Model 1s.

\* *P* values were obtained from wald tests from logistic regression models.

<sup>†</sup> Adjusted for age (continuous), live with partner or not (binary), education level (higher or equal to degree level or not), BMI, smoking status (current, ex-smoker, never), total energy intake (kJ);

<sup>‡</sup> Adjusted for age, live with partner or not, average household income (continuous), education level, BMI, smoking status, total energy intake (kJ), alcohol consumption (g/day);

TABLE 3.8: Weighted means, percentages, and 95 % CIs of the characteristics by BMI categories in the UK adults.  
(INDNS RP 2008/09-2015/16, sample size = 6155)

|  | Men (n = 2537)                |                               |                               |          |  | Women (n = 3618)              |                               |                               |          |  |
|--|-------------------------------|-------------------------------|-------------------------------|----------|--|-------------------------------|-------------------------------|-------------------------------|----------|--|
|  | Normal weight                 | Overweight                    | Obese                         | P value* |  | Normal weight                 | Overweight                    | Obese                         | P value* |  |
| Weighted prevalence (%)                    | 30.9 (28.0, 33.9)             | 43.4 (40.4, 46.4)             | 25.7 (23.2, 28.4)             |          |  | 41.7 (39.0, 44.4)             | 30.9 (28.4, 33.5)             | 27.4 (25.1, 29.9)             |          |  |
| BMI (kg/m <sup>2</sup> )                   | 22.6 (22.3, 22.8)             | 27.3 (27.2, 27.5)             | 33.7 (33.3, 34.2)             | < 0.001  |  | 22.2 (22.0, 22.4)             | 27.3 (27.2, 27.5)             | 35.0 (34.6, 35.4)             | < 0.001  |  |
| WC (cm)                                    | 84.5 (83.6, 85.4)             | 97.1 (96.4, 97.8)             | 112.7 (111.6, 113.9)          | < 0.001  |  | 76.9 (76.2, 77.5)             | 89.0 (88.3, 89.7)             | 103.7 (102.6, 104.7)          | < 0.001  |  |
| Age (years)                                | 40.3 (38.2, 42.4)             | 49.6 (47.9, 51.2)             | 50.4 (48.5, 52.3)             | < 0.001  |  | 45.0 (43.4, 46.7)             | 50.4 (48.6, 52.3)             | 50.9 (49.1, 52.7)             | < 0.001  |  |
| Country (%)                                |                               |                               |                               | 0.236    |  |                               |                               |                               | 0.589    |  |
| England                                    | 83.9 (79.2, 87.7)             | 86.9 (83.6, 89.7)             | 81.6 (76.7, 85.7)             |          |  | 84.3 (80.4, 87.5)             | 83.7 (79.7, 87.0)             | 82.4 (78.2, 85.9)             |          |  |
| Northern Ireland                           | 3.3 (1.9, 5.8)                | 2.3 (1.4, 3.6)                | 3.2 (2.0, 4.9)                |          |  | 3.0 (2.1, 4.2)                | 2.2 (1.5, 3.2)                | 3.4 (2.3, 5.0)                |          |  |
| Scotland                                   | 9.1 (6.1, 13.5)               | 6.5 (4.4, 9.7)                | 9.0 (5.9, 13.3)               |          |  | 9.0 (6.1, 13.0)               | 9.0 (6.3, 12.8)               | 8.5 (5.7, 12.6)               |          |  |
| Wales                                      | 3.7 (2.3, 5.8)                | 4.3 (3.1, 5.9)                | 6.3 (4.0, 9.7)                |          |  | 3.8 (2.9, 5.1)                | 5.1 (3.6, 7.2)                | 5.7 (4.2, 7.7)                |          |  |
| Ethnicity (%)                              |                               |                               |                               | 0.466    |  |                               |                               |                               | 0.879    |  |
| White                                      | 88.7 (83.9, 92.2)             | 89.1 (85.6, 91.9)             | 91.9 (87.3, 94.9)             |          |  | 88.4 (84.9, 91.19)            | 88.6 (84.5, 91.7)             | 87.3 (82.5, 90.9)             |          |  |
| Non-white                                  | 11.3 (7.8, 16.1)              | 10.9 (8.1, 14.4)              | 8.1 (5.1, 12.7)               |          |  | 11.6 (8.9, 15.1)              | 11.4 (8.3, 15.5)              | 12.7 (9.1, 17.5)              |          |  |
| Education (%)                              |                               |                               |                               | 0.022    |  |                               |                               |                               | < 0.001  |  |
| Degree or higher                           | 29.5 (24.5, 35.0)             | 28.3 (24.3, 32.7)             | 20.1 (16.0, 25.0)             |          |  | 35.7 (31.8, 39.8)             | 24.2 (20.4, 28.4)             | 19.4 (16.1, 23.2)             |          |  |
| Lower than Degree                          | 70.5 (65.0, 75.5)             | 71.7 (67.3, 75.7)             | 79.9 (75.0, 84.0)             |          |  | 64.3 (60.2, 68.2)             | 75.8 (71.6, 79.6)             | 80.6 (76.8, 83.9)             |          |  |
| Household income, £/year                   | 33695.9<br>(30462.3, 36929.7) | 35059.6<br>(32949.7, 37169.5) | 30295.5<br>(27948.5, 32642.6) | 0.011    |  | 34594.1<br>(32326.8, 36861.4) | 29777.7<br>(27808.3, 31747.2) | 27230.6<br>(25259.1, 29202.0) | < 0.001  |  |
| Live with partner <sup>‡</sup> , Yes, (%)  | 40.3 (34.8, 46.1)             | 65.3 (60.8, 69.6)             | 65.6 (60.1, 70.8)             | < 0.001  |  | 47.6 (43.2, 52.1)             | 52.2 (47.5, 57.0)             | 51.7 (46.7, 56.6)             | 0.288    |  |
| Smoking status                             |                               |                               |                               | < 0.001  |  |                               |                               |                               | 0.042    |  |
| Current                                    | 32.0 (26.8, 37.7)             | 18.7 (15.5, 22.4)             | 19.2 (15.0, 24.3)             |          |  | 19.5 (16.4, 22.9)             | 17.8 (14.8, 21.4)             | 16.4 (13.1, 20.3)             |          |  |
| Ex-smoker                                  | 17.3 (13.5, 22.0)             | 28.6 (24.8, 32.7)             | 32.9 (27.9, 38.4)             |          |  | 19.0 (15.9, 22.5)             | 24.4 (20.8, 28.3)             | 26.9 (22.8, 31.6)             |          |  |
| Never                                      | 50.6 (44.8, 56.4)             | 52.7 (48.2, 57.1)             | 47.9 (42.1, 53.7)             |          |  | 61.6 (57.4, 65.5)             | 57.8 (53.3, 62.2)             | 56.7 (51.8, 61.4)             |          |  |
| Physical activity <sup>†</sup> (hours/day) | 1.58 (1.33, 1.85)             | 1.42 (1.24, 1.62)             | 1.41 (1.15, 1.70)             | 0.547    |  | 0.84 (0.74, 0.94)             | 0.71 (0.62, 0.79)             | 0.65 (0.53, 0.78)             | 0.038    |  |
| Carbohydrate eating patterns (%)           |                               |                               |                               | 0.072    |  |                               |                               |                               | 0.253    |  |
| Low  | 25.9 (21.0, 31.5)             | 30.6 (26.6, 35.0)             | 31.4 (26.6, 36.6)             |          |  | 24.8 (21.5, 28.5)             | 26.8 (22.8, 31.2)             | 29.5 (25.3, 34.1)             |          |  |
| Moderate                                   | 34.2 (28.6, 40.4)             | 25.5 (21.9, 29.6)             | 25.5 (20.6, 31.0)             |          |  | 27.6 (23.8, 31.8)             | 26.3 (22.3, 30.8)             | 29.8 (25.4, 34.6)             |          |  |
| High                                       | 39.9 (34.2, 45.8)             | 43.8 (39.6, 48.2)             | 43.1 (37.7, 48.7)             |          |  | 47.6 (43.3, 51.9)             | 46.9 (42.4, 51.4)             | 40.7 (36.0, 45.6)             |          |  |
| Total energy intake (kJ)                   | 9351.2<br>(8961.7, 9740.7)    | 8786.9<br>(8595.1, 8978.7)    | 8465.3<br>(8196.4, 8734.1)    | 0.001    |  | 7048.9<br>(6894.4, 7203.4)    | 6570.1<br>(6406.2, 6734.0)    | 6566.4<br>(6360.7, 6772.1)    | < 0.001  |  |
| Carbohydrate intake (g)                    | 268.7<br>(258.3, 279.2)       | 250.1<br>(244.1, 256.1)       | 239.1<br>(231.3, 246.8)       | < 0.001  |  | 205.8<br>(200.2, 211.3)       | 190.1<br>(185.3, 194.9)       | 189.8<br>(183.7, 195.9)       | < 0.001  |  |

Note:

Abbreviations: CI, confidence intervals; INDNS RP, national dietary and nutrition survey rolling programme; BMI body mass index; WC, waist circumference.

Variables are weighted by nurse visiting weights.

\* Significant sex-specific differences by BMI categories assessed using an *F* test (with Bonferroni correction to account for multiple testing across > 2 groups) for continuous variables or design-adjusted Pearson  $\chi^2$  test for categorical variables

† Live with partner was defined as either living with a married husband/wife or a legally recognised civil partnership.

‡ Physical activity was calculated as mean time spent at moderate or vigorous physical activity including both work-related and recreational activities.

while in women, somewhat weak inverse association ( $p=0.038$ ) was confirmed. Interestingly, predefined carbohydrate eating patterns were seemingly not associated with BMI in men ( $p = 0.072$ ) or in women ( $p = 0.253$ ).

Results of the regression analyses showed inverse associations between latent classes of carbohydrate eating patterns and BMI among men (**Table 3.9**). However, the 95%CI of the regression coefficients were all too wide and including the null value 0, indicating no statistically supported evidence of the association. Nonetheless, evidence of interaction effect of whether live a partner or not on the association between carbohydrate eating patterns and BMI was found ( $p = 0.014$  and  $0.036$  for women in total and women without diabetes). For women living with her partner, latent classes of carbohydrate eating patterns were negatively associated with BMI.

TABLE 3.9: Associations of carbohydrate eating patterns with BMI in the UK adults, with or without diabetes.  
(NDNS RP 2008/09-2015/16, sample size = 6155)

| Model                          | Carbohydrate eating patterns |                     |                 |                      |                 |
|--------------------------------|------------------------------|---------------------|-----------------|----------------------|-----------------|
|                                | Low                          | Moderate            | <i>P</i> value* | High                 | <i>P</i> value* |
| <b>Men (n = 2537)</b>          |                              |                     |                 |                      |                 |
| <b>BMI</b>                     |                              |                     |                 |                      |                 |
| Crude model                    | –                            | -0.78 (-1.62, 0.06) | 0.068           | -0.28 (-0.96, 0.41)  | 0.426           |
| Model 1 <sup>†</sup>           | –                            | -0.20 (-1.06, 0.66) | 0.654           | -0.43 (-1.13, 0.26)  | 0.220           |
| <b>BMI in non-diabetics</b>    |                              |                     |                 |                      |                 |
| Crude model                    | –                            | -0.65 (-1.49, 0.19) | 0.127           | -0.21 (-0.89, 0.48)  | 0.557           |
| Model 1 <sup>†</sup>           | –                            | -0.10 (-0.97, 0.77) | 0.820           | -0.39 (-1.10, 0.31)  | 0.269           |
| <b>Women (n = 3618)</b>        |                              |                     |                 |                      |                 |
| <b>BMI</b>                     |                              |                     |                 |                      |                 |
| Crude model                    | –                            | -0.30 (-1.18, 0.57) | 0.496           | -0.76 (-1.44, -0.82) | 0.028           |
| Live with partner <sup>‡</sup> | –                            | -0.93 (-2.33, 0.46) | 0.188           | -1.76 (-2.78, -0.73) | 0.001           |
| Live alone <sup>‡</sup>        | –                            | 1.17 (-0.35, 2.70)  | 0.132           | 0.57 (-0.58, 1.719)  | 0.332           |
| <b>BMI in non-diabetics</b>    |                              |                     |                 |                      |                 |
| Crude model                    | –                            | -0.24 (-1.12, 0.65) | 0.601           | -0.71 (-1.39, -0.03) | 0.040           |
| Live with partner <sup>‡</sup> | –                            | -0.86 (-2.28, 0.55) | 0.232           | -1.62 (-2.65, -0.58) | 0.002           |
| Live alone <sup>‡</sup>        | –                            | 1.22 (-0.34, 2.78)  | 0.124           | 0.43 (-0.71, 1.56)   | 0.462           |

Note:

**Abbreviations:** BMI body mass index; WC, waist circumference; NDNS RP, national dietary and nutrition survey rolling programme.

Diabetes was defined by A1C > 6.5%. BMI was replaced with WC in Model 2s, other covariates remained the same with the corresponding Model 1s.

\* *P* values were obtained from wald tests from linear regression models.

<sup>†</sup> Adjusted for age, live with partner or not, education level, hypertension (yes or no), smoking status, total energy intake, alcohol consumption;

<sup>‡</sup> Adjusted for age, average household income, education level, smoking status, total energy intake, alcohol consumption.

Comparing with women eating low carbohydrate meals, women having a high carbohydrate eating pattern was averagely associated with 1.76 kg/m<sup>2</sup> lower BMI. 95%CI for the difference was 0.73 to 2.78 kg/m<sup>2</sup>,  $p = 0.001$ . After excluding diabetic women, BMI was still 1.62 kg/m<sup>2</sup> (95%CI: 0.58, 2.65,  $p = 0.002$ ) lower in high carbohydrate eaters versus low carbohydrate eaters on average. On the contrary, latent classes of carbohydrate eating patterns were positively associated with women who lived alone, although the regression coefficients were not statistically different from 0.

## **Chapter 4**

# **Discussion and Conclusion**

- MLCA ignored the order of observation days.
- We used the maximum probability rule and ignored that these are just probabilities.

## **Main Section 1**

### **Subsection 1**

### **Subsection 2**

## **Main Section 2**

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## Appendix A

# R code for importing and manipulating the data

```
# NDNS analysis, data management -----

# Change the data path accordingly -----
setwd("/home/wangcc-me/Downloads/UKDA-6533-stata11_se/stata11_se/") # in Ubuntu
library(epiDisplay)
library(plyr)
library(tidyverse)

# Read the data into memory -----
library(haven)
data <- read_dta("ndns_rp_yr1-4a_foodleveldietarydata_uk.dta")
data56 <- read_dta("ndns_rp_yr5-6a_foodleveldietarydata.dta")
data78 <- read_dta("ndns_rp_yr7-8a_foodleveldietarydata.dta")
names(data)
names(data56)
names(data78)
names(data)[names(data) == "seriali"] <- "id"
names(data56)[names(data56) == "seriali"] <- "id"
names(data78)[names(data78) == "seriali"] <- "id"

# Extract the data we needed -----
df14d <- data[, c(113, 1, 2, 3, 5, 6, 7, 8, 9, 21, 24, 55, 57, 58,
  59, 60, 61, 62, 63, 64)]
var <- names(df14d)
df56d <- data56 %>% select(var)
```

```

df78d <- data78 %>% select(var)
dfs1 <- rbind(df14d, df56d, df78d)
dfs2 <- dfs1[dfs1$Age >= 19, ]
rm(data, data56, data78)
dfs2

# Calculate the time (minute and hour) when they eat -----

dfs2$MealTime_chr <- as.character(dfs2$MealTime)
dfs2$MealTime_hm <- unlist(strsplit(dfs2$MealTime_chr, " "))[c(FALSE,
  TRUE)]
dfs2$MealHourN <- as.numeric(unlist(strsplit(dfs2$MealTime_hm, ":"))[c(TRUE,
  FALSE, FALSE)])
dfs2$MealMinN <- as.numeric(unlist(strsplit(dfs2$MealTime_hm, ":"))[c(FALSE,
  TRUE, FALSE)])
dfs2$MealMinN0 <- (60 * dfs2$MealHourN) + dfs2$MealMinN
dfs3 <- dfs2[order(dfs2$id, dfs2$DayNo, dfs2$MealMinN0), ]
length(unique(dfs3$id)) ## number of participants = 6155

# Create a subset data with only the first observation of each
# participant -----
NDNS <- dfs3[!duplicated(dfs3$id), ]
with(NDNS, tab1(SurveyYear, graph = FALSE, decimal = 2))

# #SurveyYear :
      # Frequency Percent Cum. percent
# NDNS Year 1      801   13.01      13.01
# NDNS Year 2      812   13.19      26.21
# NDNS Year 3      782   12.71      38.91
# NDNS Year 4     1055   17.14      56.05
# NDNS Year 5      625   10.15      66.21
# NDNS Year 6      663   10.77      76.98
# NDNS Year 7      703   11.42      88.40
# NDNS Year 8      714   11.60     100.00
# Total          6155  100.00     100.00

# create a variable combine id and day No -----

```

```

dfs3 <- dfs3 %>%
mutate(id_dy = paste(id, DayNo, sep = "D"))

# For each subject, the total energy/carbohydrate intake for each eating
# time can be calculated -----
old <- Sys.time()
Energy <- ddply(dfs3, .(id_dy, id, SurveyYear, DayNo, Age, Sex,
                      DiaryDaysCompleted, MealHourN, DayofWeek),
               summarise,
               Tot_Energ = sum(EnergykJ),
               Tot_Carb = sum(Carbohydrateg),
               Tot_Sugar = sum(Totalsugarsg),
               Tot_Starch = sum(Starchg))
new <- Sys.time() - old
print(new)
# Time difference of 3.876385 mins

rm(df14d, df56d, df78d, dfs2)

# Calculate the energy from total carbohydrates -----
Energy <- Energy %>%
  mutate(KJcarbo = Tot_Carb * 16) %>%
  mutate(CarKJpercentage = KJcarbo/Tot_Energ) %>%
  mutate(Carbo = cut(CarKJpercentage, breaks = c(0, 0.26, 0.75, 2),
                    right = FALSE)) %>% mutate(Carbo2 = cut(CarKJpercentage, breaks = c(0,
                    0.26, 2), right = FALSE))
Energy0 <- Energy[!(Energy$Tot_Energ == 0), ]
# some food consumption does not contain any carbohydrates
Energy0$Carbo <- factor(Energy0$Carbo, labels = c("Low_carb", "Med_carb",
        "High_carb"))
Energy0$Carbo2 <- factor(Energy0$Carbo2, labels = c("Low_carb", "Med_or_high_carb"))

# Generate data sets for each day -----
dta_day1 <- Energy0 %>%
  filter(DayNo == 1) %>%
  select(c("id", "Age",
        "Sex", "DayofWeek", "MealHourN", "Carbo", "Carbo2")) %>%
  mutate(DayofWeek = factor(DayofWeek,

```

```

    levels = c("Monday", "Tuesday", "Wednesday", "Thursday", "Friday",
               "Saturday", "Sunday"))))

dta_day2 <- Energy0 %>%
  filter(DayNo == 2) %>%
  select(c("id", "Age",
           "Sex", "DayofWeek", "MealHourN", "Carbo", "Carbo2")) %>%
  mutate(DayofWeek = factor(DayofWeek,
                             levels = c("Monday", "Tuesday", "Wednesday", "Thursday", "Friday",
                                           "Saturday", "Sunday"))))

dta_day3 <- Energy0 %>%
  filter(DayNo == 3) %>%
  select(c("id", "Age",
           "Sex", "DayofWeek", "MealHourN", "Carbo", "Carbo2")) %>%
  mutate(DayofWeek = factor(DayofWeek,
                             levels = c("Monday", "Tuesday", "Wednesday", "Thursday", "Friday",
                                           "Saturday", "Sunday"))))

dta_day4 <- Energy0 %>%
  filter(DayNo == 4) %>%
  select(c("id", "Age",
           "Sex", "DayofWeek", "MealHourN", "Carbo", "Carbo2")) %>%
  mutate(DayofWeek = factor(DayofWeek,
                             levels = c("Monday", "Tuesday", "Wednesday", "Thursday", "Friday",
                                           "Saturday", "Sunday"))))

vecid1 <- unique(dta_day1$id) # n = 6153
vecid2 <- unique(dta_day2$id) # n = 6153
vecid3 <- unique(dta_day3$id) # n = 6151
vecid4 <- unique(dta_day4$id) # n = 6026

Noday1 <- setdiff(vecid, vecid1) # two subjects did not have day 1 data
Noday2 <- setdiff(vecid, vecid2) # two subjects did not have day 2 data
Noday3 <- setdiff(vecid, vecid3) # four subjects did not have day 3 data
Noday4 <- setdiff(vecid, vecid4) # 129 subjects did not have day 4 data

# Transform the data shape from long to wide -----
dta_d1_wide <- dta_day1[, -7] %>%

```

```

    spread(key = MealHourN, value = Carbo)
names(dta_d1_wide)[5:28] <- paste(rep("H", 24), 0:23, sep = "")

dta_d2_wide <- dta_day2[, -7] %>%
  spread(key = MealHourN, value = Carbo)
names(dta_d2_wide)[5:28] <- paste(rep("H", 24), 0:23, sep = "")

dta_d3_wide <- dta_day3[, -7] %>%
  spread(key = MealHourN, value = Carbo)
names(dta_d3_wide)[5:28] <- paste(rep("H", 24), 0:23, sep = "")

dta_d4_wide <- dta_day4[, -7] %>%
  spread(key = MealHourN, value = Carbo)
names(dta_d4_wide)[5:28] <- paste(rep("H", 24), 0:23, sep = "")
# recode NA to not eating -----
for (i in 5:ncol(dta_d1_wide))
  if (is.factor(dta_d1_wide[, i])) levels(dta_d1_wide[,
    i]) <- c(levels(dta_d1_wide[, i]), "Not_eating")

dta_d1_wide[is.na(dta_d1_wide)] <- "Not_eating"

for (i in 5:ncol(dta_d2_wide))
  if (is.factor(dta_d2_wide[, i])) levels(dta_d2_wide[,
    i]) <- c(levels(dta_d2_wide[, i]), "Not_eating")

dta_d2_wide[is.na(dta_d2_wide)] <- "Not_eating"

for (i in 5:ncol(dta_d3_wide))
  if (is.factor(dta_d3_wide[, i])) levels(dta_d3_wide[,
    i]) <- c(levels(dta_d3_wide[, i]), "Not_eating")

dta_d3_wide[is.na(dta_d3_wide)] <- "Not_eating"

for (i in 5:ncol(dta_d4_wide))
  if (is.factor(dta_d4_wide[, i])) levels(dta_d4_wide[,
    i]) <- c(levels(dta_d4_wide[, i]), "Not_eating")

dta_d4_wide[is.na(dta_d4_wide)] <- "Not_eating"

```

## Appendix B

# Mplus code and output for Multilevel LCA models

Mplus VERSION 7.4

MUTHEN & MUTHEN

07/28/2018 9:55 AM

### INPUT INSTRUCTIONS

TITLE: 3-class at level 1 (CW), 3-classes at level 2 (CB) random effects model  
ordered polytomous variables for carb intake at each time slot over four  
days of NDNS survey 2008/09 - 2015/16

variable 0 = not eating

1 = eating & carb provided < 50% calorie

2 = eating & carb provided >= 50% calorie

DATA: File is H:\summer\_project\Mplus\TimeSlots\NDNS\_Tslots.dat;

VARIABLE: NAMES = id id\_dy Age Sex H6\_9 H9\_12 H12\_14 H14\_17 H17\_20  
H20\_22 H22\_6;

USEVAR = H6\_9 H9\_12 H12\_14 H14\_17 H17\_20  
H20\_22 H22\_6;

auxiliary = Age Sex;

CATEGORICAL = H6\_9 H9\_12 H12\_14 H14\_17 H17\_20  
H20\_22 H22\_6;



```
CLUSTER = id;
```

```
IDVARIABLE = id_dy;
```

```
BETWEEN = CB;
```

```
WITHIN = H6_9 H9_12 H12_14 H14_17 H17_20  
H20_22 H22_6;
```

```
CLASSES = CB(3) CW(3);
```

```
MISSING are .;
```

```
ANALYSIS:
```

```
type = mixture twolevel;
```

```
starts = 50 25;
```

```
process = 8(starts);
```

```
MODEL:
```

```
%within%
```

```
%overall%
```

```
%between%
```

```
%overall%
```

```
CW ON CB;
```

```
Savedata:
```

```
file is H:\summer_project\Mplus\TimeSlots\Multilevel\NDNSslot_CW3CB3.txt;
```

```
save is cprob;
```

```
format is free;
```

3-class at level 1 (CW), 3-classes at level 2 (CB) random effects model  
 ordered polytomous variables for carb intake at each time slot over four  
 days of NDNS survey 2008/09 - 2015/16

variable 0 = not eating

1 = eating & carb provided < 50% calorie

2 = eating & carb provided >= 50% calorie

#### SUMMARY OF ANALYSIS

|                        |       |
|------------------------|-------|
| Number of groups       | 1     |
| Number of observations | 24483 |

|  |   |
|--|---|
| Number of dependent variables          | 7 |
| Number of independent variables        | 0 |
| Number of continuous latent variables  | 0 |
| Number of categorical latent variables | 2 |

#### Observed dependent variables

Binary and ordered categorical (ordinal)

|       |       |        |        |        |        |
|-------|-------|--------|--------|--------|--------|
| H6_9  | H9_12 | H12_14 | H14_17 | H17_20 | H20_22 |
| H22_6 |       |        |        |        |        |

#### Observed auxiliary variables

|     |     |
|-----|-----|
| AGE | SEX |
|-----|-----|

#### Categorical latent variables

|    |    |
|----|----|
| CB | CW |
|----|----|

#### Variables with special functions

|                  |       |
|------------------|-------|
| Cluster variable | ID    |
| ID variable      | ID_DY |

#### Within variables

|       |       |        |        |        |        |
|-------|-------|--------|--------|--------|--------|
| H6_9  | H9_12 | H12_14 | H14_17 | H17_20 | H20_22 |
| H22_6 |       |        |        |        |        |

|  |           |
|--|-----------|
| Estimator  | MLR       |
| Information matrix   | OBSERVED  |
| Optimization Specifications for the Quasi-Newton Algorithm for Continuous Outcomes   |           |
| Maximum number of iterations   | 100       |
| Convergence criterion  | 0.100D-05 |
| Optimization Specifications for the EM Algorithm   |           |
| Maximum number of iterations   | 500       |
| Convergence criteria   |           |
| Loglikelihood change   | 0.100D-02 |
| Relative loglikelihood change  | 0.100D-05 |
| Derivative   | 0.100D-02 |
| Optimization Specifications for the M step of the EM Algorithm for Categorical Latent variables  |           |
| Number of M step iterations  | 1         |
| M step convergence criterion   | 0.100D-02 |
| Basis for M step termination   | ITERATION |
| Optimization Specifications for the M step of the EM Algorithm for Censored, Binary or Ordered Categorical (Ordinal), Unordered Categorical (Nominal) and Count Outcomes |           |
| Number of M step iterations  | 1         |
| M step convergence criterion   | 0.100D-02 |
| Basis for M step termination   | ITERATION |
| Maximum value for logit thresholds   | 15        |
| Minimum value for logit thresholds   | -15       |
| Minimum expected cell size for chi-square  | 0.100D-01 |
| Maximum number of iterations for H1  | 2000      |
| Convergence criterion for H1   | 0.100D-03 |
| Optimization algorithm   | EMA       |
| Integration Specifications   |           |
| Type   | STANDARD  |
| Number of integration points   | 15        |
| Dimensions of numerical integration  | 0         |
| Adaptive quadrature  | ON        |
| Random Starts Specifications   |           |
| Number of initial stage random starts  | 50        |
| Number of final stage optimizations  | 25        |

|  |           |
|--|-----------|
| Number of initial stage iterations       | 10        |
| Initial stage convergence criterion      | 0.100D+01 |
| Random starts scale                      | 0.500D+01 |
| Random seed for generating random starts | 0         |
| Parameterization                         | LOGIT     |
| Link                                     | LOGIT     |
| Cholesky                                 | OFF       |

Input data file(s)

H:\summer\_project\Mplus\TimeSlots\NDNS\_Tslots.dat

Input data format FREE

#### SUMMARY OF DATA

|                                   |      |
|-----------------------------------|------|
| Number of missing data patterns   | 1    |
| Number of y missing data patterns | 0    |
| Number of u missing data patterns | 1    |
| Number of clusters                | 6155 |

#### COVARIANCE COVERAGE OF DATA

Minimum covariance coverage value 0.100

#### UNIVARIATE PROPORTIONS AND COUNTS FOR CATEGORICAL VARIABLES

H6\_9

|            |       |           |
|------------|-------|-----------|
| Category 1 | 0.313 | 7655.000  |
| Category 2 | 0.184 | 4500.000  |
| Category 3 | 0.504 | 12328.000 |

H9\_12

|            |       |           |
|------------|-------|-----------|
| Category 1 | 0.222 | 5447.000  |
| Category 2 | 0.295 | 7227.000  |
| Category 3 | 0.482 | 11809.000 |

H12\_14

|            |       |           |
|------------|-------|-----------|
| Category 1 | 0.195 | 4783.000  |
| Category 2 | 0.454 | 11112.000 |
| Category 3 | 0.351 | 8588.000  |
| H14_17     |       |           |
| Category 1 | 0.283 | 6926.000  |
| Category 2 | 0.338 | 8277.000  |
| Category 3 | 0.379 | 9280.000  |
| H17_20     |       |           |
| Category 1 | 0.124 | 3043.000  |
| Category 2 | 0.582 | 14240.000 |
| Category 3 | 0.294 | 7200.000  |
| H20_22     |       |           |
| Category 1 | 0.356 | 8722.000  |
| Category 2 | 0.363 | 8898.000  |
| Category 3 | 0.280 | 6863.000  |
| H22_6      |       |           |
| Category 1 | 0.666 | 16295.000 |
| Category 2 | 0.169 | 4144.000  |
| Category 3 | 0.165 | 4044.000  |

RANDOM STARTS RESULTS RANKED FROM THE BEST TO THE WORST LOGLIKELIHOOD VALUES

Final stage loglikelihood values at local maxima, seeds, and initial stage start numbers:

|             |        |    |
|-------------|--------|----|
| -166348.815 | 153942 | 31 |
| -166348.815 | 573096 | 20 |
| -166348.815 | 253358 | 2  |
| -166348.816 | 318230 | 46 |
| -166348.816 | 246261 | 38 |
| -166348.873 | 285380 | 1  |
| -166348.908 | 903420 | 5  |
| -166349.394 | 120506 | 45 |
| -166349.394 | 966014 | 37 |
| -166349.394 | 207896 | 25 |
| -166349.395 | 195873 | 6  |
| -166349.513 | 68985  | 17 |

|             |        |    |
|-------------|--------|----|
| -166349.514 | 366706 | 29 |
| -166352.737 | 76974  | 16 |
| -166357.057 | 127215 | 9  |
| -166482.723 | 533738 | 11 |
| -166495.844 | 645664 | 39 |
| -166668.918 | 372176 | 23 |

THE BEST LOGLIKELIHOOD VALUE HAS BEEN REPLICATED. RERUN WITH AT LEAST TWICE THE  
RANDOM STARTS TO CHECK THAT THE BEST LOGLIKELIHOOD IS STILL OBTAINED AND REPLICATED.

THE MODEL ESTIMATION TERMINATED NORMALLY

#### MODEL FIT INFORMATION

Number of Free Parameters 134

Loglikelihood

H0 Value -166348.815

H0 Scaling Correction Factor 1.8182  
for MLR

#### Information Criteria

Akaike (AIC) 332965.630

Bayesian (BIC) 334051.799

Sample-Size Adjusted BIC 333625.950

(n\* = (n + 2) / 24)

MODEL RESULTS USE THE LATENT CLASS VARIABLE ORDER

CB CW

## Latent Class Variable Patterns

| CB<br>Class | CW<br>Class |
|-------------|-------------|
| 1           | 1           |
| 1           | 2           |
| 1           | 3           |
| 2           | 1           |
| 2           | 2           |
| 2           | 3           |
| 3           | 1           |
| 3           | 2           |
| 3           | 3           |

FINAL CLASS COUNTS AND PROPORTIONS FOR THE LATENT CLASS PATTERNS  
BASED ON ESTIMATED POSTERIOR PROBABILITIESLatent Class  
Pattern

|   |   |            |         |
|---|---|------------|---------|
| 1 | 1 | 4050.97975 | 0.16546 |
| 1 | 2 | 1561.55249 | 0.06378 |
| 1 | 3 | 1286.46696 | 0.05255 |
| 2 | 1 | 2746.94031 | 0.11220 |
| 2 | 2 | 3011.00217 | 0.12298 |
| 2 | 3 | 1341.59686 | 0.05480 |
| 3 | 1 | 2748.25320 | 0.11225 |
| 3 | 2 | 4770.55950 | 0.19485 |
| 3 | 3 | 2965.64876 | 0.12113 |

FINAL CLASS COUNTS AND PROPORTIONS FOR EACH LATENT CLASS VARIABLE  
BASED ON ESTIMATED POSTERIOR PROBABILITIES

## Latent Class

| Variable | Class |             |         |
|----------|-------|-------------|---------|
| CB       | 1     | 6898.99902  | 0.28179 |
|          | 2     | 7099.53906  | 0.28998 |
|          | 3     | 10484.46094 | 0.42823 |
| CW       | 1     | 9546.17285  | 0.38991 |
|          | 2     | 9343.11426  | 0.38162 |
|          | 3     | 5593.71240  | 0.22847 |

FINAL CLASS COUNTS AND PROPORTIONS FOR THE LATENT CLASS PATTERNS  
BASED ON THEIR MOST LIKELY LATENT CLASS PATTERN

#### Class Counts and Proportions

Latent Class  
Pattern

|   |   |      |         |
|---|---|------|---------|
| 1 | 1 | 4262 | 0.17408 |
| 1 | 2 | 1406 | 0.05743 |
| 1 | 3 | 1178 | 0.04812 |
| 2 | 1 | 2807 | 0.11465 |
| 2 | 2 | 2946 | 0.12033 |
| 2 | 3 | 1260 | 0.05146 |
| 3 | 1 | 2745 | 0.11212 |
| 3 | 2 | 5315 | 0.21709 |
| 3 | 3 | 2564 | 0.10473 |

FINAL CLASS COUNTS AND PROPORTIONS FOR EACH LATENT CLASS VARIABLE  
BASED ON THEIR MOST LIKELY LATENT CLASS PATTERN

Latent Class

| Variable | Class |       |         |
|----------|-------|-------|---------|
| CB       | 1     | 6846  | 0.27962 |
|          | 2     | 7013  | 0.28644 |
|          | 3     | 10624 | 0.43393 |



|    |   |      |         |
|----|---|------|---------|
| CW | 1 | 9814 | 0.40085 |
|    | 2 | 9667 | 0.39485 |
|    | 3 | 5002 | 0.20431 |

## CLASSIFICATION QUALITY

Entropy 0.630

Average Latent Class Probabilities for Most Likely Latent Class Pattern (Row)  
by Latent Class Pattern (Column)

## Latent Class Variable Patterns

| Latent Class | CB    | CW    |
|--------------|-------|-------|
| Pattern No.  | Class | Class |
| 1            | 1     | 1     |
| 2            | 1     | 2     |
| 3            | 1     | 3     |
| 4            | 2     | 1     |
| 5            | 2     | 2     |
| 6            | 2     | 3     |
| 7            | 3     | 1     |
| 8            | 3     | 2     |
| 9            | 3     | 3     |

| 1 | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |       |
|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1 | 0.720 | 0.091 | 0.073 | 0.016 | 0.032 | 0.004 | 0.005 | 0.033 | 0.025 |
| 2 | 0.183 | 0.609 | 0.098 | 0.005 | 0.002 | 0.030 | 0.040 | 0.005 | 0.027 |
| 3 | 0.211 | 0.084 | 0.629 | 0.008 | 0.005 | 0.007 | 0.011 | 0.036 | 0.009 |
| 4 | 0.019 | 0.004 | 0.002 | 0.692 | 0.184 | 0.051 | 0.011 | 0.034 | 0.003 |
| 5 | 0.042 | 0.001 | 0.001 | 0.158 | 0.709 | 0.045 | 0.001 | 0.035 | 0.009 |
| 6 | 0.012 | 0.037 | 0.013 | 0.065 | 0.084 | 0.702 | 0.042 | 0.003 | 0.042 |
| 7 | 0.011 | 0.029 | 0.004 | 0.012 | 0.002 | 0.022 | 0.641 | 0.126 | 0.153 |
| 8 | 0.026 | 0.003 | 0.009 | 0.025 | 0.024 | 0.001 | 0.115 | 0.675 | 0.123 |

|   |       |       |       |       |       |       |       |       |       |
|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 9 | 0.046 | 0.024 | 0.004 | 0.003 | 0.010 | 0.018 | 0.079 | 0.174 | 0.642 |
|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|

## MODEL RESULTS

## Two-Tailed

| Estimate | S.E. | Est./S.E. | P-Value |
|----------|------|-----------|---------|
|----------|------|-----------|---------|

## Within Level

## Latent Class Pattern 1 1

## Thresholds

|           |        |       |         |       |
|-----------|--------|-------|---------|-------|
| H6_9\$1   | -0.718 | 0.218 | -3.294  | 0.001 |
| H6_9\$2   | 0.973  | 0.299 | 3.258   | 0.001 |
| H9_12\$1  | -2.516 | 0.463 | -5.433  | 0.000 |
| H9_12\$2  | 0.675  | 0.132 | 5.118   | 0.000 |
| H12_14\$1 | -1.025 | 0.145 | -7.057  | 0.000 |
| H12_14\$2 | 1.240  | 0.116 | 10.725  | 0.000 |
| H14_17\$1 | -1.566 | 0.149 | -10.520 | 0.000 |
| H14_17\$2 | 1.090  | 0.100 | 10.909  | 0.000 |
| H17_20\$1 | -1.998 | 0.125 | -16.000 | 0.000 |
| H17_20\$2 | 1.549  | 0.100 | 15.556  | 0.000 |
| H20_22\$1 | -0.933 | 0.085 | -10.914 | 0.000 |
| H20_22\$2 | 1.829  | 0.103 | 17.770  | 0.000 |
| H22_6\$1  | 0.253  | 0.083 | 3.046   | 0.002 |
| H22_6\$2  | 2.308  | 0.117 | 19.691  | 0.000 |

## Latent Class Pattern 1 2

## Thresholds

|           |        |       |        |       |
|-----------|--------|-------|--------|-------|
| H6_9\$1   | -4.021 | 1.788 | -2.249 | 0.025 |
| H6_9\$2   | -0.115 | 0.259 | -0.445 | 0.656 |
| H9_12\$1  | 0.167  | 0.373 | 0.448  | 0.654 |
| H9_12\$2  | 2.142  | 0.586 | 3.657  | 0.000 |
| H12_14\$1 | -3.210 | 1.518 | -2.115 | 0.034 |
| H12_14\$2 | 0.858  | 0.167 | 5.124  | 0.000 |

|           |        |       |        |       |
|-----------|--------|-------|--------|-------|
| H14_17\$1 | 0.044  | 0.384 | 0.114  | 0.909 |
| H14_17\$2 | 1.617  | 0.293 | 5.509  | 0.000 |
| H17_20\$1 | -2.109 | 0.390 | -5.409 | 0.000 |
| H17_20\$2 | 1.399  | 0.196 | 7.126  | 0.000 |
| H20_22\$1 | -0.367 | 0.174 | -2.109 | 0.035 |
| H20_22\$2 | 2.347  | 0.382 | 6.151  | 0.000 |
| H22_6\$1  | 0.754  | 0.259 | 2.912  | 0.004 |
| H22_6\$2  | 2.542  | 0.264 | 9.646  | 0.000 |

## Latent Class Pattern 1 3

## Thresholds

|           |         |       |         |         |
|-----------|---------|-------|---------|---------|
| H6_9\$1   | -15.000 | 0.000 | 999.000 | 999.000 |
| H6_9\$2   | 2.357   | 0.783 | 3.011   | 0.003   |
| H9_12\$1  | -1.433  | 0.372 | -3.850  | 0.000   |
| H9_12\$2  | -0.604  | 0.279 | -2.166  | 0.030   |
| H12_14\$1 | -1.988  | 0.257 | -7.749  | 0.000   |
| H12_14\$2 | 0.524   | 0.125 | 4.209   | 0.000   |
| H14_17\$1 | -1.027  | 0.232 | -4.436  | 0.000   |
| H14_17\$2 | 0.274   | 0.131 | 2.087   | 0.037   |
| H17_20\$1 | -2.665  | 0.310 | -8.605  | 0.000   |
| H17_20\$2 | 0.707   | 0.112 | 6.322   | 0.000   |
| H20_22\$1 | -0.527  | 0.152 | -3.462  | 0.001   |
| H20_22\$2 | 0.702   | 0.138 | 5.102   | 0.000   |
| H22_6\$1  | 1.119   | 0.185 | 6.062   | 0.000   |
| H22_6\$2  | 1.748   | 0.183 | 9.544   | 0.000   |

## Latent Class Pattern 2 1

## Thresholds

|           |        |       |         |       |
|-----------|--------|-------|---------|-------|
| H6_9\$1   | 1.663  | 0.199 | 8.370   | 0.000 |
| H6_9\$2   | 1.839  | 0.198 | 9.274   | 0.000 |
| H9_12\$1  | -2.150 | 0.281 | -7.643  | 0.000 |
| H9_12\$2  | -0.869 | 0.140 | -6.190  | 0.000 |
| H12_14\$1 | -1.978 | 0.191 | -10.349 | 0.000 |
| H12_14\$2 | 0.323  | 0.078 | 4.139   | 0.000 |
| H14_17\$1 | 0.237  | 0.183 | 1.293   | 0.196 |
| H14_17\$2 | 0.782  | 0.123 | 6.352   | 0.000 |

|           |        |       |        |       |
|-----------|--------|-------|--------|-------|
| H17_20\$1 | -2.936 | 0.428 | -6.853 | 0.000 |
| H17_20\$2 | 0.632  | 0.081 | 7.807  | 0.000 |
| H20_22\$1 | 0.028  | 0.142 | 0.194  | 0.846 |
| H20_22\$2 | 0.868  | 0.086 | 10.145 | 0.000 |
| H22_6\$1  | 0.658  | 0.109 | 6.010  | 0.000 |
| H22_6\$2  | 1.326  | 0.100 | 13.215 | 0.000 |

Latent Class Pattern 2 2

Thresholds

|           |        |       |        |       |
|-----------|--------|-------|--------|-------|
| H6_9\$1   | 1.640  | 0.171 | 9.619  | 0.000 |
| H6_9\$2   | 1.906  | 0.179 | 10.678 | 0.000 |
| H9_12\$1  | -1.954 | 0.347 | -5.636 | 0.000 |
| H9_12\$2  | -0.360 | 0.127 | -2.842 | 0.004 |
| H12_14\$1 | -0.016 | 0.189 | -0.084 | 0.933 |
| H12_14\$2 | 0.948  | 0.135 | 7.029  | 0.000 |
| H14_17\$1 | -1.906 | 0.301 | -6.327 | 0.000 |
| H14_17\$2 | 0.371  | 0.080 | 4.614  | 0.000 |
| H17_20\$1 | -0.812 | 0.116 | -7.030 | 0.000 |
| H17_20\$2 | 0.910  | 0.089 | 10.259 | 0.000 |
| H20_22\$1 | -0.742 | 0.089 | -8.318 | 0.000 |
| H20_22\$2 | 0.998  | 0.085 | 11.705 | 0.000 |
| H22_6\$1  | 0.298  | 0.083 | 3.608  | 0.000 |
| H22_6\$2  | 1.337  | 0.099 | 13.475 | 0.000 |

Latent Class Pattern 2 3

Thresholds

|           |        |       |        |       |
|-----------|--------|-------|--------|-------|
| H6_9\$1   | -1.072 | 0.500 | -2.144 | 0.032 |
| H6_9\$2   | -0.309 | 0.346 | -0.892 | 0.372 |
| H9_12\$1  | 2.441  | 1.044 | 2.339  | 0.019 |
| H9_12\$2  | 3.599  | 1.983 | 1.815  | 0.069 |
| H12_14\$1 | -1.029 | 0.211 | -4.880 | 0.000 |
| H12_14\$2 | 0.603  | 0.123 | 4.913  | 0.000 |
| H14_17\$1 | -0.010 | 0.243 | -0.041 | 0.967 |
| H14_17\$2 | 0.784  | 0.157 | 4.977  | 0.000 |
| H17_20\$1 | -0.953 | 0.203 | -4.684 | 0.000 |
| H17_20\$2 | 0.779  | 0.135 | 5.784  | 0.000 |

|           |        |       |        |       |
|-----------|--------|-------|--------|-------|
| H20_22\$1 | -0.105 | 0.210 | -0.500 | 0.617 |
| H20_22\$2 | 1.203  | 0.135 | 8.914  | 0.000 |
| H22_6\$1  | 0.582  | 0.299 | 1.950  | 0.051 |
| H22_6\$2  | 1.370  | 0.206 | 6.653  | 0.000 |

Latent Class Pattern 3 1

Thresholds

|           |        |       |        |       |
|-----------|--------|-------|--------|-------|
| H6_9\$1   | -4.593 | 1.699 | -2.703 | 0.007 |
| H6_9\$2   | -2.975 | 0.428 | -6.957 | 0.000 |
| H9_12\$1  | -0.322 | 0.207 | -1.553 | 0.120 |
| H9_12\$2  | 0.398  | 0.363 | 1.095  | 0.274 |
| H12_14\$1 | -5.060 | 3.668 | -1.380 | 0.168 |
| H12_14\$2 | 0.307  | 0.100 | 3.080  | 0.002 |
| H14_17\$1 | 0.186  | 0.530 | 0.351  | 0.726 |
| H14_17\$2 | 0.317  | 0.245 | 1.295  | 0.195 |
| H17_20\$1 | -4.019 | 0.957 | -4.199 | 0.000 |
| H17_20\$2 | 0.747  | 0.093 | 7.987  | 0.000 |
| H20_22\$1 | -0.233 | 0.132 | -1.767 | 0.077 |
| H20_22\$2 | 0.607  | 0.109 | 5.571  | 0.000 |
| H22_6\$1  | 1.304  | 0.146 | 8.918  | 0.000 |
| H22_6\$2  | 1.850  | 0.160 | 11.579 | 0.000 |

Latent Class Pattern 3 2

Thresholds

|           |        |       |         |       |
|-----------|--------|-------|---------|-------|
| H6_9\$1   | -1.232 | 0.195 | -6.305  | 0.000 |
| H6_9\$2   | -0.858 | 0.169 | -5.068  | 0.000 |
| H9_12\$1  | -4.377 | 1.937 | -2.260  | 0.024 |
| H9_12\$2  | -1.488 | 0.316 | -4.717  | 0.000 |
| H12_14\$1 | -1.727 | 0.227 | -7.611  | 0.000 |
| H12_14\$2 | 0.302  | 0.082 | 3.666   | 0.000 |
| H14_17\$1 | -1.834 | 0.237 | -7.730  | 0.000 |
| H14_17\$2 | -0.294 | 0.186 | -1.582  | 0.114 |
| H17_20\$1 | -2.588 | 0.487 | -5.313  | 0.000 |
| H17_20\$2 | 0.631  | 0.062 | 10.187  | 0.000 |
| H20_22\$1 | -0.920 | 0.078 | -11.852 | 0.000 |
| H20_22\$2 | 0.462  | 0.073 | 6.308   | 0.000 |

|          |       |       |       |       |
|----------|-------|-------|-------|-------|
| H22_6\$1 | 0.640 | 0.119 | 5.361 | 0.000 |
| H22_6\$2 | 1.162 | 0.129 | 9.039 | 0.000 |

Latent Class Pattern 3 3

Thresholds

|           |        |       |        |       |
|-----------|--------|-------|--------|-------|
| H6_9\$1   | -4.941 | 5.813 | -0.850 | 0.395 |
| H6_9\$2   | -2.680 | 0.887 | -3.024 | 0.002 |
| H9_12\$1  | -0.765 | 0.640 | -1.195 | 0.232 |
| H9_12\$2  | 1.164  | 0.920 | 1.265  | 0.206 |
| H12_14\$1 | -1.415 | 0.439 | -3.226 | 0.001 |
| H12_14\$2 | 0.566  | 0.085 | 6.626  | 0.000 |
| H14_17\$1 | -2.052 | 0.650 | -3.158 | 0.002 |
| H14_17\$2 | 0.612  | 0.210 | 2.909  | 0.004 |
| H17_20\$1 | -1.627 | 0.427 | -3.810 | 0.000 |
| H17_20\$2 | 0.713  | 0.103 | 6.935  | 0.000 |
| H20_22\$1 | -0.850 | 0.329 | -2.585 | 0.010 |
| H20_22\$2 | 0.685  | 0.134 | 5.104  | 0.000 |
| H22_6\$1  | 1.237  | 0.195 | 6.349  | 0.000 |
| H22_6\$2  | 1.893  | 0.179 | 10.582 | 0.000 |

Between Level

Categorical Latent Variables

Within Level

Intercepts

|      |        |       |        |       |
|------|--------|-------|--------|-------|
| CW#1 | -0.076 | 0.366 | -0.208 | 0.835 |
| CW#2 | 0.475  | 0.309 | 1.539  | 0.124 |

Between Level

|      |    |       |       |       |
|------|----|-------|-------|-------|
| CW#1 | ON |       |       |       |
| CB#1 |    | 1.223 | 0.473 | 2.585 |
| CB#2 |    | 0.793 | 0.441 | 1.796 |

CW#2 ON

|       |        |       |        |       |
|-------|--------|-------|--------|-------|
| CB#1  | -0.282 | 0.535 | -0.526 | 0.599 |
| CB#2  | 0.333  | 0.455 | 0.733  | 0.464 |
| Means |        |       |        |       |
| CB#1  | -0.417 | 0.100 | -4.178 | 0.000 |
| CB#2  | -0.386 | 0.067 | -5.770 | 0.000 |

## QUALITY OF NUMERICAL RESULTS

Condition Number for the Information Matrix 0.428E-04  
 (ratio of smallest to largest eigenvalue)

## SAVEDATA INFORMATION

Save file

H:\summer\_project\Mplus\TimeSlots\Multilevel\NDNSslot\_CW3CB3.txt

Order of variables

H6\_9  
 H9\_12  
 H12\_14  
 H14\_17  
 H17\_20  
 H20\_22  
 H22\_6  
 ID\_DY  
 AGE  
 SEX  
 CPROB1  
 CPROB2  
 CPROB3  
 CPROB4  
 CPROB5  
 CPROB6

CPROB7

CPROB8

CPROB9

CB

CW

MLCJOINT

ID

Save file format                      Free

Save file record length              10000

#### DIAGRAM INFORMATION

Mplus diagrams are currently not available for Mixture analysis.

No diagram output was produced.

Beginning Time: 09:55:10

Ending Time: 10:02:01

Elapsed Time: 00:06:51

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## Appendix C

### Example of a food diary for one day

| Day   |  |  | Day: Thursday  | Date: March 31 <sup>st</sup>  |
|---|--|--|--|---|
| Time  | where?<br>with whom?<br>TV on?<br>Table?   | what   | Brand Name   | Amount eaten  |
| How to describe what you had and how much you had can be found on pages 20–25 |  |  |  |   |
| <i>6am to 9am</i>   |  |  |  |   |
| 7.30am  | Kitchen<br>Family<br>No TV<br>At table     | Orange juice, unsweetened, UHT<br>Tea<br>Milk, fresh semi skimmed<br>Sugar white<br>Weetabix<br>Milk as above<br>Sugar as above<br>Toast wholemeal, large loaf<br>Butter unsalted<br>Strawberry Jam                        | Tesco<br>Tesco<br>Tesco<br>Silverspoon<br><br>Havis<br>Anchor<br>Co-op | Large glass<br>Mug<br>A little<br>2 level teaspoons<br>2<br>Drowned<br>2 heaped teaspoons<br>2 thin slices<br>thick spread on both<br>1 teaspoon on one slice |
| <i>9am to 12 noon</i>   |  |  |  |   |
| 11am  | School playground<br>With friends          | Coca cola diet<br>Potato crisps, Salt and Vinegar  | Coca Cola<br>Walkers   | 330ml can<br>25g packet from a multipack  |
| 12noon  | School corridor<br>Alone                   | Water from water cooler<br>Mars Bar  |  | small plastic cup<br>1 kingsize   |
| <i>12 noon to 2pm</i>   |  |  |  |   |
| 12.45pm   | School canteen<br>With friends<br>At table | Sandwich, from home<br>White bread, large loaf<br>Spread<br>Ham unsmoked<br>Cheddar cheese<br>Branston Pickle<br>Apple with skin from home<br>Ribena Light, Ready to Drink, Blackcurrant, from canteen<br>Kitkat from home | Kingsmill<br>Flora Light<br>Tesco                                      | 2 med slices<br>thin spread on both slices<br>1 slice<br>2 medium slices<br>1 teaspoon<br>1 (left core)<br>220ml carton<br>2 fingers                          |
| 1.50pm  | School corridor<br>Alone                   | Chewing gum  | Orbit Sugar Free   | 1 piece   |

FIGURE C.1: NATIONAL DIET AND NUTRITION SURVEY – Food and Drink Diary Example, from 6 am to 2 pm.

| Day                |   |  | Day: Thursday                                | Date: March 31 <sup>st</sup>  |
|--------------------|---|--|--|---|
| Time               | where?<br>with whom?<br>TV on?<br>Table?                    | what   | Brand Name                                   | Amount eaten  |
| <i>2pm to 5pm</i>  |   |  |  |   |
| 3.45pm             | Bus<br>Alone  | Wine gums  | Maynards                                     | 140g packet   |
| 4.30pm             | Home, sitting room,<br>With family<br>TV on<br>Not at table | Tea (as above)<br>Chocolate Hob Nobs   | Mcvitites                                    | mug<br>3  |
| <i>5pm to 8pm</i>  |   |  |  |   |
| 6.30pm             | Friend's kitchen<br>With friends<br>No TV<br>At table       | Chicken in tomato sauce made by friend's mum<br>Tomato fresh<br>Sweetcorn tinned<br>Peach yoghurt low fat<br>Lemon squash No Added Sugar | See recipe<br><br>Mullerlight<br>Sainsbury's | 3 tablespoons<br>3 slices<br>1 dessertspoon<br>200g pot<br>medium glass |
| <i>8pm to 10pm</i> |   |  |  |   |
| 8pm                | Home, sitting room<br>Alone<br>TV on, Not at table          | Satsuma<br>Cream Crackers (no spread)  | Jacob's                                      | 1<br>4  |
| 9.30pm             | Kitchen<br>Alone<br>No TV, At table                         | Thick cut, frozen chips fried in vegetable oil<br>Brown sauce  | McCains<br>HP                                | small portion<br>1 dessertspoon   |
| <i>10pm to 6am</i> |   |  |  |   |
| 10.30pm            | Bedroom<br>Alone<br>TV on<br>Not at table                   | Hot chocolate drink made with water  | Cadbury's                                    | Mug (made with 4 tsp powder)  |
| 2am                | Bedroom (in bed)<br>Alone<br>No TV                          | Water tap  |  | $\frac{1}{2}$ small glass   |

FIGURE C.2: NATIONAL DIET AND NUTRITION SURVEY – Food and Drink Diary Example, from 2 pm to 6 am.

| Write in recipes or ingredients of made up dishes or take-away dishes             |                 |                         |               |
|---|-----------------|-------------------------|---------------|
| NAME OF DISH: <i>Chicken in tomato Sauce</i>                                      |                 | Serves: <i>4 people</i> |               |
| Ingredients   | Amount          | Ingredients             | Amount        |
| <i>Pieces of chicken</i>  | <i>3 pieces</i> | <i>Olive oil</i>        | <i>2 tbsp</i> |
| <i>Sauce made with:</i>   |                 |                         |               |
| <i>Tinned tomatoes</i>  | <i>1 tin</i>    |                         |               |
| <i>Green pepper</i>   | <i>1 medium</i> |                         |               |
| <i>Onion</i>  | <i>1 small</i>  |                         |               |
|   |                 |                         |               |
|   |                 |                         |               |
|   |                 |                         |               |
| Brief description of cooking method   |                 |                         |               |
| Chicken pieces fried in olive oil, then mixed in with tomato and vegetable sauce. |                 |                         |               |

FIGURE C.3: NATIONAL DIET AND NUTRITION SURVEY – Food and Drink Diary Example, home made food recipes.