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# Trends in blood lipids and fat soluble vitamins in Catalonia, Spain (1992–2003)

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## Abstract

*Objective:* The purpose of this study was to assess the 10-year trend in lipid and antioxidant vitamin levels in the Catalan population from 1992 to 2003.

*Design:* Two cross-sectional surveys were carried out in Catalonia, Spain, during 1992–93 and 2002–03. A subsample of the individuals participating in the surveys agreed to undergo a biochemical evaluation.

*Subjects:* Eight hundred and eighty individuals (393 males and 487 females) in the 1992–93 nutritional survey and 429 individuals (205 males and 224 females) in the 2002–03 nutritional and health survey. The subjects' ages ranged from 18 to 74 years.

*Results:* Mean total cholesterol decreased from 5.3 to 5.1 mmol $l^{-1}$ ($P < 0.005$), and the prevalence of hypercholesterolaemia decreased, especially in males (from 23% to 10% in males from 50 to 64 years old, $P < 0.05$). Mean cholesterol high-density lipoprotein (HDL) values decreased in the entire sample (from 1.4 to 1.3 mmol $l^{-1}$, $P < 0.001$) and there was an increase in the percentage of population with low values of HDL (from 10% to 19%, $P < 0.001$). An increase in the percentage of the population with values of α-tocopherol at marginal risk levels (from 6% to 9%) and with low values of β-carotene (from 59% to 66%) was observed. The mean values for retinol increased in both males (from 1.99 to 2.44 μmol $l^{-1}$, $P < 0.001$) and females (from 1.69 to 2.29, $P < 0.001$).

*Conclusion:* Although there was a decrease in the percentage of population with hypercholesterolaemia, the decrease in HDL cholesterol worsened the lipid profile of the Catalan population. The increase in the values of some antioxidant vitamins did not affect the entire population since an increase in the number of individuals with marginal values was observed.

**Keywords**
Lipoproteins
Cholesterol
Retinol
α-Tocopherol
β-Carotene
Trends
Prevalence
Nutritional status
Catalonia
Spain

Biochemical markers are useful for the evaluation of nutritional status within a population, to estimate their dietary intake and to determine the prevalence of risk factors for the leading causes of morbidity and mortality.

Plasma lipid levels are one of the main risk factors for the prevention of cardiovascular diseases, which are the principal cause of mortality in developed countries. Although mortality related to cardiovascular diseases have stabilised in Spain in the last decades[1], trends of hospital morbidity rates related to such diseases have shown an increase[2]. Even though ischaemic heart disease is still the leading cause of mortality among Spanish males and the third cause of mortality among Spanish females, Spain exhibits a lower rate of mortality related to cardiovascular diseases compared to countries in central and northern Europe[3,4]. On the other hand, the prevalence of hypercholesterolaemia in Spain increased from 6% in 1987 to 15% in 1999 and decreased to 11% in 2001[5].

Plasma levels of antioxidants have shown a relationship with all-cause mortality[6,7], cardiovascular disease[8,9], certain cancers[10,11], insulin resistance[12] and degenerative diseases[13]. Subclinical deficiencies of such vitamins are related to some of these diseases, especially in those subjects having greater oxidative stress[14].

In 1992–93, the Catalan government developed an Evaluation of Nutritional Status of the Catalan population, which included a biochemical assessment[15–17]. Blood lipid analysis included total cholesterol (TC), low-density lipoprotein cholesterol (LDL), high-density lipoprotein

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cholesterol (HDL) and serum triglycerides (TG). β-Carotene, retinol and α-tocopherol were also determined.

Following WHO (World Health Organisation) recommendations[18], the 1991 Health Plan for Catalonia[19] established as part of its objectives that by the year 2000 less than 20% of the population would have hypercholesterolaemia. To evaluate the compliance with such recommendations, it was stated to develop population nutritional surveys periodically. In 2002–03, a new Nutrition and Health Examination Survey of the Catalan population included an evaluation of the biochemical status of the population[20,21].

The purpose of this study was to evaluate the distribution of serum lipid levels (TC, HDL, LDL and TG) and fat-soluble vitamins in the adult population of Catalonia in 2002–03 and to analyse their trends since 1992–93, the latter being the date from which nutrition policies promoting healthy eating and lifestyle among the population had been implemented.

## Material and Methods

### *Sample*

The sample of the Evaluation of Nutritional Status of the Catalan population for the 1992–93 included 2346 persons aged 18 to 74 years[15]. Thirty-eight per cent of the interviewees ($n = 893$) agreed to participate in the biochemical analysis of nutritional status. Of these persons, blood samples from a subsample of 378 individuals were randomly selected for determining levels of β-carotene, retinol and α-tocopherol[15–17].

The biochemical analysis for 2002–03 was conducted in a subsample ($n = 429$) aged 18 to 74 years of those subjects participating in the Catalan Nutrition and Health Survey 2002–03 ($n = 1396$), which was in and of itself a subsample of the Catalan Health Survey 2000 (ESCA) ($n = 8400$) carried out by the Department of Health and Social Security of the Generalitat de Catalunya[21].

### *Analytical determinants*

*ENCAT 1992–93 survey*

In 1992–93, samples were obtained and processed by a mobile team at health centres that had been selected among those available in municipalities that were included in the sample. Blood samples were collected between 8 and 10 a.m. in 12-hour fasting conditions[15–17].

Samples were processed immediately after being collected. Blood was centrifuged at 3000 r.p.m. for 15 min at 8°C, after having undergone a period of pre-centrifugation for 30 min. Serum was fractioned into aliquot portions via disposable pipettes. Samples for lipid analysis were immediately placed in portable coolers, maintained at 4°C and sent to the Biochemistry Service at the Vall d'Hebrón Hospital in Barcelona for analysis within 24 hours post-extraction. Samples for analysing vitamins were frozen at −80°C and transported in portable freezers to the Biochemistry Service at the Germans Trias i Pujol Hospital in Badalona.

Serum TC, high-density cholesterol (HDL), low-density cholesterol (LDL) and triglycerides (TG) were analysed. TC and TG were determined by enzymatic methods CHOD-PAP and GPO-PAP, respectively, using the autoanalyser Hitachi 747 and reagents from Boehringer-Mannheim.

HDL was determined by the Assmann *et al.*[22] method, after precipitation of LDL, very low-density lipoproteins and chylomicrons with phosphotungstanic acid and magnesium chloride. LDL was calculated with the Friedewald formula (LDL = TC−(TG/5 + HDL)) only for those samples having triglyceride concentrations lower than 300 mg $dl^{-1}$ [16,23].

Serum concentrations of β-carotene, retinol and α-tocopherol were obtained by high-resolution liquid chromatography with ultraviolet detection[24–26]. Given that commercial quality control teams did not exist at the time samples were collected, blood bank donor samples were used as control and it was determined as a coefficient of variation. The coefficients of variation (CV) intra and inter-assay ranged from 6% to 9.9% for β-carotene, from 4.5% to 7.3% for retinol and from 3.5% to 8.4% for α-tocopherol[17].

*Nutrition and Health 2002–03 survey*

In the 2002–03 biochemical evaluation, blood samples were obtained between 9 and 11 a.m. in fasting conditions. Samples were labelled and processed in the laboratory of the health region that corresponded to the centre where extractions were realised. Upon reaching the laboratory they were centrifuged and separated into aliquots, labelled and frozen at −20°C and then transferred to the biochemical laboratory at the Germans Trías i Pujol Hospital in Badalona.

The methodology to analyse serum lipids and vitamins was the same as the one utilised in the ENCAT (Evaluation of Nutritional Status in Catalonia) 1992–93 study.

The cut-off points utilised to assess lipid concentrations were as follows[27]: TC: <5.18, 5.18–6.21 and ≥6.22 mmol $l^{-1}$; LDL: <2.59, 2.59–3.36, 3.37–4.13 and ≥4.14 mmol $l^{-1}$; HDL: <1.04, 1.04–1.55 and ≥1.56 mmol $^{-1}$; TG: <1.67, 1.67–2.25 and ≥2.26 mmol $l^{-1}$.

Values for the concentration of vitamins were standardised for serum lipid concentrations. Cut-off values applied to vitamin concentrations were[28,29] as follows: β-carotene: <0.4 μmol $l^{-1}$ (deficit), retinol: <0.7 μmol $l^{-1}$ (severe deficit) and α-tocopherol: <11.6 μmol $l^{-1}$ (severe deficit), 11.6–23.1 (marginal deficit) and ≥23.2 μmol $l^{-1}$ (normal).

The comparison of the mean values and the percentage of the distribution of the variables are shown.

## Results

In 1992–93 the final sample included 880 individuals (393 males and 487 females) for the lipid analysis and 337 individuals (144 males and 193 females) for the vitamin analysis, aged 18 to 74 years. In 2002–03, 429 subjects (205 males and 224 females) aged 18 to 74 years participated in the lipid and vitamin evaluation.

Mean plasma concentrations of TC, LDL, HDL and TG are shown in Table 1. In the 1992–93 evaluation, mean value for TC was 5.26 mmol $l^{-1}$ (203.5 mg $dl^{-1}$) in males and 5.28 mmol $l^{-1}$ (204.3 mg $dl^{-1}$) in females. Women had higher TC levels, except for the age group of 35–49 years where men had higher values. In the 2002–03 analysis[21] the mean value for TC was 5.1 mmol $l^{-1}$ (197.3 mg $dl^{-1}$) for males and females. In men, mean TC levels increased with age throughout middle age and then decreased, reaching a peak at ages 35–49 years. For women mean TC values increased in every age group, until ages 65–74 years. Mean TC levels decreased during the decade from 5.3 to 5.1 mmol $l^{-1}$ ($P< 0.005$), with males showing a higher decrease over all age groups than females. By age groups, and gender, only females from 50 to 64 years old showed a significant decrease (from 5.8 to 5.5 mmol $l^{-1}$). Individuals aged 18–34 and women aged 65–74 years maintained the same TC levels.

Mean LDL values remained stable, 3.30 mmol $l^{-1}$ (127.4 mg $dl^{-1}$) in 1992–93 and 3.26 mmol $l^{-1}$ (125.9 mg $dl^{-1}$) in 2002–03, with higher values at older ages in both genders and both surveys. In 1992–93 women showed lower LDL values than males except for those from 50 to 64 years (3.71 mmol $l^{-1}$), who had higher values than males of the same age group (3.59 mmol $l^{-1}$). In 2002–03, the LDL values in females were lower than in males except for the age group of 50–64 years and 65–74 years. The mean LDL values decreased in the interval of the period analysed in all age groups, except for males and females from 18 to 34 where the values remained stable (2.9 mmol $l^{-1}$ in males and 2.7 mmol $l^{-1}$ in females) and females from 65 to 74 where an increase was observed (from 3.5 to 3.7 mmol $l^{-1}$).

Mean HDL was 1.44 mmol $l^{-1}$ (53.9 mg $dl^{-1}$) in 1992–93 and 1.34 mmol $l^{-1}$ (50.2 mg $dl^{-1}$) in 2002–03 ($P< 0.001$), with women showing higher levels than men. The HDL values decreased in the period analysed from 1.29 to 1.20 mmol $l^{-1}$ in males ($P< 0.001$) and from 1.57 to 1.48 in females ($P< 0.005$). Only males from 65 to 74 years and females from 35 to 49 years maintained the same HDL levels.

Mean serum TG was 1.17 mmol $l^{-1}$ (103.57 mg $dl^{-1}$) in 1992–93 and 1.08 mmol $l^{-1}$ (95.6 mg $dl^{-1}$) in 2002–03 ($P< 0.01$). Men had higher TG levels than females except for women aged 65 to 74 years in the 2002–03 survey. In the period analysed, males showed a decrease in the TG levels, from 1.34 to 1.21 mmol $l^{-1}$ ($P< 0.01$), and only individuals from 18 to 34 years showed an increase (from 1.03 mmol $l^{-1}$ to 1.11 mmol $l^{-1}$). Only females from 35 to 49 years showed a significant decrease in their TG levels (from 0.90 to 0.85 mmol $l^{-1}$, $P< 0.05$).

Tables 2–5 show the distribution of the population according to the proposed cut-off points for TC, LDL, HDL and TG. The proportion of the population with high serum levels of TC (≥6.22 mmol $l^{-1}$) decreased from 18% to 12% in males and from 20% to 18% in females during the 10-year interval. Only males from 50 to 64 years showed a significant decrease in the percentage of individuals with hypercholesterolaemia (from 23% to 10%, $P< 0.05$). In 2002–03, about 31% of the

**Table 1** Trends (1992–2003) in the mean serum cholesterol and triglycerides of the Catalan population

| | Total cholesterol (mmol $l^{-1}$) | | | | | LDL-cholesterol (mmol $l^{-1}$) | | | | | HDL-cholesterol (mmol $l^{-1}$) | | | | | Triglycerides (mmol $l^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1992–93 | | 2002–03 | | | 1992–93 | | 2002–03 | | | 1992–93 | | 2002–03 | | | 1992–93 | | 2002–03 | | |
| Age (years) | *n* | Mean | *n* | Mean | *P* | *n* | Mean | *n* | Mean | *P* | *n* | Mean | *n* | Mean | *P* | *n* | Mean | *n* | Mean | *P* |
| Males | | | | | | | | | | | | | | | | | | | | |
| 18–34 | 123 | 4.62 | 55 | 4.64 | ns | 123 | 2.85 | 54 | 2.94 | ns | 123 | 1.30 | 55 | 1.21 | ns | 123 | 1.03 | 55 | 1.11 | ns |
| 35–49 | 103 | 5.61 | 52 | 5.27 | <0.05 | 100 | 3.63 | 52 | 3.49 | ns | 103 | 1.29 | 52 | 1.18 | <0.05 | 103 | 1.56 | 52 | 1.30 | ns |
| 50–64 | 104 | 5.51 | 63 | 5.21 | <0.05 | 102 | 3.59 | 63 | 3.43 | ns | 104 | 1.29 | 63 | 1.18 | <0.01 | 104 | 1.38 | 63 | 1.22 | <0.05 |
| 65–74 | 64 | 5.54 | 35 | 5.15 | ns | 62 | 3.64 | 35 | 3.34 | ns | 64 | 1.26 | 35 | 1.25 | ns | 64 | 1.52 | 35 | 1.21 | ns |
| Total | 394 | 5.26 | 205 | 5.06 | <0.05 | 387 | 3.37 | 204 | 3.30 | ns | 394 | 1.29 | 205 | 1.20 | <0.001 | 394 | 1.34 | 205 | 1.21 | <0.01 |
| Females | | | | | | | | | | | | | | | | | | | | |
| 18–34 | 143 | 4.65 | 63 | 4.56 | ns | 142 | 2.68 | 63 | 2.71 | ns | 143 | 1.55 | 63 | 1.47 | ns | 143 | 0.90 | 63 | 0.78 | ns |
| 35–49 | 148 | 5.17 | 63 | 5.03 | ns | 148 | 3.24 | 63 | 3.10 | ns | 148 | 1.53 | 63 | 1.54 | ns | 148 | 0.90 | 63 | 0.85 | <0.05 |
| 50–64 | 132 | 5.84 | 56 | 5.46 | <0.05 | 130 | 3.71 | 56 | 3.53 | ns | 133 | 1.58 | 56 | 1.45 | <0.05 | 132 | 1.22 | 56 | 1.05 | ns |
| 65–74 | 74 | 5.74 | 42 | 5.75 | ns | 74 | 3.51 | 42 | 3.73 | ns | 74 | 1.66 | 42 | 1.42 | <0.01 | 74 | 1.28 | 42 | 1.30 | ns |
| Total | 497 | 5.28 | 224 | 5.14 | ns | 494 | 3.24 | 224 | 3.21 | ns | 498 | 1.57 | 224 | 1.48 | <0.005 | 497 | 1.04 | 224 | 0.96 | ns |
| Total | | | | | | | | | | | | | | | | | | | | |
| 18–34 | 266 | 4.64 | 118 | 4.60 | ns | 265 | 2.76 | 117 | 2.82 | ns | 266 | 1.44 | 118 | 1.35 | <0.01 | 266 | 0.96 | 118 | 0.93 | ns |
| 35–49 | 251 | 5.36 | 115 | 5.14 | <0.05 | 248 | 3.40 | 115 | 3.28 | ns | 251 | 1.42 | 115 | 1.38 | ns | 251 | 1.17 | 115 | 1.05 | <0.05 |
| 50–64 | 136 | 5.69 | 119 | 5.33 | <0.005 | 232 | 3.66 | 119 | 3.48 | ns | 237 | 1.45 | 119 | 1.31 | <0.001 | 236 | 1.29 | 119 | 1.14 | <0.05 |
| 65–74 | 138 | 5.65 | 77 | 5.47 | ns | 136 | 3.57 | 77 | 3.55 | ns | 138 | 1.47 | 77 | 1.34 | <0.05 | 138 | 1.39 | 77 | 1.26 | ns |
| Total | 891 | 5.27 | 429 | 5.10 | <0.005 | 881 | 3.30 | 428 | 3.26 | ns | 892 | 1.44 | 429 | 1.34 | <0.001 | 891 | 1.17 | 429 | 1.08 | <0.01 |

LDL – low-density lipoprotein; HDL – high-density lipoprotein; ns – non-significant.

**Table 2** Trends (1992–2003) in the distribution of the Catalan population according to proposed cut-off points for total cholesterol by gender and age group

| | 1992–93 Total cholesterol (mmol l$^{-1}$) | | | | | | 2002–03 Total cholesterol (mmol l$^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <5.18 | | 5.18–6.21 | | ≥6.22 | | <5.18 | | 5.18–6.21 | | ≥6.22 | | |
| Age (years) | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *P* |
| Males | | | | | | | | | | | | | |
| 18–34 | 90 | 73.2 | 28 | 22.8 | 5 | 4.1 | 39 | 70.9 | 12 | 21.8 | 4 | 7.3 | ns |
| 35–49 | 37 | 35.9 | 41 | 39.8 | 25 | 24.3 | 24 | 46.2 | 17 | 32.7 | 11 | 21.2 | ns |
| 50–64 | 36 | 34.6 | 44 | 42.3 | 24 | 23.1 | 32 | 50.8 | 25 | 39.7 | 6 | 9.5 | <0.05 |
| 65–74 | 27 | 42.2 | 21 | 32.8 | 16 | 25.0 | 16 | 45.7 | 15 | 42.9 | 4 | 11.4 | ns |
| Total | 190 | 48.2 | 134 | 34.0 | 70 | 17.8 | 111 | 54.2 | 69 | 33.7 | 25 | 12.2 | ns |
| Females | | | | | | | | | | | | | |
| 18–34 | 109 | 76.2 | 27 | 18.9 | 7 | 4.9 | 49 | 77.8 | 10 | 15.9 | 4 | 6.3 | ns |
| 35–49 | 79 | 53.4 | 53 | 35.8 | 16 | 10.8 | 39 | 61.9 | 14 | 22.2 | 10 | 15.9 | ns |
| 50–64 | 35 | 26.5 | 44 | 33.3 | 53 | 40.2 | 23 | 41.1 | 17 | 30.4 | 16 | 28.6 | ns |
| 65–74 | 21 | 28.4 | 29 | 39.2 | 24 | 32.4 | 11 | 26.2 | 21 | 50.0 | 10 | 23.8 | ns |
| Total | 244 | 49.1 | 153 | 30.8 | 100 | 20.1 | 122 | 54.5 | 62 | 27.7 | 40 | 17.9 | ns |
| Total | | | | | | | | | | | | | |
| 18–34 | 199 | 74.8 | 55 | 20.7 | 12 | 4.5 | 88 | 74.6 | 22 | 18.6 | 8 | 6.8 | ns |
| 35–49 | 116 | 46.2 | 94 | 37.5 | 41 | 16.3 | 63 | 54.8 | 31 | 27.0 | 21 | 18.3 | ns |
| 50–64 | 71 | 30.1 | 88 | 37.3 | 77 | 32.6 | 55 | 46.2 | 42 | 35.3 | 22 | 18.5 | <0.005 |
| 65–74 | 48 | 34.8 | 50 | 36.2 | 40 | 29.0 | 27 | 35.1 | 36 | 46.8 | 14 | 18.2 | ns |
| Total | 434 | 48.7 | 287 | 32.2 | 170 | 19.1 | 233 | 54.3 | 131 | 30.5 | 65 | 15.2 | ns |

ns – non-significant.

**Table 3** Trends (1992–2003) in the distribution of the Catalan population according to proposed cut-off points for LDL cholesterol by gender and age group

| | 1992–93 LDL cholesterol (mmol l$^{-1}$) | | | | | | | | 2002–03 LDL cholesterol (mmol l$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <2.59 | | 2.59–3.36 | | 3.37–4.13 | | ≥4.14 | | <2.59 | | 2.59–3.36 | | 3.37–4.13 | | ≥4.14 | | |
| Age (years) | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *P* |
| Males | | | | | | | | | | | | | | | | | |
| 18–34 | 51 | 41.5 | 37 | 30.1 | 28 | 22.8 | 7 | 5.7 | 20 | 37.0 | 19 | 35.2 | 11 | 20.4 | 4 | 7.4 | ns |
| 35–49 | 12 | 12.0 | 30 | 30.0 | 32 | 32.0 | 26 | 26.0 | 4 | 7.7 | 18 | 34.6 | 19 | 36.5 | 11 | 21.2 | ns |
| 50–64 | 10 | 9.8 | 27 | 26.5 | 40 | 39.2 | 25 | 24.5 | 10 | 15.9 | 21 | 33.3 | 19 | 30.2 | 13 | 20.6 | ns |
| 65–74 | 6 | 9.7 | 23 | 37.1 | 17 | 27.4 | 16 | 25.8 | 5 | 14.3 | 12 | 34.3 | 12 | 34.3 | 6 | 17.1 | ns |
| Total | 79 | 20.4 | 117 | 30.2 | 117 | 30.2 | 74 | 19.1 | 39 | 19.1 | 70 | 34.3 | 61 | 29.9 | 34 | 16.7 | ns |
| Females | | | | | | | | | | | | | | | | | |
| 18–34 | 68 | 47.9 | 47 | 33.1 | 21 | 14.8 | 6 | 4.2 | 38 | 60.3 | 16 | 25.4 | 6 | 9.5 | 3 | 4.8 | ns |
| 35–49 | 32 | 21.6 | 56 | 37.8 | 45 | 30.4 | 15 | 10.1 | 19 | 30.2 | 24 | 38.1 | 11 | 17.5 | 9 | 14.3 | ns |
| 50–64 | 13 | 10.0 | 30 | 23.1 | 44 | 33.8 | 43 | 33.1 | 10 | 17.9 | 16 | 28.6 | 11 | 19.6 | 19 | 33.9 | ns |
| 65–74 | 11 | 14.9 | 19 | 25.7 | 29 | 39.2 | 15 | 20.3 | 4 | 9.5 | 8 | 19.0 | 20 | 47.6 | 10 | 23.8 | ns |
| Total | 124 | 25.1 | 152 | 30.8 | 139 | 28.1 | 79 | 16.0 | 71 | 31.7 | 64 | 28.6 | 48 | 21.4 | 41 | 18.3 | ns |
| Total | | | | | | | | | | | | | | | | | |
| 18–34 | 119 | 44.9 | 84 | 31.7 | 49 | 18.5 | 13 | 4.9 | 58 | 49.6 | 35 | 29.9 | 17 | 14.5 | 7 | 6.0 | ns |
| 35–49 | 44 | 17.7 | 86 | 34.7 | 77 | 31.0 | 41 | 16.5 | 23 | 20.0 | 42 | 36.5 | 30 | 26.1 | 20 | 17.4 | ns |
| 50–64 | 23 | 9.9 | 57 | 24.6 | 84 | 36.2 | 68 | 29.3 | 20 | 16.8 | 37 | 31.1 | 30 | 25.3 | 32 | 26.9 | ns |
| 65–74 | 17 | 12.5 | 42 | 30.9 | 46 | 33.8 | 31 | 22.8 | 9 | 11.7 | 20 | 26.0 | 32 | 41.6 | 16 | 20.8 | ns |
| Total | 203 | 23.0 | 269 | 30.5 | 256 | 29.1 | 153 | 17.4 | 110 | 25.7 | 134 | 31.3 | 109 | 25.5 | 75 | 17.5 | ns |

LDL – low-density lipoprotein; ns – non-significant.

population had moderately high cholesterol values (5.18–6.21 mmol l$^{-1}$), a proportion that increased to 47% of the population in the age group of 65–74 years old. Referring to LDL cholesterol, the percentage of males with high values decreased from 19% to 17%. In females and for all age groups in the period analysed, an increase in the percentage of individuals with the lowest as well as the highest LDL levels was shown. The percentage of population with high levels of HDL decreased from 35% to 27% ($P < 0.001$), in both males (from 20% to 11%, $P < 0.01$) and females (from 47% to 41%, $P < 0.05$) and for all age groups. The proportion of individuals with low levels of HDL increased (from 10% to 19%) in all age groups, especially in males from 35 to 49 years (from 17% to 37%). In the 2002–03 analysis, the percentage of population with high values for TG (≥2.26 mmol l$^{-1}$)

**Table 4** Trends (1992–2003) in the distribution of the Catalan population according to proposed cut-off points for HDL cholesterol by gender and age group

| | 1992–93 HDL cholesterol (mmol l$^{-1}$) | | | | | | 2002–03 HDL cholesterol (mmol l$^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <1.04 | | 1.04–1.55 | | ≥1.56 | | <1.04 | | 1.04–1.55 | | ≥1.56 | | |
| Age (years) | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *P* |
| Males | | | | | | | | | | | | | |
| 18–34 | 18 | 14.6 | 82 | 66.7 | 23 | 18.7 | 11 | 20.0 | 40 | 72.7 | 4 | 7.3 | ns |
| 35–49 | 17 | 16.5 | 64 | 62.1 | 22 | 21.4 | 19 | 36.5 | 28 | 53.8 | 5 | 9.6 | <0.05 |
| 50–64 | 22 | 21.2 | 60 | 57.7 | 22 | 21.2 | 23 | 36.5 | 32 | 50.8 | 8 | 12.7 | ns |
| 65–74 | 13 | 20.3 | 39 | 60.9 | 12 | 18.8 | 11 | 31.4 | 18 | 51.4 | 6 | 17.1 | ns |
| Total | 70 | 17.8 | 245 | 62.2 | 79 | 20.1 | 64 | 31.2 | 118 | 57.6 | 23 | 11.2 | <0.001 |
| Females | | | | | | | | | | | | | |
| 18–34 | 3 | 2.1 | 71 | 49.7 | 69 | 48.3 | 5 | 7.9 | 32 | 50.8 | 26 | 41.3 | ns |
| 35–49 | 3 | 2.0 | 80 | 54.1 | 65 | 43.9 | 3 | 4.8 | 33 | 52.4 | 27 | 42.9 | ns |
| 50–64 | 5 | 3.8 | 65 | 48.9 | 63 | 47.4 | 5 | 8.9 | 27 | 48.2 | 24 | 42.9 | ns |
| 65–74 | 5 | 6.8 | 31 | 41.9 | 38 | 51.4 | 5 | 11.9 | 22 | 52.4 | 15 | 35.7 | ns |
| Total | 16 | 3.2 | 247 | 49.6 | 235 | 47.2 | 18 | 8.0 | 114 | 50.9 | 92 | 41.1 | <0.05 |
| Total | | | | | | | | | | | | | |
| 18–34 | 21 | 7.9 | 153 | 57.5 | 92 | 34.6 | 16 | 13.6 | 72 | 61.0 | 30 | 25.4 | ns |
| 35–49 | 20 | 8.0 | 144 | 57.4 | 87 | 34.7 | 22 | 19.1 | 61 | 53.0 | 32 | 27.8 | <0.01 |
| 50–64 | 27 | 11.4 | 125 | 52.7 | 85 | 35.9 | 28 | 23.5 | 59 | 49.6 | 32 | 26.9 | <0.01 |
| 65–74 | 18 | 13.0 | 70 | 50.7 | 50 | 36.2 | 16 | 20.8 | 40 | 51.9 | 21 | 27.3 | ns |
| Total | 86 | 9.6 | 492 | 55.2 | 314 | 35.2 | 82 | 19.1 | 232 | 54.1 | 115 | 26.8 | <0.001 |

HDL – high-density lipoprotein; ns – non-significant.

**Table 5** Trends (1992–2003) in the distribution of the Catalan population according to proposed cut-off points for triglycerides by gender and age group

| | 1992–93 Triglycerides (mmol l$^{-1}$) | | | | | | 2002–03 Triglycerides (mmol l$^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <1.67 | | 1.67–2.25 | | ≥2.26 | | <1.67 | | 1.67–2.25 | | ≥2.26 | | |
| Age (years) | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *P* |
| Males | | | | | | | | | | | | | |
| 18–34 | 109 | 88.6 | 8 | 6.5 | 6 | 4.9 | 49 | 89.1 | 2 | 3.6 | 4 | 7.3 | ns |
| 35–49 | 71 | 68.9 | 17 | 16.5 | 15 | 14.6 | 42 | 80.8 | 5 | 9.6 | 5 | 9.6 | ns |
| 50–64 | 78 | 75.0 | 15 | 14.4 | 11 | 10.6 | 49 | 77.8 | 10 | 15.9 | 4 | 6.3 | ns |
| 65–74 | 49 | 76.6 | 7 | 10.9 | 8 | 12.5 | 28 | 80.0 | 4 | 11.4 | 3 | 8.6 | ns |
| Total | 307 | 77.9 | 47 | 11.9 | 40 | 10.2 | 168 | 82.0 | 21 | 10.2 | 16 | 7.8 | ns |
| Females | | | | | | | | | | | | | |
| 18–34 | 129 | 90.2 | 7 | 4.9 | 7 | 4.9 | 61 | 96.8 | 2 | 3.2 | 0 | 0.0 | ns |
| 35–49 | 139 | 93.9 | 7 | 4.7 | 2 | 1.4 | 60 | 95.2 | 1 | 1.6 | 2 | 3.2 | ns |
| 50–64 | 103 | 78.0 | 18 | 13.6 | 11 | 8.3 | 50 | 89.3 | 4 | 7.1 | 2 | 3.6 | ns |
| 65–74 | 57 | 77.0 | 13 | 17.6 | 4 | 5.4 | 32 | 76.2 | 6 | 14.3 | 4 | 9.5 | ns |
| Total | 428 | 86.1 | 45 | 9.1 | 24 | 4.8 | 203 | 90.6 | 13 | 5.8 | 8 | 3.6 | ns |
| Total | | | | | | | | | | | | | |
| 18–34 | 238 | 89.5 | 15 | 5.6 | 13 | 4.9 | 110 | 93.2 | 4 | 3.4 | 4 | 3.4 | ns |
| 35–49 | 210 | 83.7 | 24 | 9.6 | 17 | 6.8 | 102 | 88.7 | 6 | 5.2 | 7 | 6.1 | ns |
| 50–64 | 181 | 76.7 | 33 | 14.0 | 22 | 9.3 | 99 | 83.2 | 14 | 11.8 | 6 | 5.0 | ns |
| 65–74 | 106 | 76.8 | 20 | 14.5 | 12 | 8.7 | 60 | 77.9 | 10 | 13.0 | 7 | 9.1 | ns |
| Total | 735 | 82.5 | 92 | 10.3 | 64 | 7.2 | 371 | 86.5 | 34 | 7.9 | 24 | 5.6 | ns |

ns – non-significant.

decreased (from 7% to 6%) although the change was not significant.

Mean values for α-tocopherol, β-carotene and retinol are shown in Table 6. α-Tocopherol levels increased from 31.88 μmol l$^{-1}$ in 1992 to 33.59 μmol l$^{-1}$ in 2003 ($P < 0.005$). The mean concentrations of α-tocopherol increased in all age groups except for older females where the values decreased from 35.1 in 1992–93 to 34.2 μmol l$^{-1}$ in 2002–03. Only females from 18 to 34 years showed a statistically significant increase (from 31.6 to 33.4, $P < 0.05$). Values were lower in males than in females except for the older men in the 2002–03 survey, which had higher values than females for the same age group (35.2 and 34.2 μmol l$^{-1}$, respectively).

Mean plasma levels for β-carotene was 0.42 μmol l$^{-1}$ in the 1992–93 survey and 0.39 μmol l$^{-1}$ in the 2002–03 analysis ($P < 0.05$). Women had higher carotenoid levels than men. In the 10-year interval, there was a decrease in

**Table 6** Trends (1992–2003) in plasma concentration of α-tocopherol, β-carotene and retinol in the Catalan population by gender and age group

| | α-Tocoferol ($\mu mol\,l^{-1}$) | | | | | β-Carotene ($\mu mol\,l^{-1}$) | | | | | Retinol ($\mu mol\,l^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1992–93 | | 2002–03 | | | 1992–93 | | 2002–03 | | | 1992–93 | | 2002–03 | | |
| Age (years) | *n* | Mean | *n* | Mean | *P* | *n* | Mean | *n* | Mean | *P* | *n* | Mean | *n* | Mean | *P* |
| Males | | | | | | | | | | | | | | | |
| 18–34 | 45 | 30.9 | 54 | 31.5 | ns | 44 | 0.34 | 47 | 0.40 | ns | 46 | 2.15 | 55 | 2.65 | <0.001 |
| 35–49 | 38 | 31.1 | 50 | 31.4 | ns | 37 | 0.38 | 45 | 0.31 | ns | 38 | 2.02 | 52 | 2.28 | <0.05 |
| 50–64 | 43 | 31.7 | 63 | 33.1 | ns | 41 | 0.35 | 54 | 0.31 | ns | 43 | 1.88 | 63 | 2.42 | <0.001 |
| 65–74 | 23 | 31.6 | 33 | 35.2 | ns | 22 | 0.48 | 34 | 0.34 | ns | 23 | 1.81 | 35 | 2.40 | <0.005 |
| Total | 149 | 31.3 | 200 | 32.6 | ns | 144 | 0.38 | 180 | 0.34 | ns | 150 | 1.99 | 205 | 2.44 | <0.001 |
| Females | | | | | | | | | | | | | | | |
| 18–34 | 67 | 31.6 | 59 | 33.4 | <0.05 | 67 | 0.43 | 62 | 0.41 | ns | 67 | 1.84 | 60 | 2.51 | <0.001 |
| 35–49 | 53 | 31.8 | 62 | 34.3 | ns | 52 | 0.47 | 57 | 0.41 | ns | 53 | 1.69 | 62 | 2.39 | <0.001 |
| 50–64 | 50 | 32.4 | 55 | 36.1 | ns | 51 | 0.49 | 54 | 0.53 | ns | 50 | 1.53 | 56 | 2.14 | <0.001 |
| 65–74 | 23 | 35.1 | 39 | 34.2 | ns | 23 | 0.43 | 39 | 0.40 | ns | 23 | 1.57 | 41 | 2.00 | <0.005 |
| Total | 193 | 32.3 | 215 | 34.5 | <0.005 | 193 | 0.46 | 212 | 0.44 | ns | 193 | 1.69 | 219 | 2.29 | <0.001 |
| Total | | | | | | | | | | | | | | | |
| 18–34 | 112 | 31.3 | 113 | 32.5 | ns | 111 | 0.40 | 109 | 0.40 | ns | 113 | 1.97 | 115 | 2.57 | <0.001 |
| 35–49 | 91 | 31.5 | 112 | 33.0 | ns | 89 | 0.44 | 102 | 0.37 | ns | 91 | 1.82 | 114 | 2.34 | <0.001 |
| 50–64 | 93 | 32.1 | 118 | 34.5 | ns | 92 | 0.43 | 108 | 0.42 | ns | 93 | 1.69 | 119 | 2.29 | <0.001 |
| 65–74 | 46 | 33.4 | 72 | 34.7 | ns | 45 | 0.45 | 73 | 0.37 | ns | 46 | 1.69 | 76 | 2.19 | <0.001 |
| Total | 342 | 31.9 | 415 | 33.6 | <0.005 | 337 | 0.42 | 392 | 0.39 | <0.05 | 343 | 1.82 | 424 | 2.36 | <0.001 |

ns – non-significant.

the mean values of β-carotene for all age groups except for those males younger than 35 years (from 0.34 to $0.40\,\mu mol\,l^{-1}$) and for women from 50 to 64 years, although not statistically significant.

Mean levels of retinol increased in the period of study, from $1.82\,\mu mol\,l^{-1}$ in 1992–93 to $2.36\,\mu mol\,l^{-1}$ in the 2002–03 survey ($P<0.001$), both for males (from 1.99 to 2.44, $P<0.001$) and for females (from 1.69 to 2.29, $P<0.001$) and for all age groups. Men showed higher values of retinol concentrations ($2.44\,\mu mol\,l^{-1}$) than females ($2.29\,\mu mol\,l^{-1}$) except for females from 35 to 49 years in the 2002–03 ($2.39\,\mu mol\,l^{-1}$) analysis, which had higher values than males ($2.28\,\mu mol\,l^{-1}$).

Table 7 shows the distribution of the Catalan population with concentrations of α-tocopherol and β-carotene below the threshold used to define deficiency or inadequate levels. There has been an increase in the population with a marginal deficit of α-tocopherol (from 5.8% in 1992–92 to 8.7% in 2002–03), especially so in males for whom 10.5% of the population were at marginal risk in the 2002–03 survey. For males under 35 years of age, there was an important increase in the percentage of individuals with values below $23.1\,\mu mol\,l^{-1}$ (from 6.8% to 18.5%). Only individuals from 65 to 74 years showed a decrease in the percentage of marginal deficit (from 8.3% to 3.0%). In the 2002–03 survey, 1.6% of females from 35 to 49 years showed a severe deficit.

An increase in the percentage of the population at risk for low β-carotene values was observed (from 58.9% in 1992–93 to 65.8% in 2002–03), except for males younger than 35 years and females from 65 to 74 years where a decrease was shown.

## Discussion

The main finding of this study was that the Catalan population shows a slightly worsened lipid profile for the decade analysed, due to the decrease reported in the HDL levels of the population. On the other hand, a decrease in TC, LDL and TG levels, a trend that had already been previously reported for the 1980–1992 decade[30], counteracts the main findings seen. Certain European[31–34] countries and the USA[35] have shown similar trends, with a decrease in the serum lipid levels but of a different magnitude for each lipoprotein. The analysis of serum lipids conducted in the USA during the same time period also showed a decrease in the levels of TC and LDL and a decrease in the percentage of the population with hypercholesterolaemia, as shown in adults from Catalonia. The evolution of HDL and TG levels is of a different magnitude between both countries. In the USA, HDL levels increased in females, whereas levels in males remained stable. The TG levels increased in the entire population. In the Catalan population, a decrease in HDL levels is similar in both males and females. Referring to European countries, trend data from Germany[31] showed an increase in the percentage of population with hypercholesterolaemia while trend data from the MONICA[32–34] study have shown some stabilisation in HDL levels, but not a clear decrease in serum HDL cholesterol levels, which was the trend observed in the Catalan population. HDL trends have improved in certain countries such as in Finland, where a well-planned nutrition policy has been shown to have specific benefits[32,33]. On the other hand, trend data from a Swiss region

**Table 7** Distribution of the Catalan population according to concentrations of α-tocopherol and β-carotene (1992–2003)

| | α-Tocopherol | | | | | | | | | | | | | β-Carotene | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Severe deficit <11.6 μmol l$^{-1}$ | | | | Marginal deficit 11.6–23.1 μmol l$^{-1}$ | | | | Normal ≥23.2 μmol l$^{-1}$ | | | | | Deficit <0.4 μmol l$^{-1}$ | | | | |
| | 1992–93 | | 2002–03 | | 1992–93 | | 2002–03 | | 1992–93 | | 2002–03 | | | 1992–93 | | 2002–03 | | |
| Age (years) | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *P* | *n* | % | *n* | % | *P* |
| Males | | | | | | | | | | | | | | | | | | |
| 18–34 | 0 | 0.0 | 0 | 0.0 | 3 | 6.8 | 10 | 18.5 | 41 | 93.2 | 44 | 81.5 | ns | 30 | 69.8 | 30 | 63.8 | ns |
| 35–49 | 0 | 0.0 | 0 | 0.0 | 1 | 2.6 | 3 | 6.0 | 37 | 97.4 | 47 | 94.0 | ns | 23 | 62.2 | 35 | 77.8 | ns |
| 50–64 | 0 | 0.0 | 0 | 0.0 | 4 | 9.3 | 7 | 11.1 | 39 | 90.7 | 56 | 88.9 | ns | 29 | 70.7 | 45 | 83.3 | ns |
| 65–74 | 0 | 0.0 | 0 | 0.0 | 2 | 8.3 | 1 | 3.0 | 22 | 91.7 | 32 | 97.0 | ns | 11 | 47.8 | 24 | 70.6 | ns |
| Total | 0 | 0.0 | 0 | 0.0 | 10 | 6.7 | 21 | 10.5 | 139 | 93.3 | 179 | 89.5 | ns | 93 | 64.6 | 134 | 74.4 | ns |
| Females | | | | | | | | | | | | | | | | | | |
| 18–34 | 0 | 0.0 | 0 | 0.0 | 8 | 11.9 | 7 | 11.9 | 59 | 88.1 | 52 | 88.1 | ns | 41 | 61.2 | 38 | 61.3 | ns |
| 35–49 | 0 | 0.0 | 1 | 1.6 | 1 | 1.8 | 4 | 6.5 | 54 | 98.2 | 57 | 91.9 | ns | 29 | 53.7 | 34 | 59.6 | ns |
| 50–64 | 0 | 0.0 | 0 | 0.0 | 1 | 2.0 | 4 | 7.3 | 49 | 98.0 | 51 | 92.7 | ns | 22 | 44.0 | 30 | 55.6 | ns |
| 65–74 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 26 | 100.0 | 39 | 100.0 | | 16 | 61.5 | 22 | 56.4 | ns |
| Total | 0 | 0.0 | 1 | 0.5 | 10 | 5.1 | 15 | 7.0 | 188 | 94.9 | 199 | 92.6 | ns | 108 | 54.8 | 124 | 58.7 | ns |
| Total | | | | | | | | | | | | | | | | | | |
| 18–34 | 0 | 0.0 | 0 | 0.0 | 11 | 9.9 | 17 | 15.0 | 100 | 90.1 | 96 | 85.0 | ns | 71 | 64.5 | 68 | 62.4 | ns |
| 35–49 | 0 | 0.0 | 1 | 0.9 | 2 | 2.2 | 7 | 6.3 | 91 | 97.8 | 104 | 92.9 | ns | 52 | 57.1 | 69 | 67.6 | ns |
| 50–64 | 0 | 0.0 | 0 | 0.0 | 5 | 5.4 | 11 | 9.3 | 88 | 94.6 | 107 | 90.7 | ns | 51 | 56.0 | 75 | 69.4 | ns |
| 65–74 | 0 | 0.0 | 0 | 0.0 | 2 | 4.0 | 1 | 1.4 | 48 | 96.0 | 71 | 98.6 | ns | 27 | 55.1 | 46 | 63.0 | ns |
| Total | 0 | 0.0 | 1 | 0.2 | 20 | 5.8 | 36 | 8.7 | 327 | 94.2 | 378 | 91.1 | ns | 201 | 58.9 | 258 | 65.8 | ns |

ns – non-significant.

participating in the MONICA study also reported a decrease in the HDL levels of the population[36]. Mean HDL levels in the Catalan population are lower than those reported in the Finnish population[33] or in France[34], but are still higher than those in the USA population[37]. It is difficult to pinpoint the reasons that might explain this decrease. A mixture of factors such as a modification in the dietary habits or physical activity patterns as well as the use of hypolipidemic medications in the population may explain the trend. According to trend data on food habits in the Catalan population, olive oil consumption has not decreased in the last decade and it is still the main oil consumed as 'added table fats'. Referring to physical activity, a slight decrease in the sedentary habits of the population has been reported, although it is difficult to calculate the modification in the total daily energy expenditure that this may represent. On the other hand, hypolipidaemic medication use has not changed in the interval of time analysed.

The reduction in the percentage of population with high lipid levels (hypercholesterolaemia) concurs with a decrease in the mortality rates related to cardiovascular diseases in Catalonia. It is calculated that between 1990 and 2000 the mortality associated with CVD decreased 32.6% in Catalonia[38]. As the reduction in the trends of TC is due mainly to the reduction of HDL levels instead of LDL levels, other factors such as physical activity or dietary antioxidants[39,40] are thought to have some protective effects on the cardiovascular health of individuals from Mediterranean countries such as Spain. As reported in other publications, although these countries have a high prevalence of cardiovascular risk factors[41], the morbidity and mortality related to cardiovascular diseases are lower than other European countries[42]. In Catalonia, as shown in other countries, TC increased with age group[35,43,44] and females had better lipid profiles than males[44,56].

The reported decrease in triglyceride levels contrasts with the notorious increase in the prevalence of overweight and obesity in the Catalan population, according to data from the same period[47]. On the contrary, in other countries such as the USA[35], Japan[46] and Finland[48], data show that lipid levels of TG increased together with the prevalence of overweight and obesity. Moderation in alcoholic beverage consumption has been reported in Catalonia[49].

It is noteworthy that the cohort of young adults had the worst profile than other age groups, data that coincide with other publications[37]. TC, LDL and TG did not decrease in this age group, especially among males. This trend shows that improvements in the lifestyle of adults and older individuals are not affecting children and youth. Deterioration in their diet quality, as seen in observed decreases in fruit and vegetable consumption and increased fat intake, may explain these trends. In fact, the increase in obesity prevalence of the Catalan population is of a greater magnitude among children than adults[50]. According to the enKid study[51], the prevalence of obesity among Catalan individuals aged 2–24 years was 9.5% in 1998–2000.

Nevertheless, the lipid profile of the Catalan population is still one of the healthiest among western societies. According to the European-based MONICA study, in the mid-1990s, Catalonia showed one of the lowest

prevalences of hypercholesterolaemia among European countries[53]. However, should the tendency reported in this study continue, it may be that supposed protective factors that benefit Mediterraneans population's health will no longer be sufficient to prevent the increase in the incidence of related chronic disease.

Although circulating concentrations of α-tocopherol increased in the Catalan population, a simultaneous increase in the percentage of population at risk for inadequate intakes was also observed. Available data on macro- and micronutrient intake in the 2002–03 Catalan Nutrition Survey showed that a high proportion of the population (33%) had vitamin E intakes below 2/3 of the recommended dietary intake for the Spanish population[53]. However, the values shown for α-tocopherol were higher than the values reported for populations in the USA[54], France, Hungary, the UK[55], Ireland and the Netherlands[56]. Males in Catalonia showed higher concentrations of retinol and lower concentrations of β-carotene than females, a distribution that is in accordance with other population-based studies[57–59]. Some publications have shown differences between males and females in the plasma levels of α-tocopherol[54], which were not observed in the Catalan population.

There has not been a clear modification in the profile of serum antioxidants in the Catalan population. A slight worsening in levels of α-tocopherol and β-carotene was reflected in an increase in the proportion of individuals with marginal deficits for these vitamins. This would mean that modifications in vitamin levels have not been homogeneous for the entire population and that certain groups of individuals have changed their nutritional habits, such as, for example, a decreased fruit and vegetable intake. The increase in the retinol levels for the entire population is considered as a positive trend.

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