Taylor & Francis
Taylor & Francis Group

Child and Adolescent Obesity
CHAO

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcha20

Special diet in type 1 diabetes: do gender and BMI-SDS differ?

Alena Gerlinde Thiele, Nicole Prinz, Monika Flury, Melanie Hess, Daniela Klose, Thomas Meissner, Klemens Raile, Ilona Weis, Sabine Wenzel, Sascha Tittel, Thomas Kapellen & Reinhard Holl

To cite this article: Alena Gerlinde Thiele, Nicole Prinz, Monika Flury, Melanie Hess, Daniela Klose, Thomas Meissner, Klemens Raile, Ilona Weis, Sabine Wenzel, Sascha Tittel, Thomas Kapellen & Reinhard Holl (2021) Special diet in type 1 diabetes: do gender and BMI-SDS differ?, Child and Adolescent Obesity, 4:1, 131-147, DOI: 10.1080/2574254X.2021.2002061

To link to this article: https://doi.org/10.1080/2574254X.2021.2002061

Published online: 17 Nov 2021.

CHILD AND ADOLESCENT OBESITY
2021, VOL. 4, NO. 1, 131–147
https://doi.org/10.1080/2574254X.2021.2002061

Taylor & Francis
Taylor & Francis Group

Special diet in type 1 diabetes: do gender and BMI-SDS differ?

Alena Gerlinde Thiele[a,b], Nicole Prinz[c,d], Monika Flury[e], Melanie Hess[f], Daniela Klose[g], Thomas Meissner[h], Klemens Raile[i], Ilona Weis[j], Sabine Wenzel[k], Sascha Tittel[c,d], Thomas Kapellen[a,b] and Reinhard Holl[c,d]

[a]Department of Endocrinology and Diabetology, University of Leipzig, Hospital for Children and Adolescents, Leipzig, D-Germany; [b]Center for Pediatric Research Leipzig, Department of Women and Child Health, Hospital for Children and Adolescents, University Hospitals Leipzig D-Germany; [c]Institute of Epidemiology and Medical Biometry (ZIBMT), Ulm University, Ulm, D-Germany; [d]German Center for Diabetes Research (DZD), Munich-Neuherberg, D-Germany; [e]Department of Pediatrics and Adolescent Medicine, Division of Pediatric Endocrinology and Diabetes, Medical University Carl Gustav Carus, Dresden, D-Germany; [f]Division of Pediatric Endocrinology and Diabetology, Department of Pediatrics, University Children's Hospital Ukbb, Basel, Switzerland; [g]Department of Paediatric Endocrinology and Diabetology, University Childrens Hospital Heidelberg, Heidelberg, D-Germany; [h]Department of General Paediatrics, Neonatology and Paediatric Cardiology, University Children's Hospital Düsseldorf, Düsseldorf, D-Germany; [i]Department of Paediatric Endocrinology and Diabetology, Charité - Universitätsmedizin Berlin, Berlin, D-Germany; [j]Childrens Hospital, Gemeinschaftsklinikum Mittelrhein, Kemperhof Koblenz, Koblenz, D-Germany; [k]Diabetes Center Main Kinzig Main-Kinzig-Kliniken, Gelnhausen, D-Germany

ABSTRACT

Background: Diet modification has the potential to influence glycemic control and diabetes outcome in patients with type 1 diabetes (T1D). This cross-sectional study aimed to assess types of diets being reported by patients with T1D and documented in the Diabetes Patients Follow-Up Registry (DPV).

Methods: The DPV registry was screened for additional free text entries containing information about certain diets and/or physician-based diagnoses requiring special diets e. g. celiac disease. Descriptive analysis and unadjusted comparisons between patients with T1D following at least one special diet and controls (T1D without diet) were performed.

Results: Overall, 113,894 patients with T1D of all ages were included. In 2.3% (n = 2,595; median age 11.3 yrs [Q_1; Q_3: 7.0; 15.2]), at least one kind of diet was documented. These patients were significantly younger at diabetes onset than controls (median age 7.5 yrs [Q_1; Q_3: 3.9; 11.4] vs. 11.1 yrs [6.6; 16.7]; $p < 0.001$) and showed a significantly lower BMI-SDS (median [Q_1; Q_3]: 0.220 [−0.427;0.812] vs. 0.450 [−0.211;1.088]). Diet was more often reported in females (55.7% vs. 44.3%, $p < 0.001$). The three most common diets were gluten-free diet due to celiac disease, low-protein diet, and lactose-restricted diet due to lactose

CONTACT Alena Gerlinde Thiele Alena.Thiele@medizin.uni-leipzig.de Department of Endocrinology and Diabetology, University of Leipzig, Hospital for Children and Adolescents, Leipzig, D-Germany

intolerance. A combination of two diagnoses in one patient (n = 44, 1.7% of the entire diet group) was predominantly intolerance to both fructose and lactose. Among all diet subgroups the highest BMI-SDS was found in the group diets for weight loss.
Conclusions: This study revealed a wide range of eating habits in patients with T1D. A special diet was more frequently documented in females. The main reason for adhering to a diet was a concomitant disease. As any diet modification could impact glycemic control, health care providers should be encouraged to regularly ask their patients about their eating habits and provide training and support by specialized dietitians.

ARTICLE HISTORY Received 26 April 2021; Accepted 28 October 2021

KEYWORDS Type 1 diabetes; special diet; gluten-free diet; low-carb diet; lactose-restricted diet

Introduction

Adequate insulin substitution, nutritional management, and physical activity are the most important cornerstones in the therapy of patients with type 1 diabetes (T1D) (S3-Leitlinie DDG 2018: Therapie des Typ 1 Diabetes; S3-Leitlinie DDG und AGPD 2015: Diagnostik, Therapie und Verlaufskontrolle desDiabetes mellitus im Kindes- und Jugendalter; Adolfsson et al. 2018; Danne et al. 2018; Smart et al. 2018). Nutritional management aims to provide an appropriate energy and nutrient intake, to maintain ideal body weight, and to optimize growth. Furthermore, in patients with T1D it is important to improve diabetes outcome and to minimize the risk for short- and long-term diabetes complications (S3-Leitlinie DDG und AGPD 2015: Diagnostik, Therapie und Verlaufskontrolle desDiabetes mellitus im Kindes- und Jugendalter; S3-Leitlinie DDG 2018: Therapie des Typ 1 Diabetes; Smart et al. 2018). Recommendations for healthy food choice and nutrient intake for patients with T1D are the same as for metabolically healthy subjects (S3-Leitlinie DDG und AGPD 2015: Diagnostik, Therapie und Verlaufskontrolle desDiabetes mellitus im Kindes- und Jugendalter; S3-Leitlinie DDG 2018: Therapie des Typ 1 Diabetes; Smart et al. 2018). However, patients with T1D should consider time of meals in regard to their current blood glucose as well as timing of prandial bolus, and combination of different food components to optimize postprandial glycemia (Danne et al. 2018; Smart et al. 2018). Nonetheless, some patients with T1D adhere to special diets for different reasons: due to a concomitant disease (e. g. a gluten-free diet for celiac disease or low-protein diet for nephropathy) (Robertson et al. 2007; Ahola et al. 2018) or ethical and ecological reasons (e. g. vegetarian diets) (Fox and Ward 2008), or a religious background (e. g. halal or kosher nutrition). Moreover, some patients follow special diets to improve glycemic control and to prevent acute (hypoglycemia and diabetes ketoacidosis), and chronic

(macrovascular and microvascular) diabetes complications. In this regard, especially diets with low carbohydrate intake (low-carb) are discussed controversially (Nielsen et al. 2012; Krebs et al. 2016; Lennerz et al. 2018; Leow et al. 2018; Gallagher et al. 2019; Schmidt et al. 2019).

In general, data about frequency and type of diets and their effects on diabetes outcome in patients with T1D is scarce. So far, only one study from Finland addressed this issue more comprehensively and investigated adherence to special diets in a large cohort of adults with T1D (Ahola et al. 2018). The main reason to follow a diet in this cohort was secondary disease requiring a dietary treatment. Similar data from Germany, Austria, Switzerland, and Luxembourg are missing so far.

The study presented here aimed to assess which special diets are followed by patients with T1D based on data from the Diabetes Patients Follow-Up Registry (Diabetes-Patienten-Verlaufsdokumentation, DPV).

Subjects and methods

The cross-sectional study presented here is based on data from the multicenter, standardized DPV (www.d-p-v.eu). The DPV register was established in 1995 to collect anonymized data on diabetes therapy and outcome as well as socioeconomic data of patients with diabetes mellitus from specialized diabetes centers situated in Germany, Austria, Switzerland, and Luxembourg. Based on these data, practice-relevant issues can easily be investigated in larger cohorts of patients. The DPV initiative has been approved by the Ethics committee of Ulm University, Germany and the anonymized data collection by the local review boards of each participating center. For additional information see Hofer et al. (Hofer et al. 2016). Until March 2019, data of 534,756 patients with different types of diabetes from centers throughout Germany, Austria, Switzerland, and Luxembourg were available in DPV.

Included in this study were all insulin-treated patients with T1D independent of age and with diabetes onset at a minimum age of six months in order to exclude undiagnosed neonatal diabetes.

To identify patients with T1D and a special diet, the DPV database was screened for information in diagnosis fields referring to special diets as well as for physician-based diagnosis requiring a diet e. g. celiac disease. The types of diets we screened for are provided in Table 1. To counter small subgroups, similar diets were grouped by the aim they were followed for (Table 1). All other patients with no documented information on a specific diet were used as controls. According to current therapy guidelines for T1D (S3-Leitlinie DDG 2018: Therapie des Typ 1 Diabetes; Phelan et al. 2018), all patients (controls as well as group of patients with specific diet) were provided with nutritional training at onset, during the course of their disease, and in case of

Table 1. Overview of diet groups and assigned types of diets the DPV database was screened for.

Subgroup	Types of diets
Vegetarian	Vegetarian, lacto-vegetarian, lacto-ovo-vegetarian, ovo-vegetarian, pesco-vegetarian, and semi-vegetarian (occasional meat consumption)
Vegan diet	Vegan diet (no product of animal origin)
Diets restricted in carbohydrates	Low-carb-diet; Paleo diet; Ketogenic diets Atkins diet/ Modified Atkins-diet
Cardio protective diets	Low-salt diet; Low-fat diet; Mediterranean diet Omega 3 diet
Diet due to religion	Kosher; halal/ Ramadan; fasting in general
Celiac disease	Gluten-free diet
Lactose intolerance	Lactose restricted/-free (primary, secondary or unknown type, congenital)
Fructose intolerance	Fructose restricted/-free (primary, secondary or unknown type, congenital)
Histamine intolerance	Histamine restricted/-free
Diets for weight loss	Caloric restriction/ energy restricted diet Weight watchers; "Brigitte Diät"; Formula diet dinner-cancelling; „Trennkost"/ food combining
High-protein diets	no further differentiation
Low-protein diets	no further differentiation

individual issues to optimize glycemic control. This includes, for example, timing of meals and prandial bolus with respect to their current blood glucose level, and the combination of different food components to optimize postprandial glycemia.

At the time of the first documentation of the special diet (± 6 months) we analyzed the following parameters (for controls: most recent treatment year was considered): age, body mass index-standard deviation score (BMI-SDS), height-SDS, duration and age at onset of T1D, glycated hemoglobin (HbA1c), total daily insulin dosage (IU per kg body weight per day), and insulin therapy regime (conventional insulin therapy [CT, ≤3 injection time-points per day], intensified conventional insulin therapy [ICT, ≥4 injection time-points per day], or continuous subcutaneous insulin infusion [CSII] by an insulin pump), microalbuminuria, and physical activity (at least one time per week for 45 to 60 minutes). Height- and BMI-SDS were calculated for patients under 18 years of age using national reference data from the German Health Interview and Examination Survey for children and adolescents (KiGGS) (Neuhauser et al. 2013). Further, migration background, defined by either the patient or at least one of the parents born outside of one of the participating countries (Germany, Austria, Switzerland, and Luxembourg), was analyzed.

Demographic data as well as height-SDS and BMI-SDS of the entire diet cohort were compared to the control group.

Statistics

All statistical procedures were performed using SAS 9.4 (SAS Institute, Cary, NC). We presented descriptive statistics for subgroups with a minimum of 10 patients. Data are presented as median with quartiles (Q_1, Q_3) or percentage if not stated otherwise. Differences in dichotomous outcomes were analyzed using Chi-Square-Test, and Wilcoxon's rank sum test for continuous variables. Two-sided p-values < 0.05 were considered significant and adjusted for multiple testing via Bonferroni stepdown (Holm) method.

Results

A total of n = 113,894 patients with T1D and documented insulin therapy were identified from the DPV registry. 482 centers throughout Germany (n = 434), Austria (n = 43), Switzerland (n = 4), and Luxembourg (n = 1) contributed to this patient group (see supplemental material Table 1). In 2,595 patients (2.3%), at least one special diet was documented (Figure 1).

Patient characteristics are shown in Table 2. Most patients with a special diet were younger than 10 years (41.7%) or between 10–20 years (48.7%). In the majority of patients (93.2%), only one type of diet was documented, in 6.5% two diets, and in 0.3% ≥3 diets. The three most common diets or diagnoses requiring dietary treatment were: 1. gluten-free diet due to celiac disease (51.6%), 2. low-protein diet (14.4%), and 3. lactose-restricted diet due to lactose intolerance (11.9%) (Figure 2). The most common combination of two diagnoses requiring dietary treatment was fructose and lactose intolerance (n = 44, 1.7% of the entire diet group). A gluten-free diet was also recorded in patients without the documented clinical diagnosis of celiac

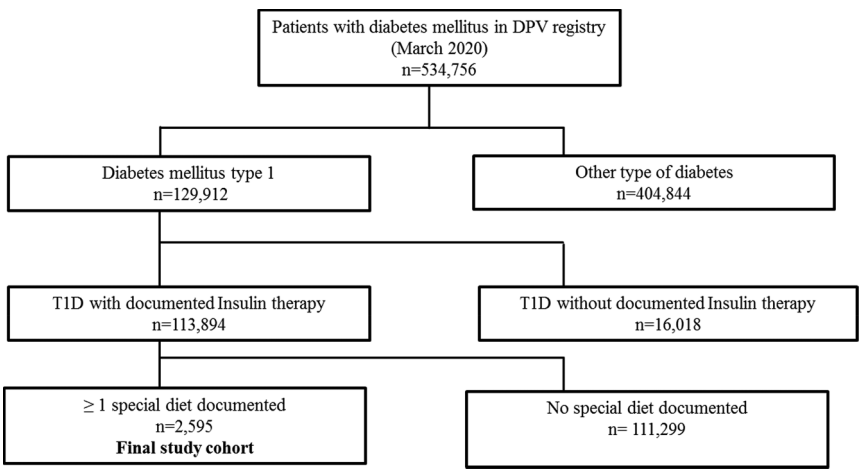

Figure 1. Flow-chart showing selection of study cohort from the DPV registry.

Table 2. Characteristics of patients with T1D and a documented special diet in comparison to the control group consisting of patients with T1D without a special diet.

Parameter	Patients with special diets n = 2,595	Patients without a special diet n = 111,299	p
Sex ratio, % male	44.3	52.5	**<0.001**
Migration background (%)	18.9	12.8	**<0.001**
Age [years]	11.3 [7.0; 15.2]	17.5 [14.2; 31.9]	**<0.001**
Age at T1D onset [years]	7.5 [3.9; 11.4]	11.1 [6.6; 16.7]	**<0.001**
Duration of diabetes until first documented diet [years]	1.9 [0.2; 6.3]	6.7 [2.7; 12.8]	**<0.001**
Height-SDS (KiGGS)	0.002 [−0.710; 0.709] [a]	0.072 [−0.629; 0.773] [b]	**0.003**
BMI-SDS (KiGGS)	0.173 [−0.473; 0.746] [a]	0.306 [−0.311; 0.903] [b]	**<0.001**
Total daily insulin dose per kg bodyweight (IU/kg/d)	0.69 [0.51; 0.92]	0.76 [0.57; 0.98]	/
HbA1c [%]	7.6 [6.9; 8.7]	7.9 [7.0; 9.1]	/
Microalbuminuria [%]	16.0	16.0	/
Insulin therapy			
Conventional insulin therapy (CT) (%)	15.9	10.1	**<0.001**
Intensified conventional insulin therapy (ICT) (%)	54.1	56.8	**0.006**
Continuous subcutaneous insulin infusion (CSII) by an insulin pump (%)	30.0	33.0	**<0.001**

Data are shown as median [first; third quartile], or proportion. Comparison between T1D patients with a special diet and the control group (T1D patients without a special diet, most recent treatment year was considered): Wilcoxon's rank sum test for continuous variables, Chi-Square-Test for dichotomous parameters. P-values in bold letters indicate significant differences between the two groups. Parameters evaluating the diabetes therapy, e. g. HbA1c were not compared as the study did not aim to assess if a diet is better than another diet with respect to glycemic control in T1D. Height- and BMI-SDS were calculated for patients under 18 years of age using national reference data from the German Health Interview and Examination Survey for children and adolescents (KiGGS) (Neuhauser et al. 2013)

[a,b]Number of patients under 18 years of age included in the calculation of height-SDS and BMI-SDS: [a] = 2,286, [b] = 76,385

disease (n = 85). Other diets were found in less than 10% of the patients. The following diets and clinical diagnoses requiring a special diet were documented in less than 10 patients, respectively: Hereditary fructose intolerance (n = 3), gluten-free diet due to non-celiac gluten/wheat sensitivity (n = 4), cow milk allergy (n = 3), and purine-restricted diet (n = 2). None of the following diets were recorded: FODMAP diet (fermentable oligo-, di-, monosaccharides, and polyols), Paleo diet, lactose-free diet due to congenital lactose intolerance, or potassium-restricted diet.

Among all diet subgroups, the oldest patients with the longest diabetes duration were found in the groups, high-protein diet and low-protein diet (Table 3). In the low-protein diet group we found the highest proportion of persons with microalbuminuria (31%) compared to all other diet groups (10% and 24%). The youngest patients within all diet groups who simultaneously had the shortest diabetes duration were those with gluten-free diet due to celiac disease. We found the highest BMI-SDS in patients with documented diet for weight loss. The highest proportion of patients who

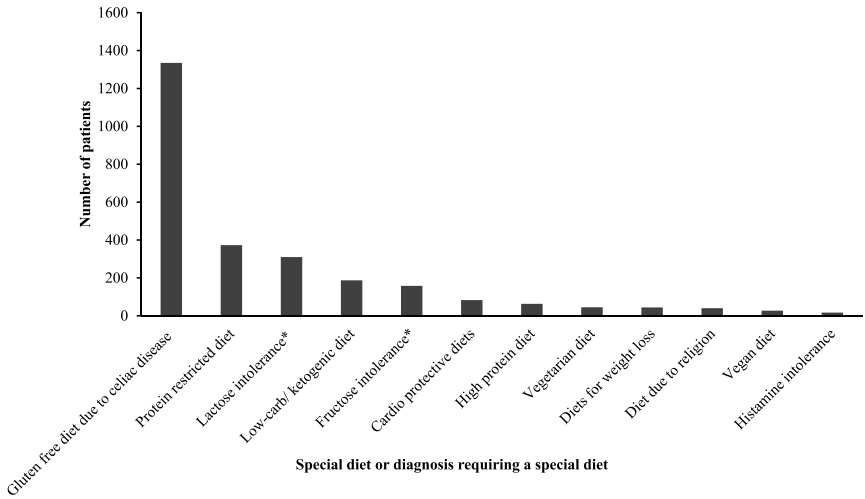

Figure 2. Number of patients per diet subgroup. Diet groups with less than 10 patients are not displayed in the figure. *primary, secondary or unknown type

reported physical activity for at least one time per week for 45 to 60 min were found in the low-carb group (87.2%), followed by the groups vegan diet (85%), vegetarian diet (82.4%), and the high-protein diet (81.8%). In contrast, the percentage of patients with regular physical activity within the other diet groups was between 51.2% and 80%.

Comparison between T1D with a special diet and controls

Comparison of the entire special diet group and single diet subgroups to patients without a special diet (control group) is shown in Tables 2 and 3. The percentage of females in the diet group was significantly higher compared to the control group. Overall, the percentage of patients with migration background was higher in the diet subgroups compared to controls with exception for patients with low-protein diet and vegetarian diets. Regarding the median age at diabetes onset, patients with a special diet were significantly younger than controls. This was true for all single diet subgroups. While height-SDS did not differ significantly, patients of the entire special diet group showed a significantly lower BMI-SDS compared to controls (Table 2).

Table 3. Characteristics of diet subgroups and comparison to the control group consisting of patients with T1D without a special diet (n = 111,299).

Special Diet	Males (%)	p	Migration background (%)	p	Age in years	p	Age at T1D onset in years	p	Diabetes duration in years	p	Height-SDS	BMI-SDS	Total daily insulin dose (IU/kg /d)	HbA1c (%)
Gluten free diet due to celiac disease (n = 1,335)	42.7	**<0.001**	18.8	**<0.001**	8.7 [5.3; 12.4]	**<0.001**	5.7 [3.1; 9.5]	**<0.001**	0.4 [0.1; 3.7]	**<0.001**	−0.006 [b] [−0.763; 0.690]	0.065 [b] [−0.588; 0.665]	0.64 [0.46; 0.86]	7.6 [6.9; 8.5]
Low-protein diet (n = 373)	48.3	0.064	8.6	**0.023**	15.8 [11.2; 34.6]	**<0.001**	9.7 [5.7; 14.9]	**0.042**	5.6 [2.1; 12.8]	0.304	−0.079 [c] [−0.637; 0.706]	0.230 [c] [−0.353; 0.737]	0.73 [0.56; 0.93]	7.7 [6.9; 8.7]
Lactose intolerance [a] (n = 310)	43.9	**0.001**	21.0	**<0.001**	12.6 [9.7; 15.8]	**<0.001**	8.9 [4.9; 12.6]	**<0.001**	2.7 [0.3; 7.8]	**<0.001**	0.003 [d] [−0.716; 0.635]	0.288 [d] [−0.351; 0.917]	0.73 [0.56; 0.97]	7.8 [7.0; 8.9]
Low carb diet or ketogenic diet (n = 187)	38.5	**<0.001**	27.8	**<0.001**	13.9 [11.0; 16.5]	**<0.001**	8.8 [5.0; 12.4]	**<0.001**	4.2 [1.2; 7.2]	**<0.001**	0.328 [e] [−0.429; 1.141]	0.383 [e] [−0.127; 0.981]	0.82 [0.58; 1.00]	7.6 [6.9; 8.7]
Fructose intolerance [a] (n = 158)	41.8	**0.008**	22.8	**<0.001**	11.5 [8.9; 14.5]	**<0.001**	8.0 [5.5; 11.4]	**<0.001**	2.1 [0.3; 5.5]	**<0.001**	0.041 [f] [−0.511; 0.802]	0.221 [f] [−0.476; 0.928]	0.76 [0.54; 0.96]	7.6 [6.9; 8.6]
Cardio protective diets (n = 83)	48.2	0.283	18.1	0.175	13.6 [10.9; 15.4]	**<0.001**	9.8 [4.6; 11.9]	**<0.001**	2.7 [1.1; 7.4]	**<0.001**	−0.0.70 [g] [−0.899; 0.536]	0.741 [g] [−0.003; 1.435]	0.77 [0.57; 1.01]	7.8 [6.9; 8.9]
High-protein diet (n = 63)	68.3	**0.028**	25.4	**0.012**	17.0 [15.3; 18.7]	0.520	10.2 [7.1; 15.6]	0.755	6.8 [2.3; 11.2]	0.583	0.085 [h] [−0.373; 0.961]	0.658 [h] [0.021; 1.367]	0.78 [0.60; 1.05]	8.1 [7.1; 9.2]
Vegetarian diet (n = 45)	28.9	**0.001**	11.1	0.524	14.7 [13.1; 17.3]	**<0.001**	9.7 [7.4; 13.6]	0.658	3.2 [0.9; 7.6]	**<0.001**	−0.152 [i] [−0.821; 0.786]	0.219 [i] [−0.510; 0.663]	0.82 [0.68; 1.13]	7.5 [6.7; 8.7]
Diets for weight loss (n = 44)	27.3	**0.001**	13.6	0.679	16.0 [14.5; 20.0]	0.123	10.9 [9.0; 15.0]	0.489	5.8 [1.3; 9.1]	**0.034**	−0.054 [j] [−0.676; 0.672]	1.280 [j] [0.568; 1.835]	0.63 [0.48; 0.91]	8.1 [7.0; 9.0]

(*Continued*)

Table 3. (Continued).

Special Diet	Males (%)	p	Migration background (%)	p	Age in years	p	Age at T1D onset in years	p	Diabetes duration in years	p	Height-SDS	BMI-SDS	Total daily insulin dose (IU/kg /d)	HbA1c (%)
Diet due to religion (n = 40)	60.0	0.587	87.5	**<0.001**	13.4 [11.4; 15.9]	**<0.001**	8.8 [5.5; 12.1]	**0.037**	4.1 [0.7; 7.1]	**<0.001**	−0.024 [k] [−0.519; 0.682]	0.353 [k] [−0.050; 1.007]	0.88 [0.71; 1.11]	8.0 [7.5; 8.5]
Vegan diet (n = 27)	22.2	**0.003**	18.5	0.903	15.6 [13.2; 17.8]	**0.037**	9.9 [7.5; 12.6]	0.351	4.2 [0.8; 9.3]	0.162	0.271 [l] [−0.388; 0.636]	0.358 [l] [−0.499; 1.010]	0.84 [0.56; 1.00]	8.0 [6.5; 8.9]
Histamine intolerance (n = 17)	41.2	0.309	17.6	0.551	13.3 [10.2; 15.0]	**<0.001**	9.7 [4.4; 12.6]	0.115	0.2 [0.1; 5.8]	**0.003**	−0.605 [m] [−0.960; 0.447]	−0.445 [m] [−0.826; 0.225]	0.67 [0.45; 1.06]	8.5 [7.3; 9.6]

Data are shown as median [first; third quartile], or proportion. Comparison between T1D patients with a special diet and the control group (T1D patients without a special diet): Wilcoxon's rank sum test for continuous variables, Chi-Square-Test for dichotomous parameters. P-values in bold letters indicate significant differences between the two groups. Parameters evaluating the diabetes therapy, e. g. HbA1c, were not compared as the study did not aim to assess if a diet is better than another diet with respect to glycemic control in T1D. Some patients are included in several diet groups, as they have sometimes followed different diets at different times.

[a]primary, secondary or unknown type

Height- and BMI-SDS were calculated for patients under 18 years of age using national reference data from the German Health Interview and Examination Survey for children and adolescents (KiGGS) (Neuhauser et al. 2013). Number of patients under 18 years of age per subgroup included in the analysis of height SDS- and BMI-SDS: [b] = 1292; [c] = 238; [d] = 265; [e] = 159; [f] = 147; [g] = 81; [h] = 41; [i] = 39; [j] = 32; [k] = 36, [l] = 21; [m] = 15

Comparison of females and males of the diet group

Females and males of the special diet group showed no significant differences regarding age, age at diabetes onset, diabetes duration, height-SDS/BMI-SDS, or diabetes therapy (data not shown). However, in females a significantly higher insulin dosage per day (median [Q_1; Q_3]: 0.71 [0.53; 0.92] IU/kg) vs. 0.68 [0.49; 0.91] IU/kg, p = 0.022), and higher HbA1c (median [Q_1; Q_3]: 7.7 [6.9; 8.8] % vs. 7.6 [6.9; 8.6] %, p = 0.037) was found compared to male patients. Except for high-protein diets or diets followed for religious reasons, all other diets were documented more frequently in females compared to males. With respect to the number of diets, males more often reported only one diet (P = 0.028), while combinations of two diets were significantly more frequent in females (P = 0.046).

Looking at the single diet subgroups, females with a "gluten-free diet due to celiac disease" had a significantly higher total daily insulin dosage (median [Q_1; Q_3]: 0.66 [0.48; 0.87] IU/kg vs. 0.61 [0.44; 0.84] IU/kg, p = 0.009) compared to males, while no significant differences regarding age (p= 0.685), age at diabetes onset (p = 0.614), or diabetes duration (p= 0.659) were found in this group. The most frequent second diagnosis in this diet group was lactose intolerance in both sexes. Regarding patients with lactose intolerance significantly more females suffered simultaneously from fructose intolerance compared to males (17.2% vs. 8.8%, p = 0.032). Among patients with a low-protein diet, males exhibited a significantly lower height-SDS compared to females (median [Q_1; Q_3]: −0.19 [−1.03; 0.36] vs. −0.09 [−0.76; 0.74], p = 0.041), while no significant differences occurred with respect to age (p= 0.297), age at diabetes onset (p= 0.769) or diabetes duration (p = 0.124). In the low-protein diet group, in 12.4% of females and 6.1% of males, adherence to a second diet, predominantly a gluten-free diet due to celiac disease was documented.

Discussion

The aim of this study was to assess the type of diets patients with T1D adhere to. In 2.3% of patients with T1D registered in DPV a special diet was documented. In general, these patients were younger at diabetes onset than patients with T1D without any special diet. Most patients followed a diet due to a concomitant disease. The three most frequent diets were gluten-free diet due to celiac disease, low-protein diet, and lactose-restricted diet due to lactose intolerance. This is in accordance with a previous study from Finland investigating adherence to special diets in adults with T1D (Ahola et al. 2018). But, in contrast to our study, 36.6% of their patients adhered to a diet, most frequently a protein-restricted diet, lactose-free diet, and a gluten-free diet. Most of these patients were female, had a longer duration of

diabetes, and showed more diabetes complications. With a median age of 49 years [interquartile range: 38–59], they were markedly older and had a longer T1D diabetes duration than our patients.

In our cohort, the most frequently documented diet was a gluten-free diet due to celiac disease. This is not surprising as celiac disease is a common comorbidity in T1D (Kaspers et al. 2004; Craig et al. 2017). As in almost all diet subgroups, except diets followed for religious reasons or high-protein diets, the percentage of females within the group gluten free diet due to celiac disease was higher compared to males. Prevalence for celiac disease in the general population is higher in females; but in combination with T1D the data are inconsistent (Fröhlich-Reiterer et al. 2011; Laass et al. 2015; Vajravelu et al. 2018; Nagl et al. 2019).

The second most documented type of diet in our cohort was a low-protein diet. Such a diet might decelerate progression of diabetic nephropathy, but evidence is missing (Robertson et al. 2007). Among the entire diet group, the group low-protein diet included aside from the group high-protein diet the oldest patients with the longest diabetes duration. In 31% of them micro-albuminuria, an early indicator of diabetic nephropathy, was present.

In contrast, 63 patients reported to adhere to a high-protein diet. Almost 70% of these patients were male and mainly between 10 and 20 years old. Previous studies showed a higher percentage of high-protein diets including the use of protein supplements among young males compared to females, especially in athletes, but also in leisure time exercisers (MRI 2008; Hartmann et al. 2016; Ewan et al. 2019). Their main motives for high-protein diets are often to gain or maintain muscle mass and strength. A former study investigating associations between physical activity and glycemic control in adults with T1D showed that the majority among the group with the highest physical activity (more than two times a week) were young males (30.4 years ± 15.8, mean age ± SD) (Bohn et al. 2015). With respect to T1D, a higher protein intake is not necessary (Smart et al. 2018). In contrast, a high protein intake over a longer period might be harmful for patients with T1D and persistent microalbuminuria or apparent nephropathy (Smart et al. 2018) as it might negatively impact renal function (Tipton 2011).

The third most frequent diet in our cohort was a lactose-restricted diet due to lactose intolerance. This was also the most common additional diagnosis in our group with gluten-free diet due to celiac disease. In patients with untreated celiac disease secondary lactose or fructose intolerance due to mucosal surface damage is quite common (Arthur 1966).

A dietary modification aimed for optimizing glucose control in patients with T1D is the restriction of carbohydrate intake. A low-carb or a ketogenic diet was the 4th most frequently documented type of diet in our cohort. Previous studies showed that restriction of carbohydrate consumption in favor of snacks rich in fat and protein is common in patients with T1D

(Meissner et al. 2014; Baechle et al. 2018). Recent studies showed lower glucose variability and significant reduction of HbA1c under restriction of carbohydrate intake in patients with T1D (O' Neill et al. 2003; Nielsen et al. 2012; Lennerz et al. 2018; Schmidt et al. 2019). However, comparison and interpretation of the results is difficult due to differences in study design, small cohorts, and inconsistent definition of the carbohydrate restriction (Nielsen et al. 2012; Krebs et al. 2016; Leow et al. 2018; Gallagher et al. 2019). Further, inclusion of highly motivated patients might bias the results (O' Neill et al. 2003; Nielsen et al. 2012; Lennerz et al. 2018; Schmidt et al. 2019; Seckold et al. 2019). As details about strictness or duration of the low-carb diet were not available in our cohort we cannot draw conclusions about the effects on glycemic control. Depending on strictness of carbohydrate reduction, this diet is associated with higher risk for nutrient deficiency, hypoglycemia, diabetes ketoacidosis, increased cardiovascular risk profile (Meissner et al. 2014), and growth retardation in children (Bolla et al. 2019). Moreover, the enormous restriction of food choice impacts everyday life of the patients, which might increase psychosocial problems and contribute to eating disorders (Gallagher et al. 2019; Baechle et al. 2019). According to current guidelines, low-carb diet is not recommended for patients with T1D (Smart et al. 2018). Instead, patients should be encouraged to a healthy food choice as recommended for the metabolically healthy population (S3-Leitlinie DDG 2018: Therapie des Typ 1 Diabetes; S3-Leitlinie DDG und AGPD 2015: Diagnostik, Therapie und Verlaufskontrolle desDiabetes mellitus im Kindes- und Jugendalter; Smart et al. 2018).

Vegetarian or vegan diets are mostly self-prescribed, and often followed for ethical or ecological reasons (Fox and Ward 2008). In only 0.03% of all patients with T1D a vegetarian and in 0.02% a vegan diet was recorded. Again, the percentage of females was higher compared to males, which is in accordance with former studies (Fox and Ward 2008; Bohn et al. 2015; Mensink et al. 2016; Patelakis et al. 2019). Previous surveys in the healthy German population showed that 4.3% of adults aged 18 to 79 years and 3.3% of children and adolescents aged 6 to 17 years stated to follow a vegetarian or vegan diet (Bohn et al. 2015; Mensink et al. 2016; Patelakis et al. 2019). Among all age groups, these individuals were more frequently female, had a higher education, and were physically more active. During the last decades, vegetarian lifestyle has become more popular as it is associated with health benefits, e. g. a lower risk for hypertension, cardiovascular disease, obesity, or type 2 diabetes (Chandalia et al. 2000; Waldmann et al. 2007). Plant-based diets are characterized by high content of dietary fiber and low glycemic index (Le and Sabaté 2014), and can positively influence metabolic parameters like serum lipids or serum glucose (Lee and Park 2017). This might

also be beneficial for patients with T1D to optimize glycemic control and to minimize the risk of chronic (macrovascular and microvascular) diabetes complications.

Using the DPV registry allowed us to analyze a large cohort of patients with T1D. The percentage of patients with a documented diet is markedly lower compared to a previous study from Finland (Ahola et al. 2018). So far, further studies investigating adherence to special diets in T1D are missing. In our study the percentage of patients with T1D following special diets might be underreported. This could be caused by the retrospective study design as it is a register-based study and data analysis is limited by quantity and quality of data entries. Within the DPV registry there are no standardized fields for documentation of special diets. Information about type of diet, duration, strictness, or the reason for the diet has to be documented in the free text. In this regard, also a lack of reporting by the patient or incomplete documentation by the healthcare team is possible, especially if diets were followed only for a short time. Further subgrouping by age to evaluate age-specific effects on eating behavior and diet implementation was not meaningful based on the overall relatively small percentage of patients following a special diet. At least a sub-analysis of patients <18 years of age revealed comparable results to our original cohort (data not shown). In addition, other factors potentially influencing eating habits and diet implementation, e. g. different comorbidities, disease stages or kind and intensity of physical exercise, could not be investigated in detail due to the study design and the existing data set.

In summary, our study revealed a wide range of eating habits in patients with T1D. We could show that special diets also play a role in this patient group. A special diet was more frequently documented in females. Nutritional modifications influence positively, but also negatively glycemic control in patients with T1D. This emphasizes the great importance of regular nutritional education, support, and follow-up of patients with T1D by a specialized dietitian as part of an interdisciplinary diabetes team. Patients should be aware of the importance of meal-time routines, limitations on snacking, and adequate adaption of insulin dosage to dietary intake in order to improve dietary quality, and to optimize glycemic outcomes (Baechle et al. 2018).

Funding

This manuscript is part of a project () that has received funding from the Innovative Medicines Initiative 2 Joint Undertaking under grant agreement No 875534. This Joint Undertaking support from the European Union's Horizon 2020 research and innovation programme and "EFPIA" and "T1D Exchange", "JDRF", and "Obesity Action Coalition". Additional support by the Federal Ministry of Education and Research (FKZ 82DZD0017G) within the German Center of Diabetes Research, the

German Robert Koch Institute (RKI). The sponsors were not involved in data acquisition and analysis.http://www.imisophia.eu

Acknowledgments

We want to thank A. Hungele and R. Ranz for their support and the development of DPV documentation software and K. Fink and E. Bollow for DPV data management support (all clinical data managers, Ulm University). We also thank all participating DPV centers for contributing anonymized data to the present study (supplemental material Table 1).

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Alena Gerlinde Thiele http://orcid.org/0000-0003-2880-1355

References

Diagnostik, Therapie und Verlaufskontrolle des Diabetes mellitus im Kindes- und Jugendalter 2015, S3-Leitlinie der DDG und AGPD 2015, AWMF-Registernummer. 16–57.

Adolfsson P, Riddell MC, Taplin CE, Davis EA, Fournier PA, Annan F, Scaramuzza AE, Hasnani D, Hofer SE. 2018. ISPAD Clinical practice consensus guidelines 2018: exercise in children and adolescents with diabetes. Pediatr Diabetes. 19 (Suppl 27):205–226. Oct. doi:10.1111/pedi.12755

Ahola AJ, Forsblom C, Groop P-H. 2018. Groop. adherence to special diets and its association with meeting the nutrient recommendations in individuals with type 1 diabetes. Acta Diabetol. 55(8):843–851. doi:10.1007/s00592-018-1159-2.

Arthur AB. 1966. Intestinal Disaccharidase Deficiency in Children with Coeliac Disease. Arch Dis Childh. 41(219):519–524. doi:10.1136/adc.41.219.519.

Baechle C, Hoyer A, Castillo-Reinado K, Stahl-Pehe A, Kuss O, Holl RW, Kersting M, Rosenbauer J. 2018. Eating frequency and carbohydrate intake in adolescents with type 1 diabetes differ from those in their peers and are associated with glycemic control. Exp Clin Endocrinol Diabetes. 126(5):277–286. doi:10.1055/s-0043-115010.

Baechle C, Hoyer A, Stahl-Pehe A, Castillo K, Toennies T, Lindner LM, Reinauer C, Holl RW, Kuss O, Rosenbauer J, et al. 2019. Course of disordered eating behavior in young people with early-onset type i diabetes: prevalence, symptoms, and transition probabilities. J Adolesc Health. 65(5):681–689. doi:10.1016/j.jadohealth.2019.05.016.

Bohn B, Herbst A, Pfeifer M, Krakow D, Zimny S, Kopp F, Melmer A, Steinacker JM, Holl RW. 2015. for the DPV-initiative and the BMBF Competence Network Diabetes mellitus. Impact of physical activity on glycemic control and cardiovascular risk factors in adults with type 1 diabetes – a multicenter study of 18,028 patients. Diabetes Care. 38(8):1536–1543. doi:10.2337/dc15-0030.

Bolla AM, Caretto A, Laurenzi A, Scavini M, Piemonti L. 2019. Low-carb and ketogenic diets in type 1 and type 2 diabetes. Nutrients. 11(5):E962–75. doi:10.3390/nu11050962.

Chandalia M, Garg A, Lutjohann D, von Bergmann K, Grundy SM, Brinkley LJ. 2000. Beneficial effects of high dietary fiber intake in patients with type 2 diabetes mellitus. N Engl J Med. 342(19):1392–1398. doi:10.1056/NEJM200005113421903.

Craig ME, Prinz N, Boyle CT, Campbell FM, Jones TW, Hofer SE, et al. 2017. Australasian diabetes data network (ADDN); T1D exchange clinic network (T1DX); national paediatric diabetes audit (NPDA) and the royal college of paediatrics and child health; Prospective diabetes follow-up registry (DPV) initiative. Prevalence of celiac disease in 52,721 youth with type 1 Diabetes: international comparison across three continents. Diabetes Care. 40(8):1034–1040. doi:10.2337/dc16-2508.

Danne T, Phillip M, Buckingham BA, Jarosz-Chobot P, Saboo B, Urakami T, Battelino T, Hanas R, Codner E. 2018. ISPAD clinical practice consensus guidelines 2018: insulin treatment in children and adolescents with diabetes. Pediatr Diabetes. 19(Suppl 27):115–135. Oct. doi:10.1111/pedi.12718

Ewan T, Bettina K, Fatma Nese S, Goktug E, Francesco M, Vincenza L, Paoli A, Gentil P, Palma A, Bianco A, et al. 2019. Protein supplement consumption is linked to time spent exercising and high-protein content foods: a multicentric observational study. Heliyon. 5(4):e01508. doi:10.1016/j.heliyon.2019.e01508.

Fox N, Ward K. 2008. Health, ethics and environment: a qualitative study of vegetarian motivations. Appetite. 50(2–3):422–429. doi:10.1016/j.appet.2007.09.007.

Fröhlich-Reiterer EE, Kaspers S, Hofer S, Schober E, Kordonouri O, Bechtold-Dalla Pozza S, et al. 2011. Diabetes patienten verlaufsdokumentationssystem–wiss study group. Anthropometry, metabolic control, and follow-up in children and adolescents with type 1 diabetes mellitus and biopsy-proven celiac disease. J Pediatr. 158 (4):589–593. doi:10.1016/j.jpeds.2010.09.050.

Gallagher KAS, DeSalvo D, Gregory J, Hilliard ME. 2019. Medical and psychological considerations for carbohydrate-restricted diets in youth with type 1 diabetes. Curr Diab Rep. 19(6):27–34. doi:10.1007/s11892-019-1153-2.

Hartmann C, Keller C, Siegrist M. 2016. Compensatory beliefs, nutrition knowledge and eating styles of users and non-users of meal replacement products. Appetite. 105:775–781. doi:10.1016/j.appet.2016.07.013

Hofer SE, Anke Schwandt A, Holl RW. 2016. Austrian/German DPV Initiative. Standardized documentation in pediatric diabetology: experience from austria and germany. J Diabetes Sci Technol. 10(5):1042–1049. doi:10.1177/1932296816658057.

Kaspers S, Kordonouri O, Schober E, Grabert M, Hauffa BP, Holl RW. 2004. Anthropometry, metabolic control and thyroid autoimmunity in type 1 diabetes with celiac disease – a multicenter survey. J Pediatrics. 145(6):790–795. doi:10.1016/j.jpeds.2004.07.031.

Krebs JD, Parry Strong A, Cresswell P, Reynolds AN, Hanna A, Haeusler S. 2016. A randomised trial of the feasibility of a low carbohydrate diet vs standard carbohydrate counting in adults with type 1 diabetes taking body weight into account. Asia Pac J Clin Nutr. 25(1):78–84. doi:10.6133/apjcn.2016.25.1.11.

Laass MW, Schmitz R, Uhlig HH, Zimmer KP, Thamm M, Koletzko S. 2015. Zöliakieprävalenz bei Kindern und Jugendlichen in Deutschland. Dtsch Artzebl Int. 112:553–560. doi:10.3238/arztebl.2015.0553

Le L, Sabaté J. 2014. Beyond meatless, the health effects of vegan diets: findings from the Adventist cohorts. Nutrients. 6(6):2131–2147. doi:10.3390/nu6062131.

Lee Y, Park K. 2017. Adherence to a vegetarian diet and diabetes risk: a systematic review and meta-analysis of observational studies. Nutrients. 9(6):603–613. doi:10.3390/nu9060603.

Lennerz BS, Barton A, Bernstein RK, Dikeman RD, Diulus C, Hallberg S, Rhodes ET, Ebbeling CB, Westman EC, Yancy WS, et al. 2018. Management of Type 1 Diabetes With a Very Low-Carbohydrate Diet. Pediatrics. 141(6):e20173349. doi:10.1542/peds.2017-3349.

Leow ZZX, Guelfi KJ, Davis EA, Jones TW, Fournier PA. 2018. The glycaemic benefits of a very-low-carbohydrate ketogenic diet in adults with Type 1 diabetes mellitus may be opposed by increased hypoglycaemia risk and dyslipidaemia. Diabet Med. 35(9):1258–1263. doi:10.1111/dme.13663.

Meer T, Wolf J, Kersting M, Fröhlich-Reiterer E, Flechtner-Mors M, Salgin B, Stahl-Pehe A, Holl RW. 2014. Carbohydrate intake in relation to BMI, HbA1c and lipid profile in children and adolescents with type 1 diabetes. Clinical Nutrition. 33 (1):75–78. doi:10.1016/j.clnu.2013.03.017.

Mensink GBM, Lage Barbosa C, Brettschneider AK. 2016. Verbreitung der vegetarischen Ernährungsweise in Deutschland. J Health Monit. 1(2):2–15. doi:10.17886/RKI-GBE-2016-033.

MRI. Nationale Verzehrsstudie II, Ergebnisbericht, Teil 1. Karlsruhe (2008).

Nagl K, Bollow E, Liptay S, Rosenbauer J, Koletzko S, Pappa A, Näke A, Fröhlich-Reiterer E, Döring C, Wolf J, et al. 2019. Lower HbA1c in patients with type 1 diabetes and celiac disease who reached celiac specific antibody negativity-a multicenter DPV analysis. Pediatr Diabetes. 20(8):1100–1109. doi:10.1111/pedi.12908.

Neuhauser H, Schienkiewitz A, Rosario AS, Dortschy R, and Kurth BM. 2013. Referenzperzentile für anthropometrische Maßzahlen und Blutdruck aus der Studie zur Gesundheit von Kindern und Jugendlichen in Deutschland (KiGGS). Beiträge zur Gesundheitsberichterstattung des Bundes: Robert Koch Institut Berlin.

Nielsen JV, Gando C, Joensson E, Paulsson C. 2012. Low carbohydrate diet in type 1 diabetes, long-term improvement and adherence: a clinical audit. Diabetol Metab Syndr. 4(1):23–27. doi:10.1186/1758-5996-4-23.

O' Neill DF, Westman EC, Bernstein RK. 2003. The effects of a low-carbohydrate regimen on glycemic control and serum lipids in diabetes mellitus. Metab Syndr Relat Disord. 1(4):291–298. doi:10.1089/1540419031361345.

Patelakis E, Lage Barbosa C, Haftenberger M, Brettschneider AK, Lehmann F, Heide K, et al. 2019. Prevalence of vegetarian diet among children and adolescents in Germany. Results from EsKiMo II. Ernahrungs Umschau. 66(5):85–91. doi:10.4455/eu.2019.018.

Phelan H, Lange K, Cengiz E, Gallego P, Majaliwa E, Pelicand J, Smart HSE. 2018. ISPAD clinical practice consensus guidelines 2018: diabetes education in children and adolescents. Pediatr Diabetes. 19(Suppl 27):75–83. doi:10.1111/pedi.12762.

Robertson LM, Waugh N, Robertson A. 2007. Protein restriction for diabetic renal disease. Cochrane Database of Systematic Reviews. 4:CD002181. doi:10.1002/14651858.CD002181.pub2

Schmidt S, Christensen MB, Serifovski N, Damm-Frydenberg C, Jensen JB, Fløyel T, Størling J, Ranjan A, Nørgaard K. 2019. Low versus high carbohydrate diet in type 1 diabetes: a 12-week randomized open-label crossover study. Diabetes Obes Metab. 21(7):1680–1688. doi:10.1111/dom.13725.

Seckold R, Fisher E, De Bock M, King BR, Smart CE. 2019. Smart CE. The ups and downs of low-carbohydrate diets in the management of Type 1 diabetes: a review of clinical outcomes. Diabet Med. 36(3):326–334. doi:10.1111/dme.13845.

Smart CE, Annan F, Higgins LA, Jelleryd E, Lopez M, Acerini CL. 2018. ISPAD Clinical Practice Consensus Guidelines 2018: nutritional management in children and adolescents with diabetes. Pediatr Diabetes. 19(Suppl 27):136–154. doi:10.1111/pedi.12738.

Tipton KD. 2011. Efficacy and consequences of very-high-protein diets for athletes and exercisers. Proc Nutr Soc. 70(2):205–214. doi:10.1017/S0029665111000024.

Vajravelu ME, Keren R, Weber DR, Verma R, De León DD, Denburg MR. 2018. Incidence and risk of celiac disease after Type 1 diabetes: a population-based cohort study using the health improvement network database. Pediatr Diabetes. 19(8):1422–1428. doi:10.1111/pedi.12770.

Waldmann A, Ströhle A, Koschizke JW, Leitzmann C, Hahn A. 2007. Overall glycemic index and glycemic load of vegan diets in relation to plasma lipoproteins and triacylglycerols. Ann Nutr Metab. 51(4):335–344. doi:10.1159/000107676.