Relationships between food groups and eating time slots according to diabetes status in adults from the UK National Diet and Nutrition Survey (2008–2017)

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ABSTRACT

Time of eating has been shown to be associated with diabetes and obesity but little is known about less healthy foods and specific time of their intake over the 24 hours of the day. In this study we aimed to identify potential relationships between foods and their eating time, and see whether these associations may vary by diabetes status. The National Diet and Nutrition Survey (NDNS) including 6802 adults (age $\geq$ 19 years old) collected 749,026 food recordings by a 4-day-diary. The contingency table cross-classifying 60 food groups with 7 pre-defined eating time slots (6-9am, 9am-12pm, 12-2pm, 2-5pm, 8-10pm, 10pm-6am) was analyzed by Correspondence Analysis (CA). CA biplots displaying the associations were generated for all adults and separately by diabetes status (self-reported, pre-diabetes, undiagnosed-diabetes, and non-diabetics) to visually explore the associations between food groups and time of eating across diabetes strata. For selected food groups, odds ratios (OR, 99% confidence intervals, CI) were derived of consuming unhealthy foods at evening/night (8pm-6am) vs. earlier time in the day, by logistic regression models with generalized estimating equations. The biplots suggested positive associations between evening/night and consumption of puddings, regular soft drinks, sugar confectioneries, chocolates, beers, ice cream, biscuits, and crisps for all adults in the UK. The OR (99% CIs) of consuming these foods at evening/night were respectively 1.43 (1.06, 1.94), 1.72 (1.44, 2.05), 1.84 (1.31, 2.59), 3.08 (2.62, 3.62), 7.26 (5.91, 8.92), 2.45 (1.84, 3.25), 1.90 (1.68, 2.16), 1.49 (1.22, 1.82) vs. earlier time in the day adjusted for age, sex, body mass index, and social-economic levels. Stratified biplots found that sweetened beverages, sugar-confectioneries appeared more strongly associated with evening/night among un-diagnosed diabetics. Foods consumed in the evening/night time tend to be highly processed, easily accessible, and rich in added sugar or saturated fat. Individuals with undiagnosed diabetes are more likely to consume unhealthy foods at night. Further longitudinal studies are required to ascertain the causal direction of the association between late-eating and diabetes status.

Keywords: Chrononutrition, time of eating, correspondence analysis, the UK National Diet and Nutrition Survey, nutrition epidemiology, diabetes

INTRODUCTION

The timing of energy intake has been shown to be associated with obesity and diabetes. (Almoosawi et al., 2016) Specifically, eating late at night or having a late dinner was found to be related to higher risk of obesity (Xiao et al., 2019; Yoshida et al., 2018), hyperglycemia (Nakajima and Suwa, 2015), metabolic syndrome (Kutsuma et al., 2014), diabetes (Mattson et al., 2014), and poorer glycemic control among diabetics (Sakai et al., 2017). However, the relationship between food choice and the time of food consumption during the day is left largely unknown. Shiftworkers have an increased risk of obesity (Balieiro et al., 2014; Barbadoro et al., 2013), and diabetes (Pan et al., 2011), possibly due to limited availability of healthy food choice during their night shifts (Bonnell et al., 2017; Balieiro et al., 2014). Previous survey data from the UK National Diet and Nutrition Survey Rolling Programme (NDNS RP) found that overall, 3.4% of men and 2.3% of women aged 19-64 had fasting glucose concentrations above the clinical cut-off for diabetes ($\geqslant$ 7 mmol/L). Moreover, the proportion of men with undiagnosed diabetes increased with age to over 20% in the UK population (Almoosawi et al., 2014). Identifying those unhealthy foods that might be chosen during late night time would be helpful when guiding people to change their eating habit for the purpose of either weight loss or glycemic control. Dietary diary recordings from NDNS RP surveys can provide detailed food choice data for exploration of the relationships between food groups and their time of consumption in the general population.

In this study, we aimed to describe the relationship between food groups and the time of day when they were consumed, and how such relationships may vary by status of type 2 diabetes using the data published by the NDNS RP from 2008 to 2017 as this survey includes diet diaries providing detailed information on the time of day of food intake.

METHODS

6802 adults (2810 men and 3992 women) and 749026 food recordings collected by the NDNS RP 2008-17 were analyzed in the current study (MRC Elsie Widdowson Laboratory and NatCen Social Research, 2018). The survey comprised a cross-section representative sample of the UK adult population taken over the period 2008-2017. The sample was randomly drawn from a list of all addresses in the UK, clustered into postcode sectors. Details of the rationale, design and methods of the survey can be found in the previously published official study reports (Bates et al., 2014; Roberts et al., 2018). The NDNS-RP, funded by Public Health England and the UK Food Standards Agency, is registered with the ISRTCN registry under study ID ISRCTN17261407 and received ethical approval from the Oxfordshire Research Ethics Committee.

A four-day food diary method was used in the NDNS RP to collect the detailed food items and their time of consumption from participants. Comparison between the food diary method and a repeated 24-hour recall questionnaire was performed in a subset of study sample prior to the launch of the NDNS RP in 2008 and found that they were similar in terms of response rate as well as the ability to collect correct nutrition intake data. And the four-day food diary method was adopted because it is considered to be more flexible and adaptable to cover wide population age range in the survey. More details can be found in the Appendix A of the official NDNS RP study report (Bates et al., 2014; Roberts et al., 2018). Furthermore, the same food diary methods is actually used in large studies conducted in the UK, such as the the MRC National Survey of Health and Development (NSHD) (1946 British Birth Cohort) (Price et al., 1997), the EPIC Norfolk Study (Bingham et al., 2001), the UK Women's Cohort Study in Leeds (Cade et al., 2004), and the Avon Longitudinal Study of Parents and Children (ALSPAC) cohort (Glynn et al., 2005). Another validation study of the food records against double-labelled water has also been undertaken among a subset of NDNS participants. Full results of the analysis have been reported in Appendix X of the official survey report (Lennox et al.).

In the food diary recordings, time of the day was categorized into 7 slots: 6-9 am, 9-12 noon, 12-2 pm, 2-5 pm, 5-8 pm, 8-10 pm and 10 pm - 6 am. Foods recorded were classified into 60 standard food groups with 1 to 10 subgroups each: the details are given in Appendix R of the NDNS official report (NatCen Social Research, MRC Elsie Widdowson Laboratory, Univeristy College London. Medical School., 2018). We focused on the 60 standard food groups in the current analysis. Diabetes status was defined as: 1) healthy if fasting glucose was lower than 6.10 (mmol/L), hemoglobin A1c (HbA1c) was less than 6.5 (%), and without self-reported diabetes and treatment for diabetes (n = 2626); 2) pre-diabetic if fasting glucose was lower between 6.10 and 6.99 (mmol/L, inclusive) but without self-reported diabetes and without treatment for diabetes (n = 133); 3) undiagnosed diabetic if either fasting glucose was higher or equal to 7.00 (mmol/L) or HbA1c higher or equal to 6.5 (%) but without self-reported diabetes and treatment for diabetes (n = 99); 4) diabetic if participant had self-reported diabetes or was under treatment for diabetes (n = 227). Consequently, there was also a large number of adults (3717 adults of whom 1519 men and 2198 women) whose diabetes status did not fall in one of above categories and could not thus be confirmed; these were retained in the whole sample (unstratified) analyses. In addition, the National Statistics Socio-economic Classification (Rose and Pevalin, 2005) was applied in the survey and accordingly, the socio-economic status of participants was classified in one of 8 categories.

Correspondence analysis (CA) (Greenacre, 2017; Chapman et al., 2017; Palla et al., 2020) was used as a tool for data mining, visualization and hypotheses generation using half of the randomly selected NDNS diary entries data. Specifically, the contingency table generated by cross-tabulating 60 food groups and 7 time slots were analyzed by CA. Through CA, the 60 categories of standard foods and the 7 time slots were projected on biplots, i.e. onto two dimensional plots that could jointly contain large percentage of the χ^2 deviation (or inertia) of the contingency table. Biplots that graphically show the association between time of day and food groups were derived for all adults and separately according to their diabetes status. CA is a statistical technique to explore relationships between categorical variables in a two-dimensional contingency table.

In the current analysis context, CA was used as a tool to visually depict the relationship between food groups and time of consumption. CA was the technique to flag up those food groups that have a similar or different "profile" across time categories or, symmetrically, those times of day that have a similar or different "profile" across food groups. In particular "profile" indicates the relative frequency of the consumption of one food across different time in the day (or, symmetrically, the relative frequency of consumption of different foods at one specific time period) and what CA measures are its departure from the average food (or time of day) profile. One simple example is that if about 77.8% of all foods were consumed during the daytime (earlier than 8 pm), but only 23.5% of beer consumption were recorded during the daytime, then we say beer has a "profile" different from the average food profile with respect to time of day of consumption and, in particular, beer is associated to evening/night consumption. CA can produce biplots to visually show the χ^2 deviation of food (and time) profiles from the average profile which is called "inertia." These biplots use the first two most informative dimensions to show the inertia of the contingency table. The horizontal axis of the biplot represents the direction along which the contingency table rows and columns show their greatest deviations from the average row or column profile. The vertical axis represents the direction, perpendicular to the first, having the second-largest deviations. There are two percentage labels for each axis which indicate how much of the total inertia were explained along that axis. The sum of the two percentages is lower than 100%, the remaining inertia cannot be shown when reducing to 2 dimensions if there are more than 3 foods or time-slots. The origin in each biplot is the average profile of all points in the plot, while the length of the vector from the origin to each profile point represents its deviation from the average profile. The distance between row (food) and column (time slots) profile points and the direction in which they lie away from the origin is indicating how they are associated with each other. The potential association is greater if 1) points are located in similar directions away from the origin and 2) the farther they are from the origin.

To account for the hierarchical structure of the data (food recorded by the same individuals who lived within the same area/sampling units) and to calculate population average odds ratios (OR), logistic regression models with generalized estimating equations (GEE) were subsequently used to test the associations that were first suggested by visual inspection of biplots generated by CA, using the remaining half of the diary entries data. The marginal ORs and their 99% confidence intervals (CI) were derived of consuming unhealthy food groups (selected by CA) later in the day (8 pm - 6 am, i.e. in the evening and night) compared to earlier in the day (in the morning or afternoon). In the fixed effect of the logistic regression models, 2-time slots and 4 diabetes statuses were entered with interaction terms. This was done to assist performing post fitting estimations of OR for each diabetes status using the same model to avoid running more models on smaller datasets with less statistical power as well as risk of multiple testings. CA and biplots were conducted and generated by the following packages under R environment (R Core Team, 2019): `FactoMineR, factoextra, ggplot2, ggrepel` (Lê et al., 2008; Kassambara and Mundt, 2019; Wickham, 2016; Slowikowski, 2019) Logistic regression models with GEE were performed with SAS procedure `GENMOD` (SAS Institute, 2013) adjusted for age, sex, body mass index (BMI) and socio-economic levels, which were deemed the main potential confounders of the associations.

RESULTS

The dataset consisted of 2810 (41.3%) men and 3992 (58.7%) women aged older than or equal to 19 years old with the mean age of 49.9 years (standard deviation, SD = 17.6). Of these individuals 22.6 % were current smokers, 24.3 % were past smokers. The average body mass index (BMI) was 27.7 kg/m^2 (SD = 5.41). Among the food recordings collected (n = 749026), 56.9% were recorded during traditional breakfast (6 am - 9 am: 14.3%), lunch (12 noon - 2 pm: 18.5%), or dinner (5 pm - 8 pm: 24.1%) time slots, more details can be found in Supplementary Table S1. Table 1. shows the top 37 food groups that contributed to 90% of the total calories consumed by adults in NDNS RP. These food groups accounted for 478028 of the total diary entries (63.8 %). The random process split the whole set of food recordings into a hypothesis generating dataset of 374682 and a testing dataset of 374344 entries.

Figure 1-5 present the CA biplots that visually summarize the associations between 60 food groups and the time of their consumption in the entire sample and then stratifying by their diabetes status. In Figure 1, the horizontal axis explains 68.9 % of the association structure (inertia) between food and time while the vertical axis reflects 15.3 % of the same relationship. Therefore, a total of 84.2 % of the inertia between food and time were captured in this figure which shows a visual summary of how those two categorical variables are related. Specifically, time slots later than 8 pm are shown in the upper side of the plot closer to alcoholic products or highly processed/energy-dense foods (sugar confectioneries, chocolates, biscuits, regular softdrinks, ice cream, crisps); times earlier than noon appear in the left hand side together with typical breakfast foods (cereals, milk, bread, etc.).

To visualize the potentially different associational patterns between food groups choice and time slots according to diabetes status, Figure 2-5 display the CA biplots in subsets of the data. Depending on different diabetes status, these biplots explained between 76.3% and 84.1% of the inertia in the data. Similarly to the biplot created from the total sample (Figure 1), later time in the day (8 pm and later) are shown in the upper side of each figure and suggested an association with the alcoholic beverages and highly processed or energy-dense food groups. Additionally, some food groups and time slots also flagged up associations potentially different by diabetes status. For example, puddings seemed to be closer to later time in the day among undiagnosed diabetics (Figure 4) while for diagnosed diabetic patients (Figure 3) they were closer to traditional dinner time (5 pm to 8 pm) or earlier in the day. Furthermore, sugar confectioneries/chocolates/biscuits/regular soft drinks appeared to be associated with later time in the day (8 pm or later) more strongly among undiagnosed diabetics (Figure 4) than the other participants.

Based on the findings suggested from Figure 1-5, we decided to focus on puddings, regular soft drinks, confectioneries, chocolates, beers, ice cream, biscuits, crisps as these foods either showed a particularly strong association with time of the day or a different pattern of association across different strata of the survey sample; hence, we tested the following null hypotheses using logistic regression models (adjusted for age, sex, and socio-economic levels) with GEE: that the odds of consuming each selected food at later time of the day (8 pm - 6 am) is the same compared to earlier in the day; and the associations of the above-mentioned food groups and time slots are the same among participants with different diabetes status (i.e. no interaction between the time of food intake and diabetes status). The results are summarized in Table 2.

The listed food groups were found to have higher odds to be consumed between 8 pm and 6 am with higher odds compared to earlier time. The OR (99% CIs) main effects of consuming these foods at evening/night were for puddings 1.43 (1.06, 1.94), for regular soft drinks 1.72 (1.44, 2.05), for sugar confectioneries 1.84 (1.38, 2.69), for chocolates 3.08 (2.62, 3.62), for beers 7.26 (5.91, 8.92), for ice cream 2.45 (1.84, 3.25), for biscuits 1.90 (1.68, 2.16), for crisps 1.49 (1.22, 1.82) vs. earlier time. Opposite directions of the association for puddings were detected across diabetes status: the ORs (99% CIs) of consuming puddings at night time (8 pm or later) compared to earlier time were 1.55 (1.13, 2.15), 0.95 (0.17, 5.20), 1.82 (0.41, 8.03), and 0.63 (0.15, 2.66) for healthy, prediabetic, undiagnosed diabetic, and diabetic participants, respectively. Furthermore, undiagnosed diabetic patients were found to have particularly high odds of consuming regular soft drinks (OR: 2.82; 99% CI: 1.24, 6.43), and sugar confectioneries (OR: 10.61; 99%CI: 2.35, 47.04) during night time periods compared to participants with other diabetes status. The same models were also used to estimate the ORs of consuming the selected food groups comparing participants with different diabetes statuses during either daytime (earlier than 8 pm) or nighttime (between 8 pm and 6 am). Results are given in Supplementary Table S2.

DISCUSSION

The present study described the potential relationships between food groups and time of their consumption in a representative sample from the NDNS RP. Many unhealthy foods emerged from CA were found to be more likely to be consumed after 8 pm. These included alcoholic/sweetened beverages, chocolates and other foods rich in added sugars and saturated fats such as biscuits and ice cream. Foods chosen in the evening/night time slots tend to be highly processed and easily accessible. Specifically, undiagnosed patients might be at a higher risk of worsening their condition as they were found to have higher odds to choose a number of less healthy foods after 8 pm (sugar confectioneries, regular soft drinks) than diabetics and non-diabetics. Those foods might need to be targeted when designing intervention to those who might be at risk of being diabetics.

These findings are concerning considering previous research have indicated that quality of macronutrient intake in the evening is likely to influence fasting glucose levels and glycaemic response to subsequent meals in the morning. (Wolever et al., 1988) One prospective study reported women who ate later than 9pm had 1.51 times (95% CI 1.16 to 1.93) higher 5-year risk of developing prediabetes/diabetes than those having their time of last eating episode between 4 to 9pm. (Faerch et al., 2019) More recently, a randomized controlled trial indicated that consuming carbohydrates at dinner irrespective of glycaemic index raised postprandial glucose response to breakfast producing what is known as a second meal effect (Haldar et al., 2020). Similar observation have been made by Nitta and colleagues who observed that eating sweet snacks post-dinner worsened glycaemic excursions in the evening and at subsequent breakfast (Nitta et al., 2019). Added to this is evidence that suggests that the late-night dinners induce post-prandial hyperglycemia in patients with type 2 diabetes and that interventions at this eating occassions can result in a profound impact on post-prandial glycaemia. On the balance of this evidence, targeting and improving the timing and quality of foods in evening eating occasions provides a unique opportunity to design intervention to those who might be at risk of being diabetics.

A compelling finding of our study is the observation that diabetes patients were found to be potentially controlling their choice of food groups such as avoiding puddings at night. However, higher odds of consuming alcoholic beverages and energy condensed foods such as chocolates and sugar confectioneries at night among individuals with diabetes suggests that their food choice might need further modifications. Food intake late in the night is in misalignment with the circadian rhythm of the insulin response, which may cause greater glycaemic exposure and elevated HbA1c levels even for healthy individuals (Faerch et al., 2019). Disrupted timing of food intake, overeating in the evening, unhealthy food chosen at later time in the day can result in poor glucose control and increase the likelihood of diabetic complications (Nakajima and Suwa, 2015; Sato et al., 2011; Kadowaki et al., 2018; Reutrakul et al., 2014). Assessing the relationships between food groups and timing of eating by diabetes status can be considered as a first step towards identifying specific public health targets for behavior change/intervention. This is important as most current public health strategies and dietary recommendations do not provide targeted advice that takes into considerations specific eating occasions while targeted advice is more likely to result in sustainable behavioural change. Our findings are consistent with previous evidence that has found that both sweetened and alcoholic beverages are responsible for large portion of energy consumption at night in other populations (Hassen et al., 2018).

However, an important limitation in this study is the cross-sectional study design. Our findings do not indicate whether it would be better for individual health to consume unhealthy foods later or earlier in the day, which should be clarified through purposedly designed intervention studies in the future. Some of the findings, such as higher consumption of alcoholic beverages at night are already known. However, the facts that certain snacks were more likely to be consumed at night and even more frequently among undiagnosed diabetic, are an important piece of public health evidence as these data are representative of national behaviour across the UK. Moreover, The inability to assess the temporal relationship between timing of food intake and diabetes status means that a cause-effect relationship between time of unhealthy food intake and diabetes status cannot be established. Hence, further prospective studies are warranted to investigate the causal relationship between diabetes and both quality and timing of eating. Moreover, the current study assumes that mis-reporting occurred equally amongst all eating occasions. This limitation has been reported by previous literature as an important methodological limitation of chrononutrition (Fayet-Moore et al., 2017); in fact further investigation would be warranted to assess the effect of differential misreporting on epidemiological studies in chrono-nutrition in order to suggest possible corrections, e.g. for differential under-reporting at different times of the day (e.g. main meals vs. snack times). Finally, we did not include variables indicating abdominal obesity and sedentary lifestyle such as physical activity or waist circumference in the second step of the current analysis mainly due to missingness of the variables. The associations comparing food consumed later vs. earlier time in the day presented here may be partly explained or mediated through low level of physical activity and/or abdominal obesity especially among those who were unaware that they have diabetes (un-diagnosed diabetes), further detailed investigation is needed.

CONCLUSION

In summary, our study indicates that foods consumed in the evening/night time tend to be highly processed, easily accessible, and rich in added sugar or saturated fat, whatever the diabetic status. Individuals with undiagnosed diabetes are more likely to consume specific unhealthy foods at night. The survey cross-sectional nature warrants further investigations by longitudinal cohort studies to establish the causal relation between time of eating of unhealthy foods and diabetes.

DISCLOSURE/CONFLICT-OF-INTEREST STATEMENT

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

CW, SA, and LP: designed research and had primary responsibility for final content; CW and LP performed statistical analysis; and all authors: wrote the manuscript, read and approved the final manuscript.

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AVAILABILITY OF DATA AND MATERIALS

Original data used in this study can be accessed upon request to the UK Data Service (`https://www.ukdataservice.ac.uk`) for academic usage (Study Number: 6533).

SUPPLEMENTARY TABLE

The Supplementary Table S1 & Table S2 for this article can be found online at: xxxx

TABLES

Table 1. The top 37 food groups sorted by increasing cumulative percentages which contributed to 90% of the total calories consumed by UK adults. (NDNS RP 2008-2017).

Food group names	n	Calories	Relative Prop	Cal Prop	Cal Cum Prop
Pasta & Rice and other cereals	18353	3512069.99	2.45%	7.36%	7.36%
White Bread	18434	3245641.19	2.46%	6.80%	14.17%
Chips, fried and roast potatoes and potato products	6749	1884058.68	0.90%	3.95%	18.12%
Cakes, buns, sweet pastries, fruit pies	7806	1710594.27	1.04%	3.59%	21.70%
Vegetable (not raw)	51317	1665474.02	6.85%	3.49%	25.19%
Biscuits	13200	1662598.06	1.76%	3.49%	28.68%
Fruit	33903	1641675.02	4.53%	3.44%	32.12%
Miscellaneous unclassified foods	48597	1639024.81	6.49%	3.44%	35.56%
Chicken/turkey	8863	1617820.30	1.18%	3.39%	38.95%
Cheese	10983	1492015.32	1.47%	3.13%	42.07%
Beer lager	8199	1484001.20	1.09%	3.11%	45.19%
Semi-skimmed milk	57611	1302649.72	7.69%	2.73%	47.92%
Potatos other (in salads and dishes)	10113	1291447.61	1.35%	2.71%	50.62%
Fat spreads	37960	1215278.60	5.07%	2.55%	53.17%
Beef	4987	1124560.42	0.67%	2.36%	55.53%
High fiber breakfast cereals	8215	1072813.73	1.10%	2.25%	57.78%
Whole meal bread	7193	1070695.89	0.96%	2.24%	60.02%
Chocolate	6495	1046112.65	0.87%	2.19%	62.22%
Wine	6967	1027792.96	0.93%	2.15%	64.37%
Brown, granary and wheatgerm bread	6183	1009074.95	0.83%	2.12%	66.48%
Butter	10203	965901.11	1.36%	2.02%	68.51%
Eggs	7554	964769.19	1.01%	2.02%	70.53%
Soft drinks not diet	11387	940516.516	1.52%	1.97%	72.50%
Reduced fat spreads	12620	848834.89	1.68%	1.78%	74.28%
Crisps and savoury snacks	5664	835671.58	0.76%	1.75%	76.04%
Sausages	3025	775004.13	0.40%	1.62%	77.66%
Meat pastries	1979	744639.89	0.26%	1.56%	79.22%
Bacon and ham	8467	738727.49	1.13%	1.55%	80.77%
Yogurt	6776	665484.55	0.90%	1.40%	82.16%
Low-fiber breakfast cereals	4303	560296.32	0.57%	1.17%	83.34%
Nuts and seeds	6259	559873.88	0.84%	1.17%	84.51%
Oily fish	2610	550425.36	0.35%	1.15%	85.67%
Whole Milk	13628	530449.07	1.82%	1.11%	86.78%
White fish, shellfish	1597	498928.82	0.21%	1.05%	87.82%
Puddings	2291	459784.62	0.31%	0.96%	88.79%
Other Milk Cream	6605	434239.37	0.88%	0.91%	89.70%
Pork	1832	420503.76	0.24%	0.88%	90.58%

NDNS RP: National Diet and Nutrition Survey Rolling Programme.
Prop: proportion; Cal Prop: calorie proportion; Cal Cum Prop: Calorie cumulative proportion.

Table 2. Odds ratio (99% confidence intervals) for food groups eaten at night (8 pm - 6 am) vs. earlier time in the day, among total and according to different diabetes status, NDNS RP 2008-2017.

Selected food groups	Overall	Healthy	Pre-diabetics	Undiagnosed diabetics	Diabetics
Pudding	1.43 (1.06, 1.94)	1.55 (1.13, 2.15)	0.95 (0.17, 5.20)	1.82 (0.41, 8.03)	0.63 (0.15, 2.66)
Regular soft drink	1.72 (1.44, 2.05)	1.70 (1.41, 2.05)	1.78 (0.90, 3.48)	2.82 (1.24, 6.43)	1.36 (0.59, 3.10)
Sugar confectionery	1.84 (1.31, 2.59)	1.55 (1.08, 2.23)	2.13 (0.34, 13.24)	10.51 (2.35, 47.04)	5.94 (1.86, 19.00)
Chocolate	3.08 (2.62, 3.62)	2.98 (2.51, 3.54)	4.06 (1.98, 8.31)	2.41 (0.88, 6.60)	4.92 (2.38, 10.20)
Beer	7.26 (5.91, 8.92)	7.55 (6.04, 9.43)	4.42 (2.19, 8.95)	8.29 (3.70, 18.56)	5.82 (2.03, 16.68)
Ice cream	2.45 (1.84, 3.25)	2.52 (1.86, 3.41)	3.39 (0.77, 14.89)	1.07 (0.15, 7.77)	1.74 (0.57, 5.32)
Biscuit	1.90 (1.68, 2.16)	1.78 (1.55, 2.05)	3.25 (1.99, 5.28)	2.96 (1.43, 6.10)	2.33 (1.45, 3.77)
Crisp	1.49 (1.22, 1.82)	1.49 (1.21, 1.85)	2.21 (0.90. 5.41)	1.59 (0.43, 5.95)	0.89 (0.34, 2.33)

Logistic regression models with GEE were adjusted for age, sex, body mass index, and social-economic levels.
NDNS RP: National Diet and Nutrition Survey Rolling Programme.

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FIGURE CAPTIONS

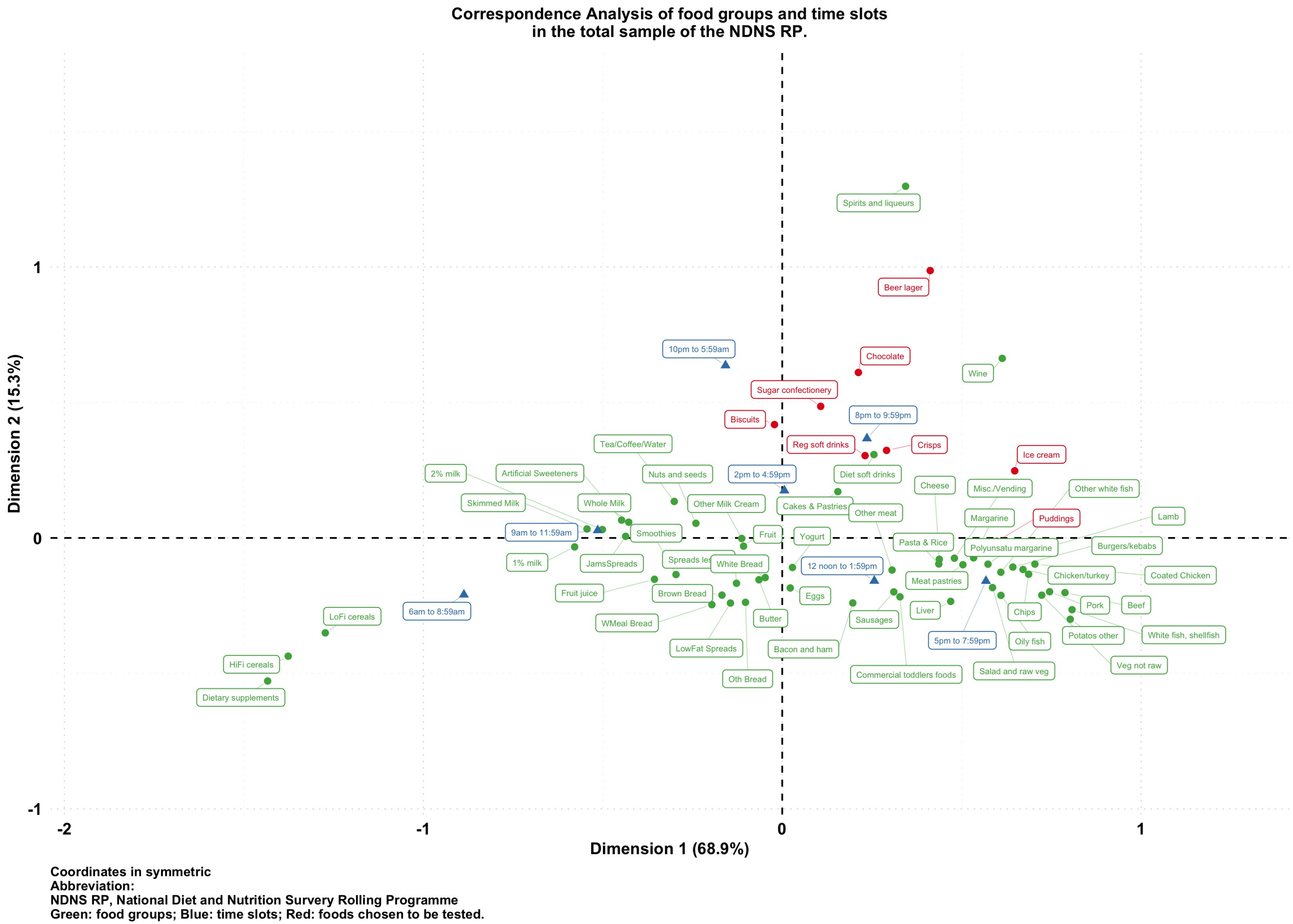

Figure 1. Biplot of food groups and eating time slots in the total sample in the NDNS RP.

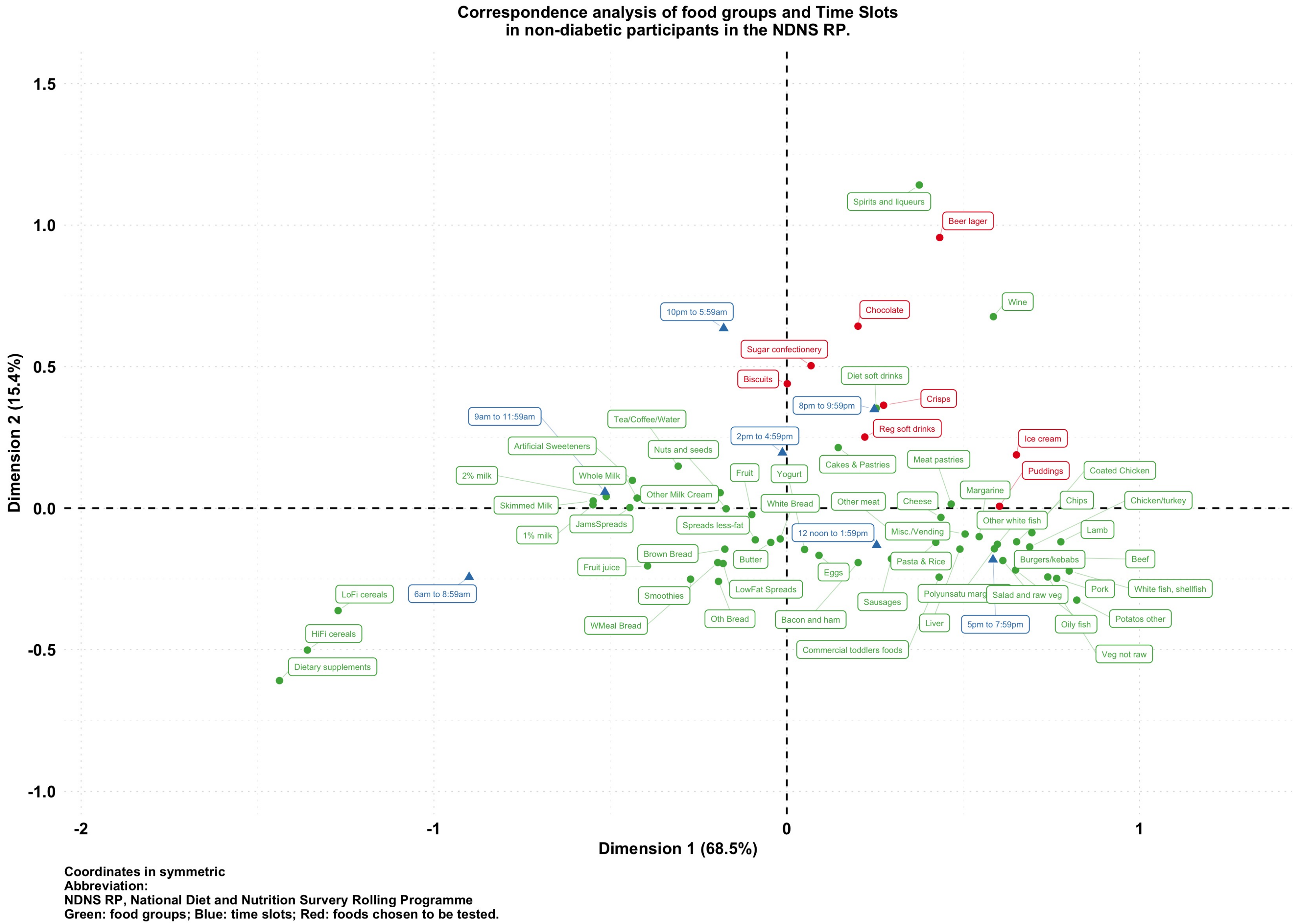

Figure 2. Biplot of food groups and eating time slots in non-diabetic participants in the NDNS RP.

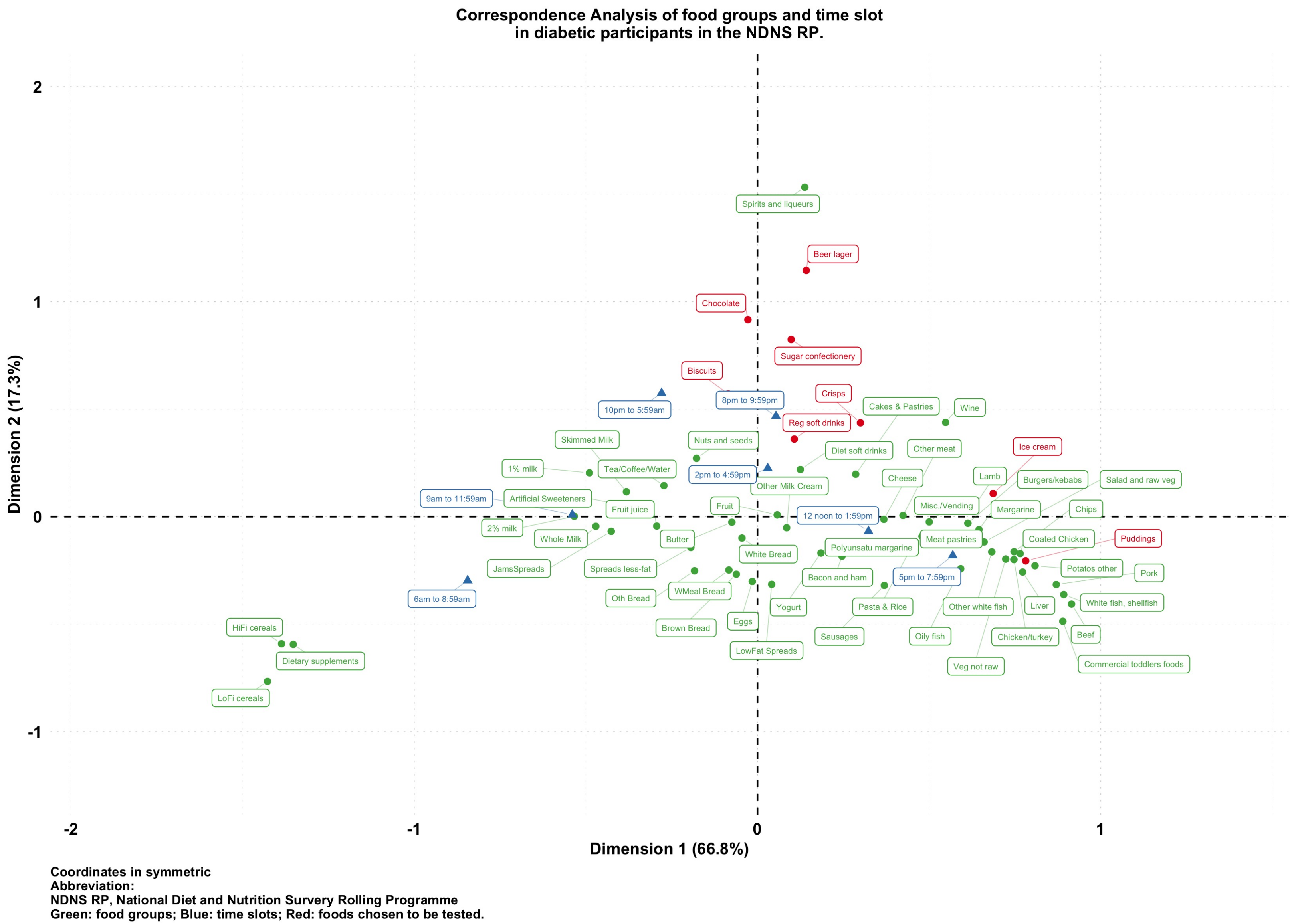

Figure 3. Biplot of food groups and eating time slots in diabetic participants in the NDNS RP.

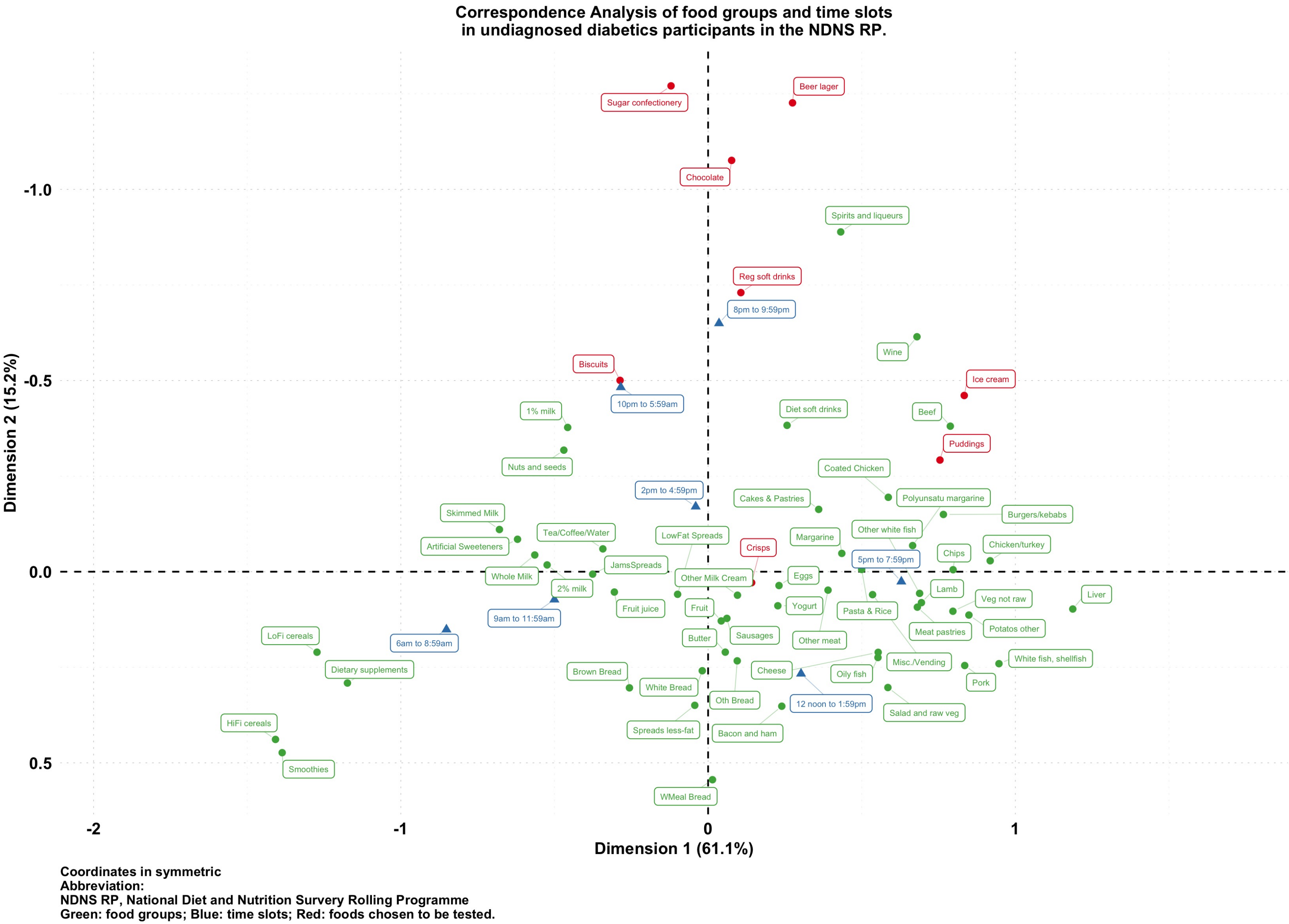

Figure 4. Biplot of food groups and eating time slots in undiagnosed diabetic participants in the NDNS RP.

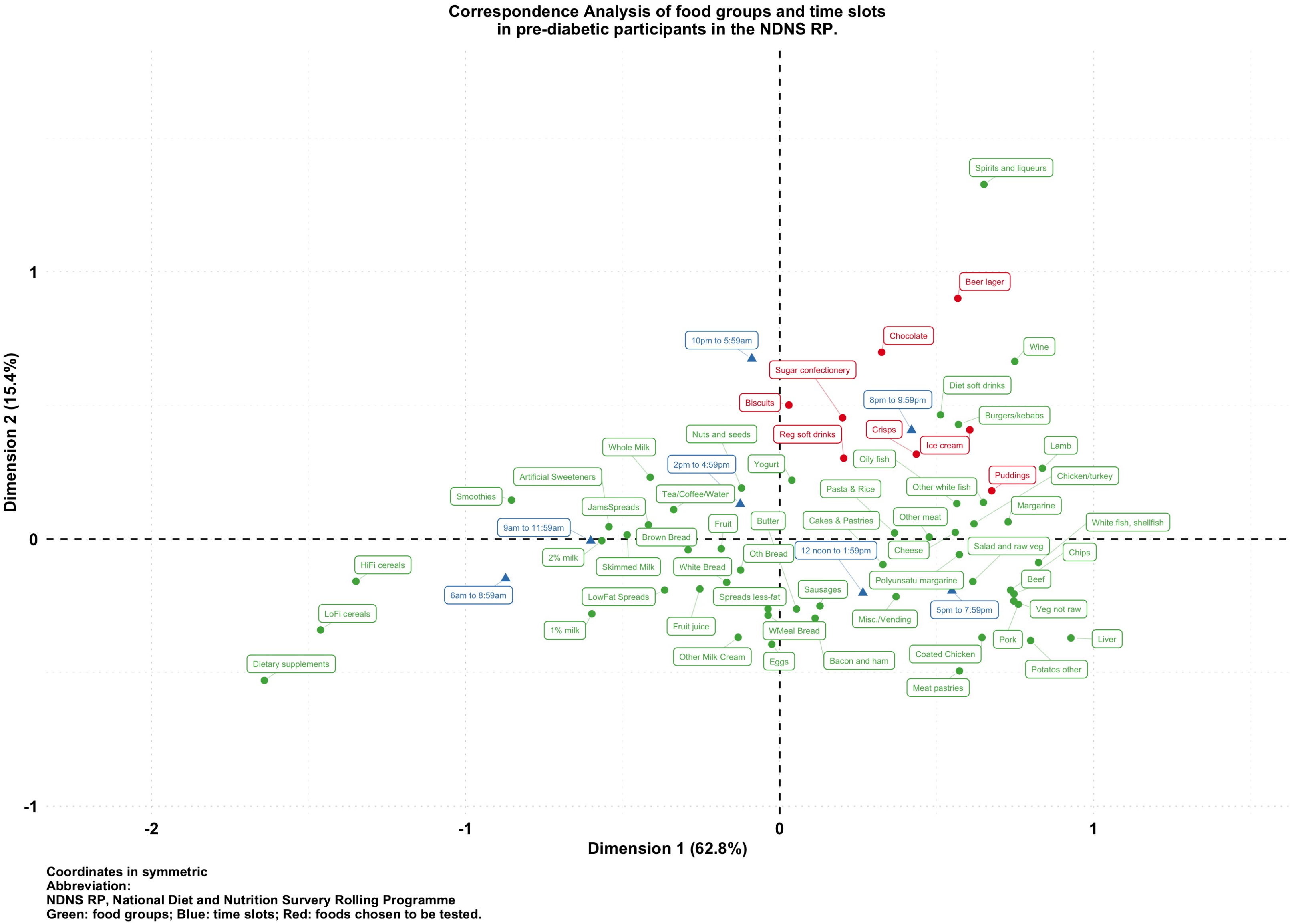

Figure 5. Biplot of food groups and eating time slots in pre-diabetic participants in the NDNS RP.