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Plant and animal protein intake and its association with overweight and obesity among the Belgian population

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Abstract

The objective of the present study was to assess animal and plant protein intakes in the Belgian population and to examine their relationship with overweight and obesity (OB). The subjects participated in the Belgian National Food Consumption Survey conducted in 2004. Food consumption was assessed by using two non-consecutive 24 h dietary recalls. About 3083 participants ($\geq$15 years of age; 1546 males, 1537 females) provided completed dietary information. Animal protein intake (47 g/d) contributed more to total protein intakes of 72 g/d than plant protein intake, which accounted for 25 g/d. Meat and meat products were the main contributors to total animal protein intakes (53 %), whereas cereals and cereal products contributed most to plant protein intake (54 %). Males had higher animal and plant protein intakes than females ($P<0{\cdot}001$). Legume and soya protein intakes were low in the whole population (0·101 and 0·174 g/d, respectively). In males, animal protein intake was positively associated with BMI ($\beta = 0{\cdot}013$; $P=0{\cdot}001$) and waist circumference (WC; $\beta = 0{\cdot}041$; $P=0{\cdot}002$). Both in males and females, plant protein intake was inversely associated with BMI (males: $\beta = -0{\cdot}036$; $P<0{\cdot}001$; females: $\beta = -0{\cdot}046$; $P=0{\cdot}001$) and WC (male: $\beta = -0{\cdot}137$; $P<0{\cdot}001$; female: $\beta = -0{\cdot}096$; $P=0{\cdot}024$). In conclusion, plant protein intakes were lower than animal protein intakes among a representative sample of the Belgian population and decreased with age. Associations with anthropometric data indicated that plant proteins could offer a protective effect in the prevention of overweight and OB in the Belgian population.

Key words: Animal protein: Plant protein: BMI: Waist circumference: Obesity

In recent decades, intakes of dietary protein have been associated with treating chronic diseases such as obesity (OB) and CVD besides improving health outcomes[1,2]. Evidence indicates that a high dietary protein intake decreases the risk of non-communicable diseases via the regulation of energy intake, increment of satiety, lowering of systolic and diastolic blood pressure, decrement of total cholesterol levels and presence of LDL-cholesterol and TAG[3–5]. In addition, high protein intakes are associated with the prevention of the development of chronic diseases, including OB, the metabolic syndrome, CVD, type 2 diabetes, osteoporosis, and breast and prostate cancer[3,6–10].

Findings from recent randomised controlled trials relate plant proteins to health benefits more than animal proteins[11–19], mainly due to factors affecting the level of hypercholesterolaemic amino acids present in plant proteins[20]. However, the debate on the potential health effects of animal protein- and plant protein-rich diets is

Abbreviations: OB, obesity; OW, overweight; WC, waist circumference.

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still ongoing. For instance, some studies have reported a positive association between animal protein intakes and the risk of chronic diseases[21–24], whereas others have indicated an inverse relationship[25–27]. One of these trials, involving healthy menopausal women, has suggested that milk whey protein can prevent bone loss[25], while two others trials with overweight (OW) or insulin-resistant subjects have indicated that proteins from meat, poultry, fish and dairy foods had beneficial metabolic effects[26,27] and improved insulin sensitivity[26,27].

In Belgium, information on plant and animal protein intakes of the population is still lacking until now. Therefore, the present study aims (1) to estimate the intake levels of animal and plant proteins in a representative sample of the Belgian population and (2) to examine their associations with OW and OB measured by BMI and waist circumference (WC).

Methodology

Study design and data collection

The Belgian National Food Consumption Survey[28] was performed in 2004 following largely the recommendations of the European Food Consumption Survey Method project[29]. More details on the survey can be found elsewhere[28]. Belgian national citizens aged 15 years or older, residing in private households in Belgium, were eligible to participate in the national survey. The population was stratified by sex and in four age groups (15–18, 19–59, 60–74 and ≥75 years). Approximately 400 individuals were allocated in each sex–age group. Participants were selected from the national register using a multi-stage stratified sampling procedure. Institutionalised individuals, not able to speak one of the national languages or physically or mentally unable to be interviewed, were excluded from the survey. In total, 7543 individuals were invited to participate.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and approved by the medical ethical committee of the Scientific Institute of Public Health, Brussels. Written or verbal informed consent was obtained from all subjects. Verbal consent was witnessed and formally recorded.

Dietary intake assessment

Two repeated, non-consecutive 24 h dietary recall interviews were used to collect information on each participant's food consumption. The first 24 h recall was obtained through a computer-assisted personal interview during a home visit by a trained dietitian. The second 24 h recall was performed 2–8 weeks later during a second home visit (median 3 weeks). Interviews were randomly allocated to different days of the week and over a 12-month period in an effort to reduce within-person variation and to avoid seasonality effects. The 24 h recalls collected information on the types and quantities of foods and beverages consumed over the preceding day to the interview.

The dietitians used European Prospective Investigation into Cancer and Nutrition software (EPIC-SOFT; International Agency for Research on Cancer (IARC), Lyon, France) to obtain standardised 24 h recall interviews. EPIC-SOFT was designed to obtain a detailed description and quantification of all foods and beverages consumed in a standardised way[30]. Quantification was facilitated using a picture book with coloured photographs describing foods of different portion sizes[28].

Animal and plant protein contents were estimated using the Belgian food composition table NUBEL[31], the Dutch food composition database NEVO[32] and the USDA food composition guidelines[33]. In the present study, consumption of soya products was analysed separately from the legumes food group because of their potential health effects. The US Food and Drug Administration[34] approved that a daily consumption of soya protein can prevent chronic diseases.

In the present study, four and six main food groups, respectively, contributed most to the animal and plant protein intakes. The four main food groups contributing to the levels of animal protein intake were dairy products, meat and meat products, fish and shellfish, and eggs and egg products. Dairy products included milk, milk beverages (including cream desserts and puddings (milk-based), dairy and non-dairy creams, milk for coffee, and creamers), yogurt, fromage blanc and petits suisses and cheeses (including fresh cheeses). The group of meat and meat products included fresh meat (beef, veal, pork and lamb), poultry and game (chicken, turkey, duck and rabbit), and processed meat, whereas the group of fish and shellfish represented all fish, crustaceans, molluscs, fish products and fish in crumbs. Eggs were the most important item in the egg and egg products group.

Plant proteins were derived mainly from potatoes and other tubers, vegetables, legumes, fruits, nuts and seeds, cereal and cereal products, and soya products. The group of potatoes and other tubers consisted mainly of potatoes. Vegetables included leafy vegetables, fruiting vegetables such as tomato and pumpkin, root vegetables, cabbages, mushrooms, grain and pod vegetables, onions, garlic, stalk vegetables and sprouts, mixed salad and mixed vegetables. Soyabeans and derived products were excluded from the legumes group and were classified as a separate group. Fruits referred to all fruits, including fresh fruits (fruits, mixed fruits and olives) and nuts and seeds. Cereals and cereal products included mainly flour, flakes, starches, semolina, pasta, rice, other grains, breakfast cereals, bread, crisp bread, rusks, salty biscuits, aperitif biscuits and dough and pastry.

Anthropometric measurements

Weight (kg) and height (m) were self-reported. WC was measured by a trained dietitian at home while participants were standing upright (upper clothes were raised to enable measurement of WC on the skin or underwear). Pregnant women reported pre-gestational weights. BMI was calculated as weight (kg)/height (m^2). Adult participants were allocated to four BMI categories according to the cut-off criteria of the WHO[35] for adult BMI: underweight (<18·5 kg/m^2); normal weight (18·5–24·9 kg/m^2); OW (25·0–29·9 kg/m^2); obese (≥30·0 kg/m^2). Adolescent participants were classified into four similar BMI categories based on the Flemish cut-off values[36] for underweight. Cut-off points for normal weight, OW and obese were based on the criteria proposed by Cole *et al.*[37]. For adult WC, sex-specific cut-off criteria were used[38]. For males, <94 cm was defined as normal, 94–102 cm as normal to borderline, ≥102 cm as high risk of OW and obese (referred to as 'too large' in Table 1). For females, <80 cm was defined as normal, 80–88 cm as normal to borderline, ≥88 cm as high risk of OW and obese. The cut-off criteria of adolescent WC were based on Taylor *et al.*[39].

Statistical analyses

The Statistical Package for the Social Sciences for Windows version 15 (SPSS, Inc., Chicago, IL, USA) was used to perform descriptive and statistical analyses. Descriptive statistics are presented in the sex–age-specific groups as means with their standard errors. Total energy, total protein, animal and plant protein intake and percentage of energy intake (Table 2) were normally distributed, whereas animal and plant protein intakes from food groups (Tables 3 and 4, respectively) were skewed. Student's t test, ANOVA with Bonferroni correction and the Mann–Whitney U test were used to examine statistically significant differences, with a two-tailed significance level set at 0·05.

Multiple linear regression analysis (generalised linear model) by the sex–age strata was used to evaluate the association between BMI, WC and animal and plant protein intakes. Each model included BMI and WC as separate dependent variables, animal and plant protein as covariates and age as the factor variable. Interactions were tested, and the significance level was estimated by type 3 Wald χ^2 test.

Results

Individuals who provided two 24 h dietary recall interviews with valid information were included in the analysis (3083 out of a total of 7543). Male (n 1546) participants had a mean of 25 kg/m^2 for BMI and a mean of 88 cm for WC. In total, 34 % of the males were defined as OW, 10·1 % as obese and 29 % had a too large WC. Mean BMI for female (n 1537) participants was 24 kg/m^2, and mean WC was 80 cm. In total, 25 % of the females were defined as OW, 10·5 % as obese and 42 % had a too large WC (Table 1).

Most of the participants in the older categories were categorised as OW or obese (60–75 years: 63 %; ≥75 years: 50 %) and with borderline or too large WC (60–75 years: 80 %; ≥75 years: 81 %).

Total protein, animal protein and plant protein intakes

Total protein intakes (1·2 MJ/d) contributed 15·4 % to the total energy intakes of the population. Animal protein intakes contributed most and delivered a mean energy intake of 0·795 MJ/d. Animal protein intake (47 g/d, range 0·030–222 g/d) was the main contributor (64 %) to the total protein intakes (mean 72 g/d), while plant protein intake accounted for 25 g/d (range 2·4–83 g/d). The total protein intakes of the present study population were in line with the WHO/FAO/United Nations University recommendations (i.e. 10·0–15·0 % of the total energy intake)[40] (data not shown).

Total protein, animal protein and plant protein intakes were significantly higher in males than in females (Table 2). Percentage energy contributions from the total protein and animal protein intakes were significantly lower in male and in female adolescents than in the older age groups. The contribution of plant proteins to

Table 1. BMI and waist circumference (WC) measurements of subjects participating in the Belgian National Food Consumption Survey
(Mean values with their standard errors, n 3083)

		BMI*						WC*				
	n	Mean (kg/m^2)	SEM	Underweight (%)	Normal wt (%)	Overweight (%)	Obese (%)	Mean (cm)	SEM	Normal (%)	Borderline (%)	Too large (%)
Sex												
Males	1546	25	0·1	3·1	52	34	10·1	88	0·7	43	27	29
Females	1537	24	0·1	5·7	58	25	10·5	80	0·7	39	19	42
Age group (years)												
15–18	762	21	0·1	9·7	79	10·2	1·3	76	0·6	72	20	7·6
19–59	828	24	0·2	3·7	60	26	10·1	81	1·0	51	24	25
60–75	789	26	0·2	1·0	36	44	18·6	91	0·9	20	27	53
≥ 75	704	25	0·2	3·2	46	40	10·8	90	1·2	19	22	59

* Weighted mean of BMI and WC.

Table 2. Total energy, total protein, animal and plant protein intake, and percentage of energy intakes of the survey participants
(Mean values with their standard errors, *n* 3083)

	Age group (years)								
	15–18		19–59		60–74		≥75		
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	P†
Total energy intake (MJ/d)**									
Males	10·5[a]	39	10·3[a]	45	9·0[b]	32	8·2[c]	31	<0·001
Females	7·5[a]	27	6·9[b]	26	6·6[b]	25	6·2[c]	23	<0·001
Total protein (g/d)**									
Males	85[a]	1·4	91[b]	1·6	82[a]	1·2	74[c]	1·1	<0·001
Females	61[a]	0·9	64[a]	1·0	62[a]	1·0	59[b]	1·1	0·002
Animal protein (g/d)**									
Males	52[a]	1·2	61[b]	1·4	55[a]	1·0	49[c]	0·9	<0·001
Females	37[a]	0·8	42[b]	0·8	42[b]	0·8	40[a]	0·9	<0·001
Plant protein (g/d)**									
Males	30[a]	0·6	30[a]	0·6	27[b]	0·5	25[c]	0·5	<0·001
Females	24[a]	0·4	22[b]	0·4	21[c]	0·4	18·8[d]	0·4	<0·001
Energy intake (%)									
Total protein									
Males	13·8[a]	0·2	15·2[b]	0·2	15·7[b]	0·2	15·5[b]	0·2	<0·001
Females	14·0[a]	0·2	16·1[b]*	0·2	16·3[b]*	0·2	16·4[b]*	0·3	<0·001
Animal protein									
Males	8·8[a]	0·2	10·2[b]	0·2	10·5[b]	0·2	10·3[b]	0·2	<0·001
Females	8·5[a]	0·2	10·6[b]	0·2	10·9[b]	0·2	11·2[b]**	0·2	<0·001
Plant protein									
Males	4·9[a]	0·1	5·1[a]	0·1	5·2[a]	0·1	5·3[b]	0·1	0·014
Females	5·4[a]	0·1	5·6[a]**	0·1	5·4[a]**	0·1	5·2[b]	0·1	0·004

[a,b,c,d] Mean values within a row with unlike superscript letters were significantly different ($P<0·05$; ANOVA with Bonferroni correction).
Mean values were significantly different between men and women: *$P<0·05$, **$P<0·001$ (Student's *t* test).
† *P* value for mean differences between the sex–age groups (ANOVA).

the total energy intakes was higher in elderly males aged ≥75 years and lowest in females aged ≥75 years.

When examined by sex, total protein intakes were higher among adults (19–59 years) and lower among the elderly population ≥75 years. Adult males (19–59 years) reported significantly higher animal protein intakes, while elderly males (≥75 years) had the lowest. For female participants, on the other hand, animal protein intakes in the age groups of 19–59 years and 60–74 years were significantly higher than those in the other age groups. Plant protein intakes decreased with age in both sex groups, resulting in significant differences between the youngest and the oldest age groups ($P<0·001$ for both).

Main food groups

Tables 3 and 4 show, respectively, the food groups contributing 57 % to the total animal protein intakes (dairy products, meat and meat products, fish and shellfish, and egg and egg products) and 28 % to the total plant protein intakes (potatoes and other tubers, vegetables, legumes (excluding soya products), soya products, fruits, and cereal and cereal products). Meat protein was the main contributor to the total protein intakes (34 %), with a mean intake of 26 g/d, followed by cereal protein (19·3 %), with a mean intake of 13·7 g/d, and dairy protein (15·1 %), with a mean intake of 11·0 g/d (data not shown).

For both sexes, meat and meat products contributed most to the total animal protein intakes (males: 55 %, mean intake of 31 g/d; females: 50 %, mean intake of 21 g/d; $P<0·001$), followed by dairy products (males: 22 %, mean intake of 11·9 g/d; females: 26 %, mean intake of 10·0 g/d; $P<0·001$) (data not shown). Compared with males, females consumed less meat and dairy proteins derived from the above-mentioned food groups in general and their specific subgroups, except for yogurt. In particular, proteins from fresh and processed meat were consumed significantly less by females in all age groups (range of consumption: males and females, respectively: 14·3–18·2 and 10·2–11·6 g/d for fresh meat; 7·3–9·2 and 3·9–5·1 g/d for processed meat; $P<0·001$ for both).

The elderly population (60–74 or ≥75 years) consumed less proteins derived from dairy and meat products compared with the other age groups. Female adolescents had significantly lower meat protein intakes than others (18·9 g/d contributing to 30 % of the total animal protein intake). The elderly population (60–74 years) reported the lowest and the highest fish and shellfish protein intakes (males: 7·9 %, mean intake of 6·4 g/d; females: 6·7 %, mean intake of 4·4 g/d). Protein intakes from eggs and egg products were not significantly different between the sex–age groups, with the exception of elderly females (≥75 years) who had the lowest consumption among the sample.

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Table 3. Mean total animal protein intakes and intakes from main sources stratified by age (years) and sex
(Mean values with their standard errors, *n* 3083)

	Contribution to animal protein intake (%)*				Mean animal protein intake (g/d)*				
	Males		Females		Males		Females		
Animal protein food sources	Mean	SEM†	Mean	SEM†	Mean	SEM†	Mean	SEM†	*P*†
Total animal protein									
15–18	56[a]	0·7	53[a]	0·7	49[a]	1·2	33[a]	0·8	<0·001
19–59	58[a]	0·7	57[b]	0·6	54[b]	1·3	37[b]	0·8	<0·001
60–74	60[b]	0·6	58[b]	0·6	49[a]	1·0	37[b]	0·8	<0·001
≥ 75	58[a]	0·6	58[b]	0·7	43[c]	0·9	35[a]	0·8	<0·001
Dairy products									
15–18	15·4[a]	0·6	16·8[a]	0·6	13·5[a]	0·6	10·4[a]	0·4	<0·001
19–59	14·7[a]	0·6	17·2[a]	0·5	13·4[a]	0·6	11·1[a]	0·4	0·027
60–74	13·0[b]	0·5	14·6[b]	0·5	10·8[b]	0·5	9·3[b]	0·4	0·112
≥ 75	13·3[b]	0·5	15·1[b]	0·6	9·8[b]	0·4	8·9[b]	0·4	0·256
Milk									
15–18	6·2[a]	0·4	6·0[a]	0·4	5·6[a]	0·4	3·7[a]	0·2	<0·001
19–59	3·1[b]	0·2	4·1[b]	0·3	2·8[b]	0·2	2·7[b]	0·2	0·841
60–74	2·6[b]	0·2	2·9[c]	0·2	2·1[b]	0·2	1·8[c]	0·1	0·525
≥ 75	3·3[c]	0·2	3·8[d]	0·3	2·4[b]	0·2	2·2[c]	0·2	0·454
Yogurt									
15–18	1·3[a]	0·2	1·8[a]	0·2	1·1[a]	0·1	1·1[a]	0·1	0·058
19–59	1·9[b]	0·2	3·1[b]	0·2	1·7[b]	0·2	2·1[b]	0·2	0·018
60–74	1·5[b]	0·2	3·2[b]	0·3	1·4[a]	0·2	2·1[b]	0·2	<0·001
≥ 75	1·7[b]	0·2	2·4[a]	0·2	1·3[a]	0·1	1·5[c]	0·2	0·173
Cheeses									
15–18	7·9[a]	0·4	9·1[a]	0·5	6·7[a]	0·4	5·6[a]	0·3	0·160
19–59	9·7[b]	0·5	10·1[b]	0·4	8·9[b]	0·5	6·5[b]	0·3	0·029
60–74	8·9[a]	0·5	8·8[a]	0·4	7·4[a]	0·4	5·5[a]	0·3	0·006
≥ 75	8·3[b]	0·4	8·9[a]	0·5	6·1[a]	0·4	5·2[a]	0·3	0·166
Meat and meat products									
15–18	36[a]	0·9	30[a]	0·9	31[a]	1·1	18·9[a]	0·7	<0·001
19–59	36[a]	0·9	32[a]	0·8	34[a]	1·1	21[b]	0·8	<0·001
60–74	37[a]	0·9	34[b]	0·9	31[a]	0·9	22[b]	0·7	<0·001
≥ 75	36[a]	0·9	36[c]	1·0	27[b]	0·8	22[b]	0·7	<0·001
Fresh meat (beef, veal, pork and lamb)									
15–18	19·2[a]	0·8	15·9[a]	0·9	16·6[a]	0·8	10·2[a]	0·6	<0·001
19–59	19·3[a]	0·8	16·1[a]	0·8	18·2[a]	0·9	10·7[a]	0·6	<0·001
60–74	19·6[a]	0·8	17·9[a]	0·8	16·2[a]	0·7	11·4[a]	0·5	<0·001
≥ 75	19·1[a]	0·8	19·3[b]	0·9	14·3[b]	0·7	11·6[b]	0·6	0·029
Poultry (chicken, duck, rabbit and game)									
15–18	8·1[a]	0·6	7·5[a]	0·6	7·6[a]	0·7	4·8[a]	0·4	0·086
19–59	7·0[a]	0·6	8·1[a]	0·6	6·6[a]	0·6	5·4[a]	0·5	0·549
60–74	8·0[a]	0·6	7·9[a]	0·6	6·8[a]	0·6	5·4[a]	0·5	0·265
≥ 75	7·5[a]	0·7	8·9[a]	0·8	5·6[a]	0·5	5·5[a]	0·5	0·943
Processed meat									
15–18	8·4[a]	0·4	6·3[a]	0·4	7·3[a]	0·4	3·9[a]	0·2	<0·001
19–59	9·9[b]	0·5	7·5[a]	0·4	9·2[b]	0·5	4·8[a]	0·3	<0·001
60–74	9·4[a]	0·5	8·2[b]	0·4	8·1[a]	0·5	5·1[b]	0·3	<0·001
≥ 75	9·7[a]	0·5	7·7[a]	0·5	7·3[a]	0·4	4·5[a]	0·3	<0·001
Fish and shellfish									
15–18	3·6[a]	0·4	4·4[a]	0·4	3·1[a]	0·3	2·8[a]	0·3	0·956
19–59	5·9[a]	0·5	6·2[b]	0·5	5·6[b]	0·5	4·0[b]	0·3	0·209
60–74	7·9[b]	0·6	6·7[b]	0·6	6·4[b]	0·5	4·4[b]	0·4	0·008
≥ 75	6·8[a]	0·6	5·9[a]	0·6	5·1[b]	0·5	3·6[a]	0·4	0·098
Eggs and egg products									
15–18	1·6[a]	0·2	1·9[a]	0·2	1·2[a]	0·1	1·2[a]	0·1	0·778
19–59	1·4[b]	0·2	2·1[a]	0·2	1·2[a]	0·1	1·3[a]	0·1	0·385
60–74	1·7[a]	0·2	2·1[a]	0·2	1·3[a]	0·1	1·2[a]	0·1	0·664
≥ 75	1·9[a]	0·2	1·4[b]	0·2	1·4[a]	0·2	0·750[b]	0·101	0·009

[a,b,c,d] Mean values within a column with unlike superscript letters were significantly different (*t* test, ANOVA with Bonferroni correction and Mann–Whitney *U* test).
* Weighted mean of animal protein intake and its percentage.
† *P* value for mean differences between males and females for animal protein intake (Student's *t* test and Mann–Whitney *U* test).

Cereals and cereal products (males: 55 %, mean intake of 15·9 g/d; females: 52 %, mean intake of 11·4 g/d) contributed most to the total plant protein intakes followed by potatoes and other tubers, vegetables and fruits. The consumption of soya proteins was very low (0·174 g/d). Intakes from potatoes and other tubers, vegetables and fresh fruits were significantly higher in the elderly population (60–74 and ≥75 year groups) than in the

Table 4. Mean total plant protein intakes and intakes from main sources stratified by age (years) and sex

(Mean values with their standard errors, *n* 3083)

	Contribution to plant protein intake (%)*				Mean plant protein intake (g/d)*				
	Males		Females		Males		Females		
Plant protein food sources	Mean	SEM†	Mean	SEM†	Mean	SEM†	Mean	SEM†	*P*†
Total plant protein									
15–18	29[a]	0·7	30[a]	0·5	23[a]	0·5	18[a]	0·4	< 0·001
19–59	28[a]	0·5	28[b]	0·5	25[a]	0·5	18[a]	0·4	< 0·001
60–74	27[a]	0·5	29[b]	0·5	22[b]	0·4	17[b]	0·3	< 0·001
≥ 75	28[a]	0·5	26[c]	0·4	20[c]	0·4	15[c]	0·3	< 0·001
Potatoes and other tubers									
15–18	2·8[a]	0·2	3·1[a]	0·2	2·9[a]	0·1	1·8[a]	0·1	< 0·001
19–59	3·4[b]	0·2	2·8[a]	0·1	2·8[a]	0·1	1·7[a]	0·1	< 0·001
60–74	4·4[c]	0·1	4·1[c]	0·2	3·5[b]	0·1	2·4[b]	0·1	< 0·001
≥ 75	4·8[c]	0·2	4·4[c]	0·2	3·5[b]	0·1	2·5[b]	0·1	< 0·001
Vegetables									
15–18	2·1[a]	0·1	2·5[a]	0·1	1·7[a]	0·1	1·5[a]	0·1	0·153
19–59	2·5[a]	0·1	3·3[b]	0·1	2·1[b]	0·1	2·1[b]	0·1	0·899
60–74	2·9[b]	0·1	3·7[c]	0·2	2·4[c]	0·1	2·3[b]	0·1	0·121
≥ 75	2·9[b]	0·1	3·2[b]	0·1	2·1[c]	0·1	1·9[c]	0·1	0·235
Legumes (excluding soya products)									
15–18	0·116[a]	0·038	0·091[a]	0·030	0·097[a]	0·031	0·060[a]	0·019	0·678
19–59	0·282[a]	0·090	0·253[a]	0·079	0·255[a]	0·073	0·149[a]	0·044	0·325
60–74	0·253[a]	0·064	0·170[a]	0·057	0·212[a]	0·052	0·095[a]	0·032	0·129
≥ 75	0·207[a]	0·061	0·149[a]	0·052	0·144[a]	0·044	0·091[a]	0·033	0·572
Soya products									
15–18	0·125[a]	0·054	0·416[a]	0·149	0·117[a]	0·051	0·265[a]	0·096	0·136
19–59	0·249[a]	0·080	0·387[a]	0·092	0·223[a]	0·069	0·254[a]	0·063	0·098
60–74	0·210[a]	0·065	0·262[a]	0·071	0·167[a]	0·052	0·148[a]	0·042	0·717
≥ 75	0·167[b]	0·067	0·104[b]	0·050	0·111[b]	0·044	0·085[b]	0·047	0·646
Fruits									
15–18	0·828[a]	0·090	2·1[a]	0·2	0·690[a]	0·079	1·2[a]	0·1	< 0·001
19–59	1·4[b]	0·1	1·8[a]	0·1	1·3[b]	0·1	1·2[b]	0·1	0·030
60–74	1·6[c]	0·1	2·2[b]	0·1	1·3[c]	0·1	1·4[c]	0·1	0·005
≥ 75	1·6[c]	0·1	2·0[b]	0·1	1·1[c]	0·1	1·2[c]	0·1	0·027
Fresh fruits									
15–18	0·533[a]	0·054	1·2[a]	0·1	0·421[a]	0·038	0·713[a]	0·046	< 0·001
19–59	0·899[b]	0·070	1·3[a]	0·1	0·753[b]	0·054	0·822[b]	0·041	< 0·001
60–74	1·2[c]	0·1	1·9[b]	0·1	0·927[c]	0·051	1·2[c]	0·1	0·001
≥ 75	1·4[c]	0·1	1·9[b]	0·1	0·993[c]	0·062	1·1[c]	0·1	0·010
Nuts and seeds									
15–18	0·295[a]	0·712	0·879[a]	0·198	0·269[a]	0·067	0·493[a]	0·106	0·241
19–59	0·556[b]	0·108	0·527[a]	0·112	0·522[b]	0·103	0·366[a]	0·086	0·135
60–74	0·453[a]	0·119	0·271[a]	0·062	0·391[a]	0·104	0·190[a]	0·047	> 0·05
≥ 75	0·180[c]	0·072	0·172[b]	0·084	0·149[c]	0·044	0·114[b]	0·058	0·904
Cereals and cereal products									
15–18	22[a]	0·5	22[a]	0·5	18·0[a]	0·5	13·2[a]	0·3	< 0·001
19–59	20[b]	0·5	19·9[b]	0·4	18·0[a]	0·5	12·5[a]	0·3	< 0·001
60–74	18·0[c]	0·4	17·2[c]	0·5	14·4[b]	0·4	10·3[b]	0·3	< 0·001
≥ 75	18·4[c]	0·4	16·1[c]	0·4	13·1[c]	0·3	9·1[c]	0·2	< 0·001

[a,b,c] Mean values within a column with unlike superscript letters were significantly different (*t* test, ANOVA with Bonferroni correction and Mann–Whitney *U* test).

* Weighted mean of plant protein intake and its percentage.

† *P* value for mean differences between males and females for plant protein intake (Student's *t* test and Mann–Whitney *U* test).

adolescent and adult groups. The latter groups consumed, however, significantly more proteins from cereals and cereal products (data not shown).

Associations between BMI and animal and plant protein intakes

The χ^2 test showed significant positive linear relationships between BMI and animal protein intake in the elderly group (60–74 years) for both sexes (Table 5). On the other hand, negative associations were observed between BMI and plant protein intakes in the age group of adolescents (15–18 years) and adults (19–59 years) in males and females. Moreover, animal protein intake was not significantly associated with BMI of females and was not retained in the final model.

Associations between waist circumference and animal and plant protein intakes

Table 6 shows the associations between WC and animal and plant protein intakes, which were in line with the observations for BMI. The intake of plant proteins was inversely associated with WC in all sex–age groups,

Table 5. Generalised linear model for the associations between BMI and animal and plant protein intakes in the sex–age-specific strata

(β Coefficients with their standard errors and 95 % confidence interval, *n* 3054)

	Coefficients		95 % CI			
BMI (kg/m²)	β	SE	Lower bound	Upper bound	Wald χ^2	*P*
Males (*n* 1535)						
Intercept	26	0·323	25	26	6420	<0·001
Animal protein	0·013	0·004	0·005	0·021	11·0	0·001
Plant protein	−0·036	0·009	−0·054	−0·018	15·7	<0·001
Age (years)*						
15–18	−4·3	0·261	−4·8	−3·8	277	<0·001
19–59	−0·448	0·261	−0·960	0·064	2·9	0·087
60–74	1·1	0·255	0·640	1·6	19·9	<0·001
Females (*n* 1519)						
Intercept	26	0·347	25	26	5648	<0·001
Plant protein	−0·046	0·014	−0·073	−0·018	10·6	0·001
Age (years)*						
15–18	−3·9	0·319	−4·6	−3·3	152	<0·001
19–59	−1·5	0·307	−2·1	−0·899	24	<0·001
60–74	1·1	0·310	0·474	1·7	12·1	<0·001

* Age (≥75 years) reference category.

except for males aged 60–74 years. Animal protein intake was positively associated with males' WC but not with females' WC.

Discussion

The present findings suggest that in a representative sample of the Belgian population, the most important contributors to animal protein intakes were fresh meat, cheese and milk products. In addition, cereals and cereal products were the most important contributor to plant protein intakes. Other food groups, including soya, contributed to a very low degree to the total plant protein intakes observed.

Given the lack of information on the total protein intakes from previous Belgian national nutrition surveys, we relate the present study findings to those available in other countries including the USA, Europe, Spain and China(41–44). Differences in study design, food consumption assessment methods and food group classifications used in the various surveys should be taken into consideration when interpreting the relationships. The total energy intakes in Belgian males and females (9·5 and 6·6 MJ/d, respectively) were slightly lower than those in the UK population (males: 9·7 MJ/d; females: 6·9 MJ/d) and were considerably lower than in the Dutch population (Third Dutch National Food Consumption Survey – 1997/98) (males: 10·8–11·0 MJ/d; females: 7·8–8·4 MJ/d)(45,46). In addition, the total protein intakes expressed as percentage of energy intake were slightly lower in the Belgian population (males: 15·0 %; females: 15·7 %) than in the UK population (males: 16·5 %; females: 16·6 %). On the other hand, Belgians had similar intakes to the Dutch population (males: 14·7–15·2 %; females: 15·6–16·6 %), with the exception of the adolescent age group.

Table 6. Generalised linear model for the associations between waist circumference and animal and plant protein intakes in the sex–age-specific strata

(β Coefficients with their standard errors and 95 % confidence intervals, *n* 2874)

	Coefficients		95 % CI			
Waist circumference (cm)	β	SE	Lower bound	Upper bound	Wald χ^2	*P*
Males (*n* 1450)						
Intercept	102	1·0	100	104	9588	<0·001
Animal protein	0·041	0·013	0·015	0·066	9·8	0·002
Plant protein	−0·137	0·030	−0·195	−0·079	21	<0·001
Age (years)*						
15–18	−20	0·839	−22	−18·4	572	<0·001
19–59	−7·9	0·845	−9·6	−6·2	88	<0·001
60–74	0·397	0·826	−1·2	2·0	0·231	0·631
Females (*n* 1424)						
Intercept	96	1·1	94	99	8145	<0·001
Plant protein	−0·096	0·043	−0·180	−0·013	5·1	0·024
Age (years)*						
15–18	−18·6	0·972	−20	−16·7	365	<0·001
19–59	−11·8	0·950	−13·6	−9·9	154	<0·001
60–74	−2·3	0·951	−4·2	−0·478	6·1	0·014

* Age (≥75 years) reference category.

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We have also compared the present findings with the results of the Third US National Health and Nutrition Examination Survey (1988–91)[43] and the Spanish Catalan Nutritional Survey (2002–3)[42], which used the same dietary assessment methods. It was observed that the total energy intakes of the Belgian population were lower than those of the US population (males: 10·8 MJ/d; females: 7·3 MJ/d). Belgian males and elderly females (60–75 years), however, had higher total energy intakes than the Spanish (males: 9·0 MJ/d; females: 5·7 MJ/d).

Total protein, animal protein and plant protein intakes

According to the present study, total protein intakes were lower in the Belgian population, especially in males, when compared with US males and females (97 and 65 g/d, respectively)[43] and with Spanish males and females (97 and 79 g/d, respectively)[42] presumably due to lower intakes of animal protein. Protein intakes expressed as percentage of energy intake among Belgian sex–age-specific groups were rather similar to US adults and the elderly population (males: 15·0–16·0 %; females: 15·0–17·0 %), but lower than those observed in Spanish sex–age groups (males: 18·9 %; females: 19·4 %). The Belgian population, with the exception of participants in the ≥75 years age category, however, had higher total protein, animal protein and plant protein intakes than average intakes of the European Prospective Investigation into Cancer and Nutrition Potsdam Study participants (total protein: 70 g/d; animal protein: 44 g/d; plant protein: 24 g/d)[47].

Compared with the US survey, the Belgian population had lower protein intakes from milk, yogurt, and eggs and egg products than the US population (milk and yogurt: 11·3 % in males and 13·4 % in females; eggs and egg products: 4·1 % in males and 4·3 % in females). The present results showed that fish and shellfish, and cheese contributed more to the total protein intakes in the Belgian population than in the US population. More specifically, participants in the age groups of 60–74 years and ≥75 years consumed approximately twice as much fish-derived proteins than their US counterparts (males: 5·3 %; females: 5·6 %). On the other hand, fish proteins contributed more to total protein intakes in Spain (14·7 %) than in Belgium (males: 3·6–7·9 %; females: 4·4–6·7 %). In contrast, meat and meat products contributed less to animal intakes in the Belgian population (males: 36–37 %; females: 30–36 %) than in the Spanish (39·4 %).

It was also observed that the consumption of meat proteins from subgroups including fresh meat, poultry and processed meat was lower among the Belgian than the Spanish population; females, in particular, had lower intakes of the above-mentioned meat subgroups. For example, protein intakes from poultry were much lower among Belgians (males: 7·0–8·1 %; females: 7·5–8·9 %) than among Spanish (14·0 %). In addition, dairy and egg protein intakes were slightly higher among the Spanish population (12·5 and 3·1 %, respectively).

Fresh fruits contributed less to the total protein intakes in the Belgian population (males: 0·533–1·4 %; females: 1·2–1·9 %) than in the US population (males: 1·4 %; females: 1·8 %) and in the Spanish population (2·0 %). Protein intakes from legumes in the Belgian population were also lower than both the US (males: 2·3 %; females: 2·1 %) and the Spanish population (2·1 %). Plant protein intake from vegetables in the present study population (males: 2·1–2·9 %; females: 2·5–3·7 %) was much lower than in the US population (males: 7·7 %, females: 8·7 %), but higher than in the Spanish population (2·3 %). On the other hand, higher amounts of plant proteins from cereals and cereal products were consumed by the Belgian population in all sex–age-specific groups in comparison with the US (males: 18·0 %; females: 18·1 %) and the Spanish populations (13·0 %).

Soya protein intakes were separately analysed in the present study, as soyabeans are rich sources of protein (35–49 %) and of essential amino acids[48,49]. The analysis suggested that the consumption of the Belgian population was very low and lower than those of the Chinese Guangzhou populations (males: 0·111–0·228 and 3·6 g/d; females: 0·085–0·271 and 4·1 g/d, respectively)[44] and of other East Asian populations (2·0–9·6 g/d, soya protein:total protein ratio: 3·5–15·3 %)[50]. This finding is supported by the European Prospective Investigation into Cancer and Nutrition study, which found that soya product intakes were low across all ten participating European countries[41].

BMI and animal and plant protein intake

The present results showed that animal protein intakes were positively associated with BMI of males, whereas plant protein intakes were inversely associated with the BMI of both sexes. After adjustment for potential confounders, these associations remained statistically significant. Others have reported similar results[7,51]. Hermanussen[51] concluded that the BMI of German male and female adolescents showed significant positive associations with total protein (r 0·143; $P<0·0001$) and animal protein intakes (r 0·151; $P<0·0001$). Plant protein intakes in the study of Mahon *et al.*[7] were inversely associated with the BMI of the US OW post-menopausal women.

Other studies have, however, suggested an inverse relationship between both plant and animal protein intakes and BMI[52,53], which are supported by some separate studies on animal protein intake[51,54,55] and plant protein intake[11,56–59]. In relation to animal protein intake, some studies have reported different results[7,60]. Umesawa *et al.*[60], for instance, found no association between BMI and animal protein intake, while BMI decreased slightly when females increased their animal protein consumption. Two[60,61] similar studies have reported that plant protein-based diets had no significant effect on the BMI of East Asian and Western populations.

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Waist circumference and animal and plant protein intake

The WHO guidelines state that risks for metabolic complications increase in men with a WC ≥102 cm and in women with a WC ≥88 cm[62]. Although the Belgian population had WC values below these cut-offs, the results of the present study indicate that Belgian females and the elderly in particular are at higher risk of being OW and obese.

The present findings also suggest that animal protein intakes might result in an increased WC for males, and plant protein intakes decrease in both males and females. This is in line with the observations that plant-based protein diets, compared with animal-based protein diets, have an inverse impact on WC of obese subjects[11,63]. For example, the results of a randomised controlled clinical trial on OW and obese people suggested that soya protein-based diets resulted in bigger reductions in participants' WC than those not consuming soya protein-based diets[11]. Other studies[27,52,64,65] have, however, reported the opposite. For instance, a randomised trial involving obese adults reported no significant difference between the effect of animal protein and plant protein on WC, with total protein intakes significantly lowering the WC ($P<0{\cdot}05$)[52]. Hence, the results of randomised trials indicate that plant protein-based diets have a more protective effect against OB than animal protein-based diets[52,64,66]. Recent studies have, however, suggested that the negative relationship between animal protein and BMI refers only to OW and obese individuals and does not affect individuals with a normal BMI[26,67,68].

The mechanisms that relate animal and plant protein intakes with BMI and WC are unclear. One proposed mechanism is that animal proteins from beef, pork and poultry provide an important amount of energy and are positively associated with cholesterol and SFA intakes. Therefore, animal protein intake may result in an increase in BMI and the risk of OW and OB. The intake of plant proteins, conversely, is considered an important factor to control body weight and improved body composition and blood lipid profiles because of their associations with lower intakes of energy, total fat, cholesterol and SFA, and higher PUFA:SFA ratios[16,69,70].

Strengths and limitations of the study

This nutrition survey was representative for the Belgian population. One of the limitations of the present study is the use of self-reported body composition variables including weight and height. However, WC was measured by trained dietitians. Furthermore, the present study did not consider physical activity and energy expenditure, factors that could have an effect on the observed associations. Information on food intake was collected via two non-consecutive 24 h recalls, which allows statistical adjustments for within-person variability. Yet, one of the limitations of the 24 h recall method is that it does not allow quantifying proportions of non-consumers for particular food items, *a fortiori* for infrequently consumed foods. Moreover, information on the food consumption relies on individuals' memory and might therefore be biased towards misreporting. Additionally, underestimation or overestimation of portion sizes could result in inaccurate associations between dietary intake and body composition.

Conclusion

The results of the present study suggest that meat protein contributed most to animal protein intakes, and cereals and cereal products contributed to plant protein intakes. Animal and plant protein intakes were significantly different between males and females, and intakes decreased with age in both sexes. It was also observed that the consumption of legume- and soya-derived protein was very low in Belgium. Furthermore, the results indicated that animal protein intake was positively associated with BMI and WC of males, while plant protein intake was found to be negatively associated with BMI and WC of the whole population. The present study findings indicate that the intakes of plant protein could offer a potential protective effect against OW and OB.

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