The methodology of the Italian Total Diet Study 2012-2014

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Rome, Italy

Ann Ist Super Sanità 2013 | Vol. 49, No. 3: 000-000
DOI: 0000000000000000

Dietary exposure to trace elements and radionuclides: the methodology of the Italian Total Diet Study 2012-2014

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Abstract

This article presents the methodology of the Italian Total Diet Study 2012-2014 aimed at assessing the dietary exposure of the general Italian population to selected non-essential trace elements (Al, inorganic As, Cd, Pb, methyl-Hg, inorganic Hg, U) and radionuclides (^{40}K, ^{134}Cs, ^{137}Cs, ^{90}Sr). The establishment of the TDS food list, the design of the sampling plan, and details about the collection of food samples, their standardized culinary treatment, pooling into analytical samples and subsequent sample treatment are described. Analytical techniques and quality assurance are discussed, with emphasis on the need for speciation data and for minimizing the percentage of left-censored data so as to reduce uncertainties in exposure assessment. Finally the methodology for estimating the exposure of the general population and of population subgroups according to age (children, teenagers, adults, and the elderly) and gender, both at the national level and for each of the four main geographical areas of Italy, is presented.

Key words
- metals
- arsenic
- radioisotopes
- exposure assessment
- food safety
- total diet study

INTRODUCTION

Trace elements are chemical substances taken up at trace levels from the diet. Whereas essential trace elements are nutrients needed in very minute quantities for the proper growth, development, and physiology of the organism (e.g. iron, copper, zinc, iodine, selenium, molybdenum), dietary exposure to non-essential elements such as cadmium, lead or mercury is of concern [1-3]. Environmental sources are the main contributors to contamination of food with metals and other non-essential elements. Even though they are ubiquitous and thus naturally present in the diet, higher levels may occur as a result of environmental pollution from industrial and other anthropogenic activities.

Non-essential elements may enter the food chain at any point during growth and harvesting, through to storage and processing, including packaging. Food is the major contributor to exposure of the general (non-occupationally exposed) population, although other routes may also be significant for specific elements.

Certain food groups are known to accumulate some trace elements naturally and, consequently, they can contain relatively high concentrations of these ones. For example, fish and shellfish are known to accumulate mercury in the toxic form of methylmercury. Wheat takes up cadmium whereas rice accumulates arsenic largely in the toxic form of inorganic arsenic. It is to be noted that other food items such as fish and seafood contain very high concentrations of arsenic, but it occurs as organic species of lower or negligible toxicity. Therefore, for risk assessment of arsenic speciation data are needed in order to characterize the presence of the toxic inorganic form [4, 5]. Also in the case of mercury speciation is important, since methylmercury is considerably more toxic than inorganic mercury [5, 6].

Another element of concern is aluminium, which is found in food as a result of its natural occurrence in the environment, contamination from various sources, leaching from food contact materials and the use of aluminium-containing food additives [7, 8]. As regards

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Ministero della Salute
24 maggio 2016

Total Diet Studies

*Total Diet Studies (TDSs) are designed to produce a solid base for population **dietary exposure assessment** to chemicals and its potential impact in public health*

A Total Diet Study (TDS) consists in:

- **Selection** of foods commonly consumed
- Random **purchase** of foods at retail level
- **Processing** the food as usually consumed
- **Pooling** and **homogenising** the prepared food items into representative food groups
- **Analysis** of the pooled samples for the substances of interest

JOINT GUIDANCE OF EFSA, FAO AND WHO Towards a harmonised total diet study approach: a guidance document. *EFSA J* 2011;9(11):2450-515

Guidelines for an harmonised Total Diet Study approach

Reference:

European Food Safety Authority (EFSA), Food and Agriculture Organization (FAO), World Health Organization (WHO).

2011.

Towards a harmonised total diet study approach: a guidance document.

EFSA J 9(11):2450

efsa European Food Safety Authority

World Health Organization

EFSA Journal 2011; 9(11):2450

JOINT GUIDANCE OF EFSA, FAO AND WHO

Towards a harmonised Total Diet Study approach: a guidance document[1]

European Food Safety Authority (EFSA), Parma, Italy[2, 3]

Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

World Health Organization (WHO), Geneva, Switzerland

ABSTRACT

tds ▶ exposure

TDS Exposure project (4 years, concluded in January 2016) fostered harmonisation of the TDS approach at the pan-European level

KEY WORDS

Total Diet Study, Dietary Exposure, Contaminants, Nutrients, Harmonisation

[1] On request from EFSA, Question No EFSA-Q-2010-00058, issued on 11 November 2011

[2] Correspondence: datex@efsa.europa.eu

[3] Acknowledgement: EFSA wishes to thank the members and hearing experts of the Working Group on Total Diet Studies: Kimmo Peltonen (Chair), U. Ruth Charrondiere, Ioana Madalina Georgescu, Liis Kambek, Ginevra Lombardi-Boccia, Oliver Lindtner, Victoria Marcos Suarez, Luisa Oliveira, Jiří Ruprich, Joseph Shavila, Veronique Sirot and Philippe Verger for the preparation of this EFSA scientific output and Steve Crossley, Katie Egan, Yongning Wu, Orish Ebere Orisakwe and Richard Vannoort for the peer review of the document and EFSA's staff: Stefan Fabiansson, Elena Scaravelli and Liisa Valsta for the support provided to this EFSA scientific output.

Suggested citation: European Food Safety Authority, Food and Agriculture Organization of the United Nations, World Health Organization; Towards a harmonised Total Diet Study approach: a guidance document. EFSA Journal 2011;9(11):2450. [66 pp.] doi:10.2903/j.efsa.2011.2450. Available online: www.efsa.europa.eu/efsajournal

Essential principles of a Total Diet Study

TDSs are designed to cover the **whole diet** and to **measure** the **amount** of each chemical substance of interest **ingested by the population** living in a country over their **lifetime**, using average and high-level consumption data as appropriate for the substances being assessed (**chronic dietary exposure**)

Essentials principles of a TDS:

1. Representative of the whole diet
2. Pooling of foods
3. Food analysed as consumed

Exposure through drinking water and water used in cooking is considered in the TDS approach

EFSA J 2011;9(11):2450-515

Italian TDS 2012-14

- Launched by Italian Ministry of Health
- Coordinated by Istituto Superiore di Sanità

Reference:

D'Amato M., Turrini A., Aureli F., Moracci G., Raggi A., Chiaravalle E., Mangiacotti M., Cenci T., Orletti R., Candela L., di Sandro A., Cubadda F. 2013. Dietary exposure to trace elements and radionuclides: the methodology of the Italian Total Diet Study 2012-2014.

Annali dell'Istituto Superiore di Sanità **49**(3):272-280

Free Full Text available:

http://www.ncbi.nlm.nih.gov/pubmed/24071607


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ORIGINAL ARTICLES AND REVIEWS

Ann Ist Super Sanità 2013 | Vol. 49, No. 3: 272-280
DOI 10.4415/ANN_13_03_07

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ORIGINALLY LAUNCHED FOR
trace elements and element species
THEN EXTENDED TO
mycotoxins, dioxins and PCBs, and micronutrients

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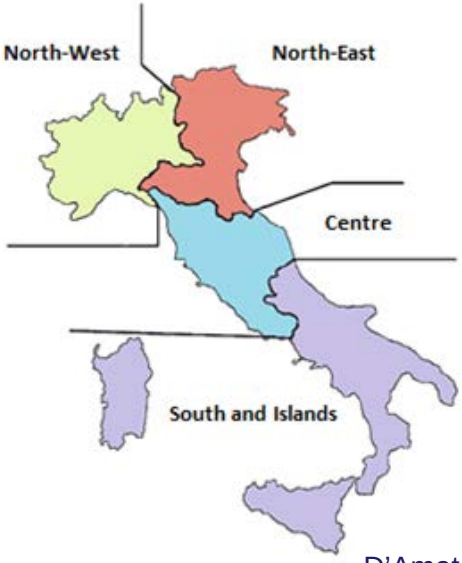
Italian TDS 2012-14: the methodology (1)

Target population

Two genders and four age classes, i.e. children (3-9.9 years), teenagers (10-17.9 years), adults (18-64.9 years) and elderly people (≥ 65 years) were included in the study

Geographical variation

4 cities were selected to represent the **four main geographical areas of Italy**:
Milan (North-West), Bologna (North-East), Rome (Centre), Bari (South and Islands)



D'Amato M. et al. 2013. Ann Istit Super Sanità 49(3):272-280

Italian TDS 2012-14: the methodology (2)

Food list

The most widely consumed foods by adults and/or children (consumer rate of at least 5%) were selected

Foods were grouped so that commodities known to:

- *be susceptible to contamination (e.g. offal, crustaceans and molluscs, spices and herbs) or*
- *represent major exposure sources (e.g. rice)*

were kept separate, as were foods which are consumed in large quantities (e.g. bread, pasta).

The **core foods (n = 51),** grouped into **13 categories,** covered about **99.7% of the whole diet** of adults and children

D'Amato M. et al. 2013. Ann Istit Super Sanità 49(3):272-280
INRAN-SCAI 2005-06 Public Health Nutrition 12,2504

TDS food list

TDS Food List showing the average daily consumption in g/d by food category in the total population (all ages, males and females), the percentage contribution of each food (in parenthesis), the percentage of consumers of each food and food category, the TDS sampling year, the number of TDS samples analysed (pooled samples) and collected at retail (individual sample)

Food categories	Consumption	Consumers (%)	Sampling year	Pooled samples	Individual samples
Cereals, cereal products and substitutes	**258.4**	**99.8**			
Bread	(40)	92.1	1	4	32
Pasta	(21)	91.1	1	4	32
Pizza	(3)	13.9	1	4	16
Rice	(6)	41.2	1	4	16
Wheat, other cereals and flours	(14)	84.1	1	4	16
Breakfast cereals	(1)	10.1	1	4	16
Biscuits	(5)	50.6	1	4	16
Savoury fine bakery products	(3)	38.0	1	4	16
Cakes and sweet snacks	(7)	44.4	1	4	16
Pulses, fresh and processed	**11.3**	**34.6**	1	4	16
Vegetables, fresh and processed	**211.2**	**99.6**			
Leafy vegetables, fresh	(20)	84.0	3	4	16
Tomatoes, fresh	(20)	83.6	3	4	16
Other fruiting vegetables, fresh	(15)	64.3	3	4	16
Roots and onions, fresh	(9)	97.8	3	4	16
Other vegetables, fresh	(18)	82.9	3	4	16
Vegetables, processed	(17)	78.0	3	4	16
Spices and herbs	(1)	83.1	3	4	16

TDS food list *(continued)*

Food categories	Consumption	Consumers (%)	Sampling year	Pooled samples	Individual samples
Potatoes, tubers and their products	**50.9**	**69.2**	1	4	16
Fruit, fresh and processed	**208.5**	**93.7**			
Citrus fruit, fresh	(22)	46.9	3	4	16
Exotic fruit, fresh	(8)	38.9	3	4	16
Other fruit, fresh	(68)	83.1	3	4	32
Nuts, seeds, olives and their products, dried fruit	(1)	27.1	3	4	16
Meat, meat products and substitutes	**110.1**	**99.0**			
Beef and veal, not preserved, excl. offal	(39)	75.2	3	4	16
Pork, not preserved, excl. offal	(12)	31.4	3	4	16
Poultry and game, not preserved, excl. offal	(19)	42.4	3	4	16
Other meats, not preserved, excl. offal	(5)	10.2	3	4	16
Ham, salami, sausages and other preserved meats, excl. offal	(25)	81.3	3	4	16
Offal, blood and their products	(1)	3.3	3	4	16
Fish, seafood and their products	**44.7**	**68.0**			
Fish	(70)	62.0	2	4	16
Crustaceans and molluscs	(30)	21.8	2	4	16
Milk, milk products and substitutes	**198.0**	**99.2**			
Milk, milk-based beverages, infant formula	(60)	78.6	2	4	32
Yoghurt and fermented milk	(10)	86.3	2	4	16
Cheese	(29)	96.7	2	4	32

Food categories	Consumption	Consumers (%)	Sampling year	Pooled samples	Individual samples
Oils and fats	**40.4**	**99.7**			
Olive oil	(81)	99.7	3	4	16
Other vegetable oils	(6)	41.8	3	4	16
Butter and creams	(10)	45.7	3	4	16
Other fats	(2)	17.9	3	4	16
Eggs	**20.9**	**74.3**	2	4	16
Alcoholic beverages	**91.0**	**74.5**			
Regular wine	(70)	69.7	2	4	32
Beer, cider	(27)	16.6	2	4	16
Sweet wine, spumante, wine-based appetizers, spirits and liquors	(3)	13.2	2	4	16
Sweet products and substitutes	**33.1**	**93.2**			
Ice cream and ice lolly	(30)	20.3	3	4	16
Chocolate and substitutes	(8)	22.7	3	4	16
Candies, jam and other sweet products (incl. sugar-free)	(10)	26.6	3	4	16
Sugar, fructose, honey and other nutritious sweeteners	(50)	84.9	3	4	16
Cocoa and cocoa-based powder	(2)	9.6	3	4	16
Water and other non-alcoholic beverages	**836.1**	**99.9**			
Tap water (as such, in beverages or recipes)	(23)	57.1	1	4	16
Bottled water	(54)	76.5	2	4	32
Coffee, tea, and herbal tea	(15)	87.7	2	4	32
Fruit and vegetable juices	(4)	56.2	2	4	16
Other soft drinks	(3)	21.8	2	4	16

Italian TDS 2012-14: food sampling and sample preparation

❑ Food Sampling

- The **> 3000 elementary food items** making up the 51 core foods were bought at retail in selected 4 cities, from November 2012 to July 2014
- Specific **retail outlets** (e.g. hyper and supermarkets, traditional markets, bakeries, pizzerias, etc.) have been selected for each core food **according to consumer habits**
- **Fruit and vegetables** were sampled during two **different seasons**

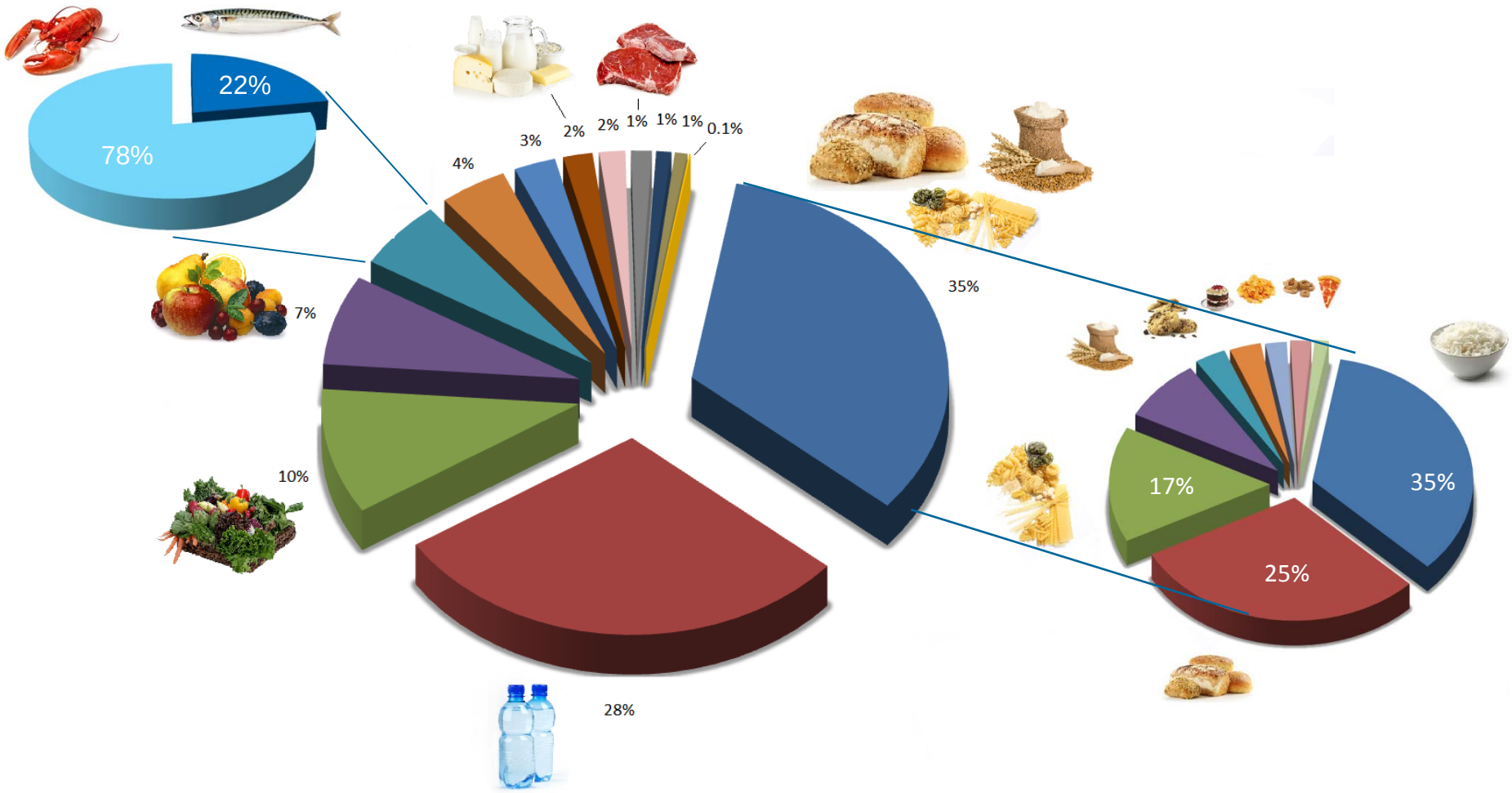
Seasonality covered

❑ Sample preparation and analysis

- Individual food samples were prepared and cooked according to **normal consumer practices**.
- Samples were then pooled in 204 samples, i.e. the **51 core foods** representative of the population diet, obtained **for each** of the four main **geographical areas**.
- Samples were freeze-dried (except for water and matrices not requiring complex treatment for their long-term storage) to enable **long-term storage** and successive analysis for other chemicals later on.
- Inorganic arsenic was determined by **HPLC-ICP-MS**

NOVEL
First TDS where inorganic arsenic is measured

Italian TDS 2012-14: food categories and single food items contribution



Example of the level of detail provided by TDS data: exposure to inorganic As in Italy (total population)

Chemical substances: 48 individual chemicals measured

Non-essential elements

Cd, Pb, MeHg and Inorganic-Hg, Inorganic-As (speciation)

Radionuclides

^{40}K, ^{134}Cs, ^{137}Cs, ^{90}Sr

Dioxins & PCBs

PCDDs (7), PCDFs (10), DL-PCBs (12)

Mycotoxins

9 individual molecules (AFB1, AFM1, OTA, FB1, D

Micronutrients

Essential trace elements (Fe, Cu, Zn, Se, I)

For toxic substances, in all cases, exposure was lower compared to EFSA estimates:

CORRECT!

EFSA APPROACH SHOULD NOT UNDERESTIMATE EXPOSURE, TDS PROVIDES MORE ACCURATE DATA

Risk characterization:

Average intake of toxic chemicals is <HBGV (TWI, BMDL), but MOEs are sometimes very small and sensitive population groups/high consumers may exceed the HBGVs

Conclusions

- **The Italian TDS covered:**

- Average and high level (P95) exposure for total population and consumers only
- Exposure to contaminants and intake of (micro)nutrients
- Two genders and four age classes
- Geographical variation (4 main geographical areas of Italy)
- Seasonal variation (fruit & vegetables)
- 51 core foods
- Water as both food and cooking medium
- Long-term storage of samples (successive analysis for other chemicals later on)
- Element chemical species: inorganic As measured and not estimated for the first time in a TDS

- **The exposure of toxic chemicals and the intake of nutrients has been assessed for the Italian population (incl. sub-groups) and the relevant risk characterized**