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Dietary lycopene and cardiovascular health in ethnic Lithuanians

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Background. Lycopene is a potent antioxidant, and it has been suggested that intake of lycopene-rich food results in a decreased risk of cardiovascular diseases. However, no official recommendation of lycopene consumption from natural dietary sources exists, and intake data of the Lithuanian population are limited. The goal of this study was to evaluate the median intake of lycopene in ethnic Lithuanians and to relate lycopene intake with biochemical blood risk factors for CVD in the general population and different ethnolinguistic groups.

Materials and methods. One thousand one hundred forty randomly selected individuals (2–85 years of age) from six Lithuanian ethnolinguistic regions provided 3-day diet records for evaluation of lycopene consumption. Individuals were interviewed using a validated questionnaire consisting of lifestyle and clinical data. Serum concentrations of total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, triglyceride, high-sensitivity C-reactive protein, glucose, apolipoprotein A-I, apolipoprotein B, lipoprotein (a) were measured using standardised procedures. Due to the non-normal distribution of variables, nonparametric tests were applied using the IBM SPSS v20.0 software.

Results. The mean dietary lycopene intake in the study population was 5.05 ± 7.48 or 0.07 ± 0.11 mg/kg body weight per day. Major food sources of lycopene were tomatoes and tomato products (79%). The lycopene intake from natural dietary sources varied significantly between the Lithuanian ethnolinguistic groups (the lowest intake 3.52 ± 5.64 mg/day, the highest intake 6.22 ± 7.66 mg/day, $p = 0.01$) and genders (women 5.26 ± 7.78 mg/day and men 4.8 ± 7.22 mg/day, $p = 0.01$). The mean lycopene intake was significantly ($p < 0.001$) higher in summer than in winter: 6.06 ± 8.30 and 3.75 ± 6.03 mg/day, respectively. The lowest consumption of lycopene was in the group of individuals older than 65 years (2.54 ± 3.25 mg/day). Higher lycopene intake significantly correlated with higher high-density lipoprotein cholesterol concentration ($r = 0.079$; $p < 0.001$).

Conclusions. The mean lycopene intake in the general Lithuanian population and different ethnolinguistic groups was one of the lowest compared to intakes reported in other European countries. In our study, we have not found any significant association between the mean lycopene intake and cardiovascular morbidity; the association of lycopene intake with higher high-density lipoprotein cholesterol concentration indicates the anti-atherogenic effect of dietary lycopene.

Key words: lycopene, lycopene intake, antioxidants, cardiovascular diseases

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INTRODUCTION

Cardiovascular diseases (CVD) are the most common chronic diseases in the Lithuanian population. Prevalence of the circulatory system diseases in Lithuania in 2013 was 3.1% among children (0–17 years) and 28.6% among adults (>18 years). Furthermore, in 2013 more than half (56.6%) of all deaths in Lithuania were caused by diseases of the circulatory system. The largest part of deaths due to circulatory system diseases was caused by ischaemic heart disease (64.7%) (1). Oxidative stress plays an important role in the pathogenesis of CVD (2). Lycopene is a carotenoid pigment and one of the strongest natural antioxidants. Experimental and epidemiological studies have shown that a lycopene-rich diet reduces the risk of chronic non-infectious diseases (3–5), particularly the risk of CVD (6). Data on the lycopene intake in the Lithuanian population are scarce. Only one small epidemiological study with 48 male patients (aged 61–62) with atherosclerosis was performed, and the main dietary lycopene sources and the mean intake were estimated (7).

The main objectives of the study are to estimate the mean lycopene intake and the main dietary sources in the ethnic Lithuanian population; to analyse main differences in the lycopene intake depending on age, gender and an ethnolinguistic group; to evaluate the relationship between the lycopene intake and biochemical atherosclerosis risk factors: total cholesterol (total-C), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triacylglycerols (TAG), high-sensitivity C-reactive protein (hsCRP), glucose, apolipoprotein A-I (Apo A-I), apolipoprotein B (Apo B) and lipoprotein (a) Lp(a); also to evaluate the relationship between the lycopene intake and cardiovascular diseases like myocardial infarction, stroke, and hypertension.

MATERIALS AND METHODS

The study population comprised 1,140 individuals (54.8% female and 45.2% male), aged 2–85, randomly selected from six Lithuanian ethnolinguistic regions: 265 individuals (23%) were Eastern Highlanders (EH), 159(14%) Southern Highlanders (SH), 175(15.5%) Western Highlanders (WH), 198(17.5%) Northern Samogitians (NS), 216 (19%) Southern Samogitians (SS), and 127 (11%) Western Samogitians (WS). About two-thirds (66.5%) of the individuals were from urban areas, and the rest (33.5%) were from rural areas. The Lithuanian descent was confirmed in three generations, e. g. the parents and grandparents of the investigated individuals were Lithuanians.

The data on the lycopene intake and dietary sources were collected using 3-day diet records. The records concentrated on the intake of lycopene-rich products: tomatoes and tomato products (fresh, cooked, and canned tomatoes; tomato sauce soup and juice; and ketchup), apricots (dried), pink grapefruit (fresh), watermelon (fresh), papaya, and guava. The respondents were asked to indicate the exact amount they consumed of the aforementioned products. The calculation of lycopene intake from the consumption of these products was based on the amount of lycopene in various food products as indicated in the European carotenoid database (8). The calculation of the lycopene amount in dietary products was performed using the Nutrisurvey software.

The lifestyle, family history, dietary habits and health condition were surveyed using a specially created validated questionnaire (7). Among other questions, the respondents were asked about their history of cardiovascular diseases (myocardial infarction, stroke, and hypertension). The answers of randomly selected 8% of respondents were verified according to the medical documents at local primary healthcare centers. All the cardiovascular diagnoses indicated by the patients were confirmed by the medical documents.

Venous blood samples for biochemical testing were drawn after an overnight fast at 7.30–11.00 a. m. at local primary healthcare centers and immediately transported to the Center of Laboratory Medicine, Vilnius University Hospital Santariškių Clinics. Biochemical blood parameters were tested using standardised procedures: the methods and analysers used are summarised in Table 1.

Total cholesterol (total-C), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triacylglycerols (TAG), high-sensitivity C-reactive protein (hsCRP), apolipoprotein A-I (Apo A-I), apolipoprotein B (Apo B), lipoprotein (a) Lp (a).

Table 1. Methods and analysers used in biochemical testing

Test	Method	Analyser
Total-C	Enzymatic colorimetric assay	Architect ci8200 (Abbott, USA)
HDL-C	Enzymatic colorimetric assay	Architect ci8200 (Abbott, USA)
LDL-C	Estimated using Friedewald equation * in case of triglyceride concentration >4.5 mmol/l direct enzymatic clearance assay was used	– * Architect ci8200 (Abbott, USA)
TAG	Enzymatic colorimetric assay	Architect ci8200 (Abbott, USA)
hsCRP	Immunoturbidimetric assay	Architect ci8200 (Abbott, USA)
Glucose	Immunoturbidimetric assay	Architect ci8200 (Abbott, USA)
Apo A-I	Immunonephelometric assay	BN II (Siemens, Germany)
Apo B	Immunonephelometric assay	BN II (Siemens, Germany)
Lp (a)	Immunonephelometric assay	BN II (Siemens, Germany)

Statistical analysis. Descriptive data were presented as medians, means, and standard deviations (SD). The comparison of variables was performed using nonparametric tests (Mann–Whitney U test and Kruskal–Wallis test) due to the non-normal distribution of variables. The relation between the variables was assessed by using the Spearman's correlation coefficient. For the prognosis of cardiovascular morbidity logistic regression models were constructed. The results were considered statistically significant when $p < 0.05$. A statistical data analysis was performed using the Microsoft Excel and IBM SPSS v20.0 software.

RESULTS

The summarised characteristics of the studied population are given in Table 2, and the age distribution is shown in Fig. 1.

Total cholesterol (total-C), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triacylglycerols (TAG),

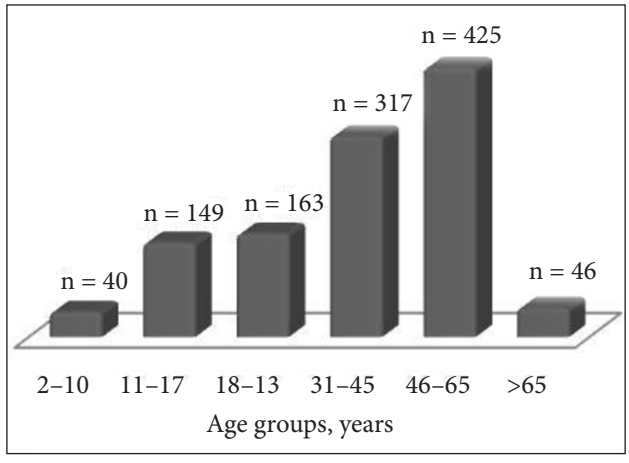

Fig. 1. Age distribution of the study population

Table 2. Characteristics of the study population

Characteristic	Children (2–17 years)			Adults (18–85 years)		
	Median	Mean	SD	Median	Mean	SD
Body mass index (BMI), kg/m^2	19.3	19.8	3.9	26.4	27.4	10.1
Total-C, mmol/l	4.38	4.5	0.96	5.88	5.91	1.19
HDL-C, mmol/l	1.48	1.48	0.29	1.45	1.48	0.37
LDL-C, mmol/l	2.6	2.66	0.84	3.76	3.79	1.05
TAG, mmol/l	0.7	0.77	0.36	1.13	1.41	1.07
hsCRP, mg/l	0.3	0.99	2.51	1.1	2.6	5.43
Glucose, mmol/l	4.94	4.98	0.51	5.22	5.4	1.24
Apo A-I, g/l	1.48	1.5	0.24	1.6	1.62	0.28
Apo B, g/l	0.66	0.7	0.2	1	1.01	0.29
Lp(a), g/l	0.07	0.15	0.25	0.08	0.18	0.23

high-sensitivity C-reactive protein (hsCRP), apolipoprotein A-I (Apo A-I), apolipoprotein B (Apo B), lipoprotein (a) Lp (a).

The analysis of dietary intake revealed that the main sources of lycopene in the Lithuanian population were tomatoes and tomato products (78.8%), watermelons (11.9%), and pink grapefruits (9.3%) (Table 3). The highest amount of lycopene, 1.74 ± 2.7 mg/d (35%), is received with fresh tomatoes (mean daily intake 58.03 ± 89.25 g). Another significant source of this antioxidant is tomato juice (1.02 ± 3.96 mg/d (20%)).

The calculated mean personal daily lycopene intake was 5.05 ± 7.48 mg, and the median was 2.2 mg or 0.07 mg/kg of body weight.

The season had a significant impact on the lycopene intake: during the cold season (October–March), the lycopene intake was almost two times lower than it was during the warm season (April–September) (Table 4). There was no statistically significant difference in the lycopene intake between the individuals living in urban and rural areas (4.97 ± 7.58 vs 5.1 ± 7.44 mg/d, respectively). The dietary lycopene intake was significantly higher in women than in men (5.26 ± 7.22 vs 4.48 ± 7.78 mg/d, respectively; $p = 0.01$). The lycopene intake depending on the season, gender and living area is summarised in Table 4.

The lycopene intake was significantly different in various age groups, with individuals older than 65 years of age consuming the least (2.54 ± 1.72 mg/d) (Fig. 2).

The consumption of lycopene-rich food was significantly different in various ethnolinguistic regions (Kruskal–Wallis test $p = 0.001$). The mean lycopene intake according to the ethnolinguistic region is summarised in Table 5. The largest difference in the lycopene intake was between Southern Samogitians and Western Samogitians (Fig. 3). Statistically significant differences were found in the comparison of Eastern Highlanders and Southern Highlanders ($p = 0.024$), Northern

Table 3. The mean intake of lycopene-rich food products (g/d) and the mean amount of lycopene consumed with food daily (mg/d)

Food product	Overall intake, g/d		Lycopene intake, mg/d	
	Mean	Mean CI	Mean	Mean CI
Tomatoes and tomato products	88.71	81.79–95.63	3.98	3.63–4.33
Fresh tomatoes	58.03	52.85–63.21	1.74	1.58–1.90
Cooked tomatoes	1.08	0.45–1.71	0.04	0.02–0.06
Canned tomatoes	7.08	5.12–9.04	0.36	0.26–0.46
Tomato sauce	4.50	3.97–5.03	0.28	0.25–0.31
Tomato soup	2.50	1.40–3.60	0.20	0.11–0.29
Tomato juice	12.74	9.87–15.61	1.02	0.79–1.25
Ketchup	2.78	2.34–3.22	0.34	0.28–0.40
Apricot (dried)	6.81	2.29–11.33	0.01	0.01–0.01
Pink grapefruit (fresh)	13.91	10.77–17.05	0.47	0.36–0.58
Watermelon (fresh)	14.97	10.19–19.75	0.60	0.41–0.79

Table 4. Lycopene intake depending on season, gender and living area

		n	Lycopene intake, mg/d			Mann–Whitney U test (p value)
			Median	Mean	SD	
Season	October–March	497	1.37	3.75	6.03	0.001*
	April–September	643	3.01	6.06	8.30	
Living area	Urban	758	2.5	5.1	7.44	0.12
	Rural	382	2.0	4.9	7.58	
Gender	Female	625	2.8	5.26	7.22	0.01*
	Male	515	1.83	4.8	7.78	

* Statistically significant difference ($p < 0.05$).

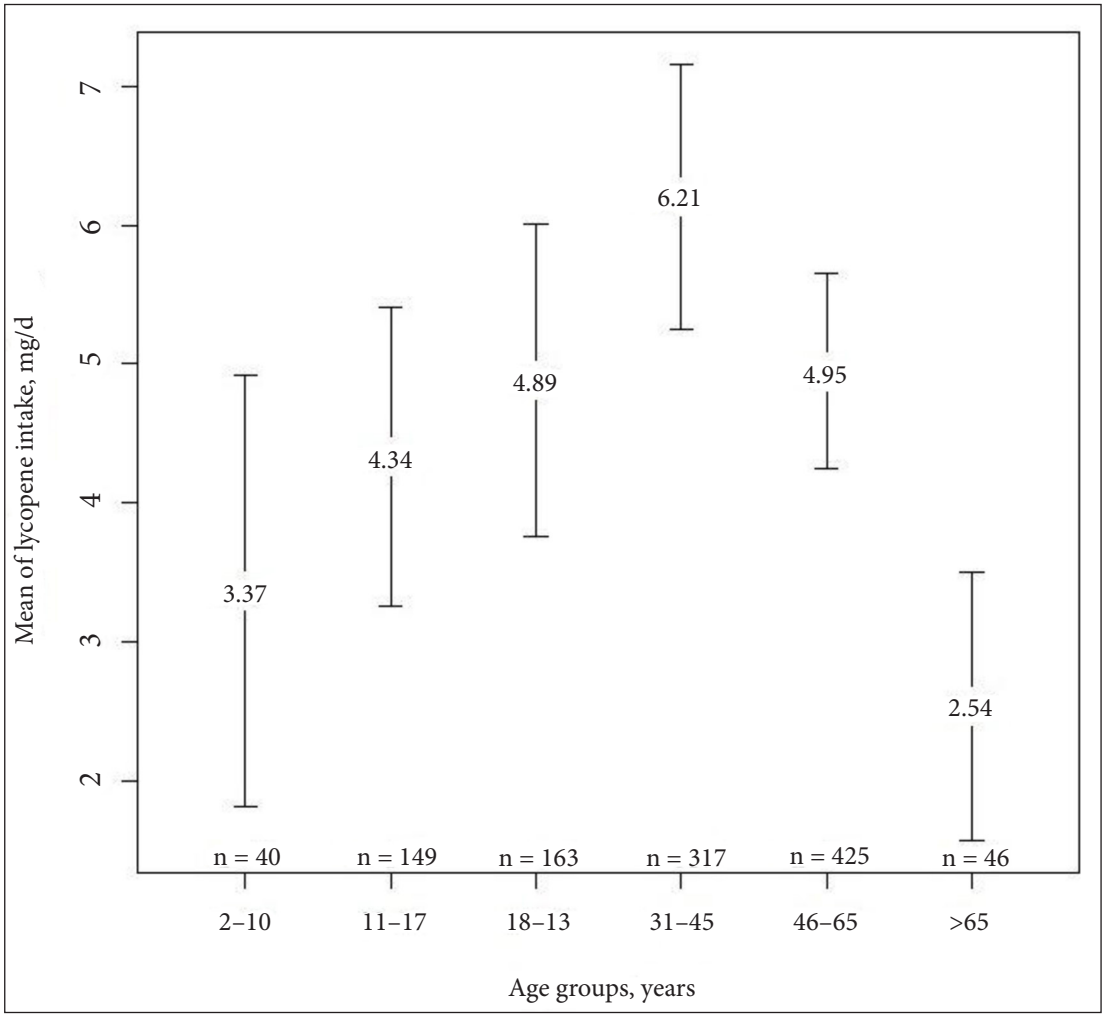

Fig. 2. Lycopene intake in various age groups. Numbers indicate means of lycopene intake (mg/d) and interval bars correspond to 95% confidence interval

Table 5. Lycopene intake in different Lithuanian regions

Ethnolinguistic regions	Lycopene intake, mg/day		
	Median	Mean	SD
Southern Highlanders	1.54	3.88	5.64
Eastern Highlanders	2.80	5.22	7.70
Western Highlanders	3.00	5.97	8.44
Northern Samogitians	3.07	6.22	7.66
Western Samogitians	2.00	3.52	5.61
Southern Samogitians	1.55	4.76	8.05

Samogitians and Southern Highlanders ($p = 0.000$), Eastern Highlanders and Western Samogitians ($p = 0.026$), Eastern Highlanders and Western Samogitians ($p = 0.026$), and Eastern Highlanders and Southern Samogitians ($p = 0.028$).

The relationship between the lycopene intake and biochemical blood parameters is summarised in Table 6. A statistically significant correlation was found between the lycopene intake and the HDL-C level ($r = 0.079$; $p < 0.011$).

Table 6. Relationship between lycopene intake and biochemical blood parameters

Biochemical parameter	Spearman's correlation coefficient	*p* value
	N = 1 140	
Glucose, mmol/l	0.015	0.639
Total-C, mmol/l	–0.001	0.963
LDL-C, mmol/l	0.020	0.519
HDL-C, mmol/l	0.079*	0.011
TAG, mmol/l	–0.027	0.384
hsCRP, mg/l	0.011	0.720
Apo A-I, g/l	0.130	0.081
Apo B, g/l	–0.018	0.781

* Statistically significant correlation ($p < 0.05$).

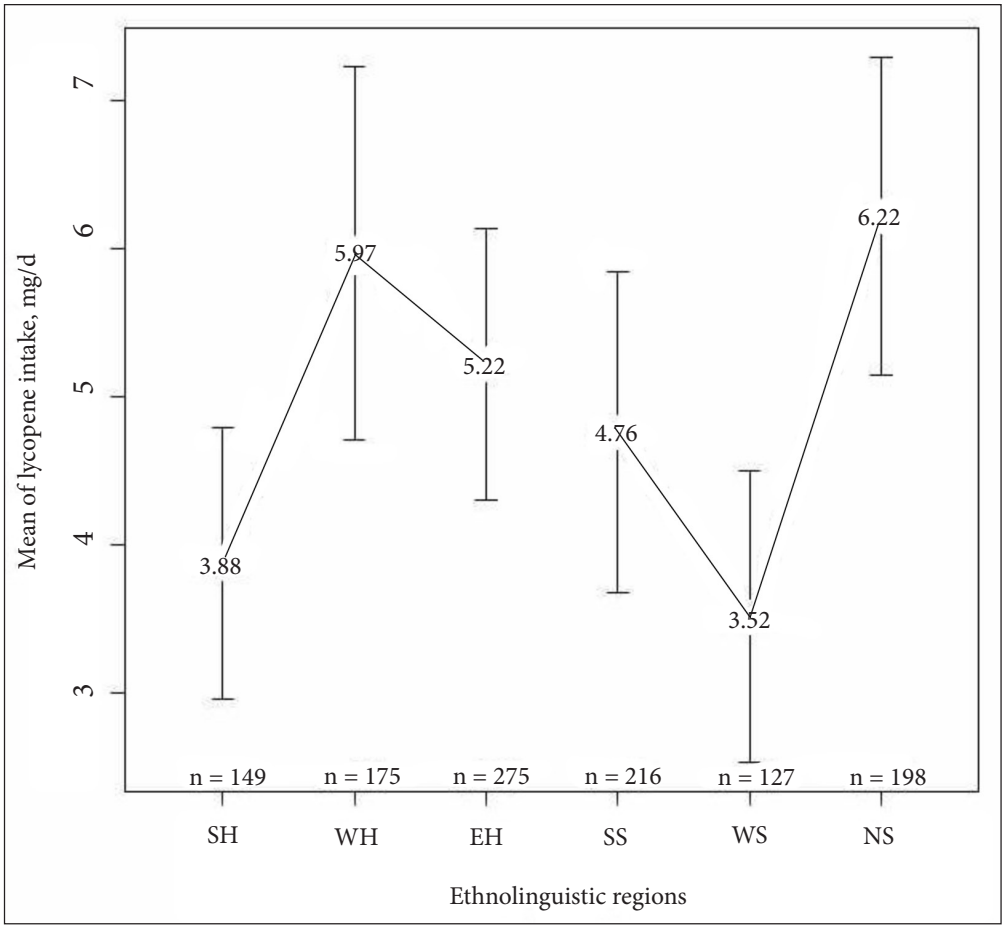

Fig. 3. Mean lycopene intake in different Lithuanian regions. SH – Southern Highlanders, WH – Western Highlanders, EH – Eastern Highlanders, SS – Southern Samogitians, WS – Western Samogitians, NS – Northern Samogitians

Total cholesterol (total-C), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triacylglycerols (TAG), high-sensitivity C-reactive protein (hsCRP), apolipoprotein A-I (Apo A-I), apolipoprotein B (Apo B), lipoprotein (a) Lp (a).

Cardiovascular morbidity in the study population was as follows: 50 individuals (2.4%) had a history of myocardial infarction, 27 patients (1.3%) had a history of stroke, and 251 patients (12.2%) had a history of hypertension. Cardiovascular morbidity was the highest among the Southern Highlanders (Table 7).

The mean lycopene intake in individuals with cardiovascular diseases was slightly lower (4.93 ± 7.1 mg/d) than in those without cardiovascular diseases (5.09 ± 7.6 mg/d), but the difference was not statistically significant ($p = 0.945$).

A logistic regression analysis was used for the prognosis of cardiovascular morbidity. The dependent variable was cardiovascular morbidity (myocardial infarction, stroke, and hypertension), and the independent variables were the mean lycopene intake, age, gender, and an ethnolinguistic group. The results showed that only age but not lycopene intake had a significant impact on cardiovascular morbidity.

Table 7. Cardiovascular morbidity in ethnolinguistic regions of Lithuania

Ethnolinguistic region		n	Cardiovascular morbidity, %
Highlanders:	Southern	149	46(31)
	Western	175	37(21)
	Eastern	275	74(27)
Samogitians:	Northern	198	44(22)
	Western	127	27(21)
	Southern	216	48(22)

DISCUSSION

Lycopene is found in few dietary products and its main dietary sources in the Lithuanian population are not different from other countries (9): the largest amount of lycopene is received by consuming tomatoes and their products. Seasonal differences in the lycopene intake were not found in studies performed in England, Ireland and Finland, but the seasonal difference was significant in Spain, with the highest lycopene intake during summer (10). Our results show that in the Lithuanian population important sources of lycopene (making up to 20% of daily lycopene intake) are pink grapefruits (more are consumed during winter) and watermelons (more are consumed during summer).

The comparison of the dietary lycopene intake between genders showed that women consume approximately 10% more lycopene than men, but intake distributions were wide in both groups, women and men.

The average lycopene intake in the Lithuanian population is one of the lowest compared with intakes reported in similar studies performed in other European countries (Table 8).

Despite obvious positive health effects, lycopene is not listed among the essential nutrients, and there are no recommended daily allowances approved for this antioxidant. The Acceptable Daily Intake (ADI) level for lycopene approved by the European Food Safety Authority is 0.5 g/kg of body weight per day. Our results showed that the mean lycopene intake was 0.07 mg/kg of body weight, which is more than seven times lower than ADI.

Table 8. Average lycopene intake in six European countries in winter ([1] O'Neill et al. (6); [2] Mažeikienė et al. (5))

Country	n	Lycopene intake	
		Median	Interquartile range (Q1–Q3)
France[1]	76	4.75	(2.14–8.31)
Spain[1]	70	1.64	(0.50–2.64)
United Kingdom	71	5.01	(3.2–7.28)
Ireland[1]	76	4.43	(2.73–7.13)
Holland[1]	75	4.86	(2.79–7.53)
Lithuania (2008)[2]	48	1.98	(1.16–4.06)
Lithuania	497	1.37	(0.00–4.62)

The results of our study showed that the lycopene intake can differ significantly not only between countries but also between different regions within the same country. It is worth mentioning that in the Southern Highland region, where the lycopene intake is one of the lowest, cardiovascular morbidity is one of the highest. On the other hand, in the region with the lowest lycopene intake, Western Samogitia, increased cardiovascular morbidity was not found.

Meta-analysis of many case studies (11–14) has demonstrated that individuals consuming more fruits and vegetables have a lower cardiovascular risk. Multiple clinical studies have confirmed an inverse correlation between the lycopene level in blood and cardiovascular risk (15–18). However, most studies (19–23) about dietary intake of lycopene, including ours, did not find a significant relationship between the lycopene intake and cardiovascular morbidity. Controversy concerning the results can partly be explained by differences in lycopene resorption influenced by genetic variation (24). Further investigation of lycopene intake, its blood level, and genetic factors is needed.

CONCLUSIONS

1. In Lithuania the daily average consumption of lycopene is 5.05 ± 7.48 mg or 0.07 mg/kg of body weight. The main source of lycopene is tomatoes and tomato products (78.8%), watermelons (11.9%), and pink grapefruits (9.3%).

2. The gender, season, age, and ethnolinguistic region have a statistically significant impact on the lycopene intake in the Lithuanian population.

3. The daily lycopene intake directly correlates with the high density lipoprotein cholesterol level ($r = 0.079$; $p < 0.001$).

4. The lycopene intake in individuals with cardiovascular diseases was not significantly different compared to individuals without cardiovascular diseases (4.93 ± 7.1 vs 5.09 ± 7.6 mg/d, $p = 0.945$).

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LIKOPENO SUVARTOJIMO YPATUMAI IR POVEIKIS SERGAMUMUI ŠIRDIES IR KRAUJAGYSLIŲ LIGOMIS ETNINIŲ LIETUVIŲ GRUPĖJE

Santrauka

Darbo tikslas. Apskaičiuoti vidutinį likopeno suvartojimą, nustatyti pagrindinius maistinius jo šaltinius ir sąsajas su sergamumu širdies ir kraujagyslių ligomis bei kraujo biocheminiais šių ligų rizikos veiksniais etninių lietuvių grupėje.

Tyrimo medžiaga ir metodai. Tyrime dalyvavo atsitiktinės atrankos būdu atrinkta 1 140 lietuvių kilmės 2–85 metų asmenų iš šešių etnolingvistinių Lietuvos regionų: Rytų Aukštaitijos (24,1 %), Pietų Aukštaitijos (Dzūkijos) (13,1 %), Vakarų Aukštaitijos (Sūduvos) (15,4 %), Šiaurės Žemaitijos (17,4 %), Pietų Žemaitijos (18,9 %) ir Vakarų Žemaitijos (11,1 %).

Mitybos įpročiai, šeimos anamnezės duomenys ir gyvensenos veiksniai tirti naudojant validizuotą klausimyną. Maistiniai likopeno šaltiniai ir jų suvartojimas tirtas taikant 24 valandų 3 dienų iš eilės apklausos metodą, atkreipiant ypatingą dėmesį į daug likopeno turinčių produktų vartojimą.

Bendrojo cholesterolio, didelio tankio lipoproteinų cholesterolio (DTL-Ch), mažo tankio lipoproteinų cholesterolio (MTL-Ch), triacilglicerolių (TAG), apoproteino A-I (Apo A-I), apoproteino B (Apo B), lipoproteino a (Lp(a)), didelio jautrumo C reaktyviojo baltymo (hsCRB) ir gliukozės koncentracija buvo matuojama standartizuotais biocheminiais tyrimo metodais.

Tyrimo rezultatai. Lietuvoje vienas asmuo suvartoja vidutiniškai 5,05 (± 7,48) mg (t. y. 0,07 miligramo kilogramui kūno masės) likopeno per parą. Pagrindiniai likopeno šaltiniai yra pomidorai ir jų produktai (78,8 %), arbūzai (11,9 %), raudonieji greipfrutai (9,3 %).

Daugiausia likopeno – 1,74 (± 2,7) mg/p, t. y. 35 %, gaunama vartojant šviežius pomidorus ir geriant pomidorų sultis (1,02 (± 3,96) mg/p, t. y. 20 %).

Likopeno suvartojimui įtakos turi sezoniškumas – šaltuoju metų laiku (spalio–kovo mėnesiais) su maistu jo gaunama beveik du kartus mažiau nei šiltuoju (atitinkamai 3,75 (± 6,03) ir 6,06 (± 8,30) mg/p); $p = 0{,}000$).

Moterys šio antioksidanto su maistu gauna daugiau nei vyrai (atitinkamai 5,26 (± 7,22) ir 4,8 (± 7,78 mg/p); $p = 0{,}01$). Mažiausiai likopeno su maistu suvartoja vyresni nei 65 metų asmenys (2,54 (± 1,72) mg/p).

Lietuvos etnolingvistinių regionų likopeno suvartojimo rodiklių skirstiniai statistiškai reikšmingai skiriasi ($p = 0{,}001$). Mažiausiai likopeno suvartojama Vakarų Žemaitijos regione (3,88 (± 5,64) mg/p), daugiausiai – Šiaurės Žemaitijoje (6,22 (± 7,66) mg/p).

Širdies ir kraujagyslių ligomis sergančių asmenų grupėje vidutinis likopeno suvartojimas yra truputį mažesnis (4,93 (± 7,1) mg/p) nei KŠL nesergančiųjų (5,09 (± 7,6) mg/p), tačiau statistiškai reikšmingo skirtumo nerasta ($p = 0{,}945$).

Vertinant ryšį tarp su maistu gaunamo likopeno kiekio ir įvairių biocheminių kraujo rodiklių, nustatyta, jog didesnis vidutinis likopeno kiekis koreliuoja su didesne DTL-Ch koncentracija kraujyje ($r = 0{,}079$; $p < 0{,}001$).

Išvados. Lietuvoje likopeno suvartojimo rodikliai vieni žemiausių Europoje. Lytis, sezoniškumas, amžius ir gyvenamasis etnolingvistinis regionas turi statistiškai reikšmingą poveikį likopeno suvartojimo skirtumams etninių lietuvių populiacijoje. Mūsų tyrimo duomenimis, neradome statistiškai reikšmingo ryšio tarp vidutinio likopeno suvartojimo ir sergamumo širdies ir kraujagyslių ligomis, tačiau likopeno suvartojimo koreliacija su didesne DTL-Ch koncentracija rodo maisto, kuriame gausu likopeno, antiaterogeninį poveikį.

Raktažodžiai: likopenas, likopeno suvartojimas, antioksidantai, širdies ir kraujagyslių ligų rizikos veiksniai